Yueh-Min Huang
Shu-Chen Cheng
João Barroso
Frode Eika Sandnes (Eds.)

LNCS 13449

Innovative Technologies and Learning

5th International Conference, ICITL 2022
Virtual Event, August 29–31, 2022
Proceedings

Springer

Lecture Notes in Computer Science 13449

More information about this series at https://link.springer.com/bookseries/558

Yueh-Min Huang · Shu-Chen Cheng ·
João Barroso · Frode Eika Sandnes (Eds.)

Innovative Technologies and Learning

5th International Conference, ICITL 2022
Virtual Event, August 29–31, 2022
Proceedings

Springer

Editors
Yueh-Min Huang
National Cheng Kung University
Tainan City, Taiwan

Shu-Chen Cheng
Southern Taiwan University of Science and Technology
Tainan City, Taiwan

João Barroso
University of Trás-os-Montes and Alto Douro
Vila Real, Portugal

Frode Eika Sandnes
OsloMet – Oslo Metropolitan University
Oslo, Norway

ISSN 0302-9743 ISSN 1611-3349 (electronic)
Lecture Notes in Computer Science
ISBN 978-3-031-15272-6 ISBN 978-3-031-15273-3 (eBook)
https://doi.org/10.1007/978-3-031-15273-3

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

The International Conference of Innovative Technologies and Learning (ICITL 2022) provides a platform for those who are working on educational technology to get together and exchange experiences. Benefiting from the use of a variety of emerging innovative technologies, the e-learning environment has become highly diversified along the way. Diversified innovative technologies have fueled the creation of advanced learning environments by adopting appropriate pedagogies. Moreover, these technologies not only facilitate learning but also actively help students reach maximized learning performances. However, due to the rapid evolution of new technologies, how to make use of these technologies by complying with effective pedagogies to create adaptive or smart learning environments remains a challenge. Therefore, this conference aims to provide a platform for those researchers in education, computer science, and educational technology to share experiences of effectively applying cutting-edge technologies to learning and to spark further research. It is hoped that the findings of each work presented at the conference will enlighten researchers in relevant fields or education practitioners to create more effective learning environments. ICITL is always ready to share work with the public.

Due to the unfolding COVID-19 outbreak and travel restrictions, this year's conference was held online. Therefore, all accepted papers shifted to a fully virtual format, with presentations in each session held interactively in a virtual meeting room. This year we received 123 submissions from authors in 26 countries worldwide. After a rigorous single-blind review process, 53 papers were selected as full papers and three papers were selected as short papers, yielding an acceptance rate of 45%. These contributions covered the latest findings in the relevant areas, including 1) Artificial Intelligence in Education; 2) VR/AR/MR/XR in Education; 3) Design and Framework of Learning Systems; 4) Pedagogies to Innovative Technologies and Learning; and 5) Application and Design of Innovative Learning. Moreover, ICITL 2022 featured two keynote presentations and two invited plenary presentations by renowned experts and scholars. Tassos A. Mikropoulos and Wu-Yuin Hwang brought us insights on the keynote topics: "Introducing virtual reality and other extended technologies in education: technological and pedagogical issues" and "Big Education: Active Learning in Authentic Contexts- Big Scalability, Long Sustainability and High Cognition". While the two plenary topics, "Digital competence when technology meets ecology" and "Applying a Business Simulation Game in a Flipped Classroom: Impact on Higher-Order Thinking Skills", were presented in detail by Margus Pedaste and Ting-Ting Wu, respectively.

We would like to thank the Organizing Committee for their efforts and time spent to ensure the success of the conference. We would also like to express our gratitude to the Program Committee members for their timely and helpful reviews. Last but not least, we would like to thank all the authors for their contribution in maintaining a high-quality

conference – we count on your continued support in playing a significant role in the Innovative Technologies and Learning community in the future.

August 2022

Yueh-Min Huang
Chi-Cheng Chang
Joao Barroso
Frode Eika Sandnes
Shu-Chen Cheng
Tânia Rocha
Yu-Cheng Chien

Organization

Honorary Chair

Yueh-Min Huang	National Cheng Kung University, Taiwan

Conference Co-chairs

Chi-Cheng Chang	National Taiwan Normal University, Taiwan
Joao Barroso	University of Trás-os-Montes e Alto Douro, Portugal
Frode Eika Sandnes	Oslo Metropolitan University, Norway

Technical Program Co-chairs

Shu-Chen Cheng	Southern Taiwan University of Science and Technology, Taiwan
Tânia Rocha	University of Trás-os-Montes e Alto Douro, Portugal
Yu-Cheng Chien	National Cheng Kung University, Taiwan

Finance Chair

Ting-Ting Wu	National Yunlin University of Science and Technology, Taiwan

Executive Chair

Yu-Ping Cheng	National Cheng Kung University, Taiwan

Program Committee

Ana Balula	University of Aveiro, Portugal
Andreja Istenic Starcic	University of Ljubljana, Slovenia
António Coelho	University of Porto, Portugal
Arsênio Reis	University of Trás-os-Montes e Alto Douro, Portugal
Chantana Viriyavejakul	King Mongkut's Institute of Technology Ladkrabang, Thailand
Charuni Samat	Khon Kaen University, Thailand

Claudia Motta	Federal University of Rio de Janeiro, Brazil
Constantino Martins	Polytechnic Institute of Porto, Portugal
Danial Hooshyar	University of Tartu, Estonia
Daniela Pedrosa	University of Aveiro, Portugal
Grace Qi	Massey University, New Zealand
Gwo-Dong Chen	National Central University, Taiwan
Hana Mohelska	University of Hradec Kralove, Czech Republic
Hanlie Smuts	University of Pretoria, South Africa
Hugo Paredes	University of Trás-os-Montes e Alto Douro, Portugal
João Pedro Gomes Moreira Pêgo	University of Porto, Portugal
José Cravino	University of Trás-os-Montes e Alto Douro, Portugal
José Alberto Lencastre	University of Minho, Portugal
Jui-long Hung	Boise State University, USA
Jun-Ming Su	National University of Tainan, Taiwan
Leonel Morgado	Universidade Aberta, Portugal
Lisbet Ronningsbakk	UiT The Arctic University of Norway, Norway
Manuel Cabral	University of Trás-os-Montes e Alto Douro, Portugal
Margus Pedaste	University of Tartu, Estonia
Paula Catarino	University of Trás-os-Montes e Alto Douro, Portugal
Paulo Martins	University of Trás-os-Montes e Alto Douro, Portugal
Qing Tan	Athabasca University, Canada
Rustam Shadiev	Nanjing Normal University, China
Satu-Maarit Frangou	University of Lapland, Finland
Shelley Shwu-Ching Young	National Tsing Hua University, Taiwan
Synnøve Thomassen Andersen	UiT The Arctic University of Norway, Norway
Ting-Sheng Weng	National Chiayi University, Taiwan
Wu-Yuin Hwang	National Central University, Taiwan
Yi-Shun Wang	National Changhua University of Education, Taiwan

Organizers

Sponsors

Contents

Artificial Intelligence in Education

Developing a Game-Based Speech Recognition System to Facilitate Oral Training Performance for Hearing Loss Children

Yen-Ting Lin(✉), Tz-Chi Wang, and Yun-Jhih Yi

Department of Computer Science, National Pingtung University, No. 4–18, Minsheng Rd., 900391 Pingtung City, Pingtung County, Taiwan (R.O.C.)

Abstract. Oral training of hearing loss children is an important issue since hearing loss children are difficult to hear what people are saying and also difficult to correct their oral expression. Although hearing aids or cochlear implants can assist hearing loss children in learning language and communicating, they still cannot own healthy hearing. Therefore, hearing loss children still needs long-term listening and speech therapy to improve oral expression ability. However, speech-language pathologists are significantly insufficient to support the therapy of hearing loss children in Taiwan. Therefore, this study applied speech recognition technology to develop a game-based oral training system to assist hearing loss children in conducting oral training. To evaluate the effectiveness of the proposed system, three hearing loss children were invited to use the system for a week to conduct oral training, and the effectiveness of the system was measured by recording the game process and a questionnaire. The results indicated that the proposed system can improve the children' pronunciation abilities. Moreover, the children have high motivation and satisfaction to use the system to conduct oral training.

Keywords: Game-based learning · Speech recognition · Hearing loss children · Oral training

1 Introduction

Hearing loss children are difficult to hear what people are saying and also difficult to correct their oral expression [1]. Moreover, hearing loss may make children frustrating and further affect children's learning and mentality [2–4].

Thanks to the advances of medicine and technology, the developments of hearing aids and cochlear implants are effective to improve the quality of life of the hearing impaired [5]. Nevertheless, hearing aids and cochlear implants can only assist the hearing impaired in learning language and communicating with people basically [6]. In other words, the hearing impaired with hearing aids or cochlear implants still cannot own healthy hearing. Therefore, the hearing impaired still needs long-term listening and speech therapy to improve oral expression ability [7].

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 3–12, 2022.
https://doi.org/10.1007/978-3-031-15273-3_1

According to 2021 statistics from the Ministry of Health and Welfare in Taiwan, the number of people with hearing loss and speech disorders is 142,591, but the number of speech-language pathologists is about 1,256. Therefore, speech-language pathologists are significantly insufficient to support the therapy of hearing impaired. Previous studies indicated that visual and tactile stimuli can enhance hearing loss students to learn and train oral expression effectively [8].

Based on the above, this study adopted digital game-based learning combined with speech recognition technology to develop an oral training system. Through the sound and light effects in the digital game, hearing loss students' visual and auditory senses were stimulated to enhance their learning motivation and effectiveness. To evaluate the effectiveness of the proposed system, three hearing loss children were invited to use the system for a week to conduct oral training, and the effectiveness of the system was measured by recording the game process and a questionnaire.

2 Literature Review

2.1 Digital Game-Based Learning

As technology and multimedia continues to advance, various effects can be designed in digital games and can further inspire researchers to develop various digital games to support different educational subjects [9, 10]. As a result, several studies presented that digital games have become a modern learning approach in primary and secondary schools. Literatures also indicated that game-based learning approaches not only increase learning outcomes, but also enhance students' conceptual understanding, engagement, and self-efficacy [11, 12].

To conduct a game-based learning approach, the game design has to satisfy teaching goals and the game tasks have to enable students to obtain the accomplishment after playing the game [13, 14]. Moreover, during the play process, the game has to provide unambiguous feedback, sense of control, playability, and gamefulness to students [15]. Furthermore, according to Ash [16], learning assessments with immediate feedback should be provided naturally in the game during the play process. If students pass an assessment, the difficulty of the game and assessment should be increase. Otherwise, students should re-challenge the game and assessment. In addition, students' play records should also be collected by the game system and further enable teachers and students to make remedial teaching [17].

2.2 Technology Supported Oral Training for Hearing Loss Students

In recent years, oral training for hearing loss students is different from the past. Thanks to the development of information technology, assistive devices for oral training are significant to satisfy the requirements of hearing loss students. In various assistive devices for oral training, visual effects are a major feedback to support students' training [18]. Different from special education teachers or speech-language pathologists, assistive devices enable hearing loss students to conduct oral training anytime and anywhere. Moreover, assistive devices can also provide training feedback to hearing loss students immediately and objectively [19].

Therefore, several studies investigated the effects of using computer-assisted oral training for hearing loss students. Hsieh and Liu asked 15 hearing loss children who have wearing hearing aids and then conducted an eight-weeks computer-assisted oral training experiment to investigate the oral training performance. The result revealed that the children's articulation of speech was significantly improved [20]. Aldaz, Puria, and Leifer [21] invited 16 hearing-aided adults (10 males and 6 females) to use smart phones to conduct oral training. The result indicated that 14 adults' oral communication capabilities were improved significantly. Sztahó, Kiss, and Vicsi [22] developed a dynamic visualization training system and invited 16 hearing loss children to use the system to train their pronunciation. The result found that the system could assist the children in understanding their own pronunciation and significantly improve their articulation of speech.

In summary, more and more oral training systems for hearing loss students are combined with technology to facilitate oral teaching and training, so that hearing loss students can effectively improve their articulation of speech. Moreover, the systems can enable hearing loss students to obtain immediate and accurate feedback on their pronunciation and understand their own pronunciation status.

3 Digital Game-Based Speech Recognition System

To support and facilitate oral training for hearing loss students, this study applied speech recognition technology to develop a digital game-based oral training system. The proposed digital game is a web-based system that enables students to use a device with a browser and microphone to play the game. Moreover, the system can collect students' play records during their play processes. In addition, teachers can capture students' learning status and further conduct remedial teaching to students.

3.1 System Architecture and Implementation

This study proposed a digital game-based learning system with speech recognition technology to hearing loss students for oral training. The system architecture is shown in Fig. 1. The proposed system is mainly divided into a digital game-based learning system and a database. The digital game-based learning system enables students to play the game and learn pronunciation and enables teachers to access and observe students' learning status. To support the above functions, the digital game-based learning system contains a game system, an oral learning system, an inquiry records system, and a speech recognition system. The descriptions of the sub-systems as follows.

1. **Game System.** The game system provides 5 game levels from very easy to very difficulty to students who can play different levels to train their pronunciation and challenge game scores. The game level design is based on the difficulty level of articulation investigated by Lin [23] and Liu [24]. Moreover, the rhymes with the easiest articulation are selected, while the vowels are articulated according to their difficulty level.

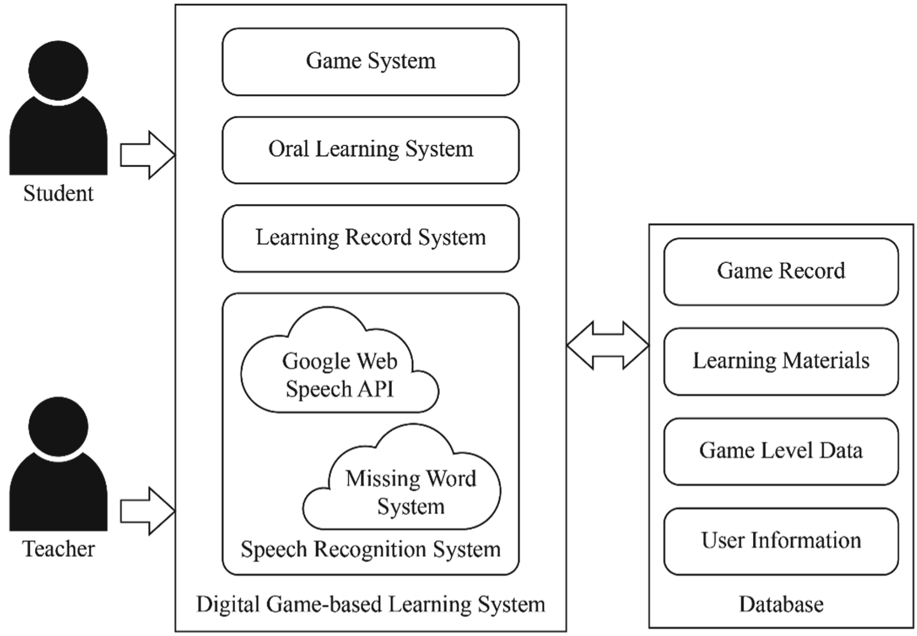
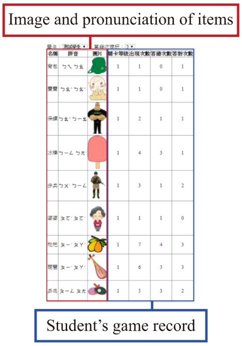
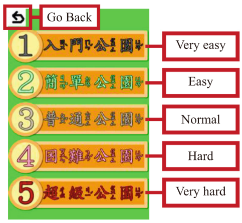


Fig. 1. The system architecture.

2. **Oral Learning System.** The oral learning system provides students to train incorrect pronunciations of the words during the play process. Students can repeatedly practice the incorrect pronunciations of the words after playing the game. The oral learning system enables students to repeatedly practice the incorrect pronunciations of the words and the system can automatically check whether their pronunciations are correct.
3. **Learning Record System.** The learning record system enables teachers to access and observe students' play records, such as play times, game scores, and correct/incorrect pronunciations. Therefore, teachers can utilize the data to provide remedial teaching to students.
4. **Speech Recognition System.** The speech recognition system was developed based on Google Web Speech API proposed by Google and the "Missing Word System - Pinyin API" proposed by Academia Sinica. The system is used to convert students' pronunciation into Chinese characters through Google Web Speech API and further convert the acquired Chinese characters into Mandarin Phonetic Symbols through Missing Word System - Pinyin API.

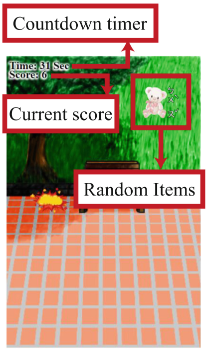
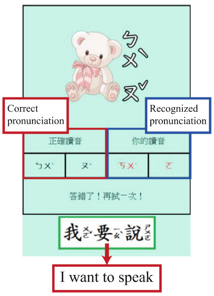
As mentioned above, the proposed game system adopts a digital game-based learning approach for oral training of hearing loss students. The game system interfaces and interactions are shown in Table 1.

Table 1. The system interface and interaction details.

Interface Name	Screen	Description
Home page		This page is designed for account login and register. Students click the Login button to enter personal account and password to login to the game system. To apply an account, students can click the Register button to enter personal account information for accessing the game system.
Game Record Search Page		Teachers can login into the game system to access students' play and learning records. The information includes times of correct / incorrect pronunciations for items in each game level.
Main Screen of the Game		When students login to the game system successfully, they can click "Go to Play" button to select the game level.
Level Selection Page		Students can select a suitable game level to play the game. The game levels range from very easy to very hard.

(*continued*)

Table 1. (*continued*)

<table>
<tr><th>Interface Name</th><th>Screen</th><th>Description</th></tr>
<tr><td>Game Screen (Ready Stage)</td><td>
</td><td>When students selected a game level and enter the game, the game system shows a welcome page that enables students to ready to start the game.</td></tr>
<tr><td>Game Screen (Play Stage)</td><td>
</td><td>In the game, the system starts to count down and randomly shows different items to students who have to use microphone to pronounce each item's pronunciation. If the pronunciation is correct to an item, students would get scores, and vice versa.</td></tr>
<tr><td>Score Screen</td><td>
</td><td>When game is over, the game system shows the total score to students. Moreover, students can click "Finish" button to next stage for learning incorrect pronunciations.</td></tr>
<tr><td>Learning Page</td><td>
</td><td>If students make incorrect pronunciations during the play process, the items would be showed in this stage and students have to pronounce the items again. When students click the "I want to speak" button, they have to use microphone to pronounce the particular item. Moreover, the system can recognize students' pronunciations and show whether the pronunciations are correct. If students make a mispronunciation, the system would mark the wrong pronunciation in red and ask they to read it again.</td></tr>
</table>

4 Research Methods

4.1 Experimental Design

The purpose of this study is to investigate the effects of a digital game-based speech recognition system for oral training of hearing loss children. Three elementary and preschool hearing loss children were invited to participate in an experiment conducted by this study. Before the children used the system to conduct the experiment, the researchers explained the system operation and then the children used the system to conduct an evaluation to obtain their oral expression status. Moreover, the children asked to use the system to conduct oral training twice within one week. The duration of each oral training with the system is 30 min and the interval of the two oral trainings with the system has to more than one day. After the experiment, the participants were asked to use the system to conduct an evaluation to obtain their oral expression status again. In addition, a questionnaire was used to evaluate the children's motivation and satisfaction.

4.2 Research Instrument

To evaluate the children's motivation and satisfaction with regard to the training process, this study used the self-regulated learning motivation questionnaire proposed by Santhanam, Sasidharan, and Webster [25] and the student satisfaction questionnaire proposed by Arbaugh [26] to develop a questionnaire. The questionnaire includes the motivation to learn scale with 0.84 Cronbach's alpha value, the computer learning self-efficacy scale with 0.85 Cronbach's alpha value, and the student satisfaction scale with 0.96 Cronbach's alpha value. Moreover, the questionnaire adopts a seven-point Likert scale.

5 Results

Based on the data collected from the aforementioned experimental process, the results of this study were analyzed and investigated in three levels: student learning effectiveness, learning motivation, and system satisfaction.

5.1 Learning Performance Analysis

In order to analyze the children's oral training performance with the proposed system, 30 samples were used to analyze the pronunciation corrections of the children including the three children's play records with five game levels in the game before and after participating in the experiment. Table 2 shows the statistical analysis result by using a paired sample *t*-test. The result indicated that there was a significant difference in the children's pronunciation corrections before and after participating in the experiment ($t(14) = -5.105$, $p < .05$).

Table 2. Analysis of pre and post-test pass rate of hearing impaired children by paired sample t-test.

	N	Mean	SD	$t(14)$	p
Pre-test	15	.377	.340	-5.105^{*}	.000
Post-test	15	.735	.152		

$^{*}p < 0.05$

5.2 Learning Motivation Analysis

In order to analyze the children's learning motivation with regard to the use of the proposed system, the motivation scale of the questionnaire was filled out by the three children. The descriptive statistics of the learning motivation of the three children are shown in Table 3. The result indicated that all children have high learning motivation while using the system to conduct oral training.

Table 3. Learning motivation results of participants.

Participant	N	Mean	SD
S1	3	7	0
S2	3	6	0
S3	3	7	0
		6.667	0.471

5.3 Learning Satisfaction Analysis

In order to analyze the children's learning satisfaction with the proposed system, the system satisfaction scale of the questionnaire was filled out by the three children. The descriptive statistics of the system satisfaction of the three children are shown in Table 4. The result indicated that all children have high satisfaction with the proposed system.

Table 4. System satisfaction results of participants.

Participant	N	Mean	SD
S1	12	6.583	1.382
S2	12	6.583	0.500
S3	12	3.667	2.656
		5.583	2.216

6 Conclusion and Future Outlook

This study proposed a digital game-based speech recognition system to support oral training for hearing loss children. The experimental results indicated that the proposed system can improve the children' pronunciation abilities. Moreover, the children have high motivation and satisfaction to use the system to conduct oral training. Although the results of this study showed an oral training improvement to the three hearing loss children, it is not appropriate to directly extrapolate the results to other hearing loss children because of the discrepancy in the oral speech capability of the hearing loss children. With regard to the system development, the proposed system was designed as a web-based game for cross-platform operations. However, the system performance may be affected by network speed and web request and reply. Therefore, it is recommended that future developers could consider to design an offline application or native application to enhance the system performance.

References

1. Geffner, D., Ross-Swain, D.: Auditory Processing Disorders: Assessment Management and Treatment. Plural Publishing, San Diego (2012)
2. Kliegman, R.M., Stanton, B.M.D., Geme, J.S., Schor, N.F., Behrman, R.E.: Nelson Textbook of Pediatrics E-Book. Elsevier Health Sciences, Philadelphia (2011)
3. Møller, A.R.: Hearing: Anatomy, Physiology, and Disorders of the Auditory System, 3rd edn. Plural Publishing, San Diego (2012)
4. Wong, L., Hickson, L.: Evidence-Based Practice in Audiology: Evaluating Interventions for Children and Adults with Hearing Impairment. Plural Publishing, San Diego (2012)
5. Battle, D.E.: Communication Disorders in Multicultural Populations. Elsevier, New York (2012)
6. Marschark, M., Lang, H.G., Albertini, J.A.: Educating Deaf Students: From Research to Practice. Oxford University Press, New York (2002)
7. Bentler, R., Mueller, H.G., Ricketts, T.A.: Modern Hearing Aids: Verification, Outcome Measures, and Follow-up. Plural Publishing, New York (2016)
8. Hamrol, A., Ciszak, O., Legutko, S., Jurczyk, M.: Advances in Manufacturing. Springer International Publishing, Cham (2017). https://doi.org/10.1007/978-3-319-68619-6
9. Gee, J.P. What video games have to teach us about learning and literacy, 2nd edn. Revised and Updated Edition. Palgrave Macmillan, New York (2007)
10. Lenhart, A., Kahne, J., Middaugh, E., Macgill, A.R., Evans, C., Vitak, J.: Teens, video games, and civics: teens' gaming experiences are diverse and include significant social interaction and civic engagement. Pew Internet & American Life Project, pp. 1–64 (2008)
11. deFreitas, S.I.: Using games and simulations for supporting learning. Learn. Media Technol. **31**(4), 343–358 (2006)
12. Martinez-Garza, M.M., Clark, D., Nelson, B.: Advances in assessment of students' intuitive understanding of physics through gameplay data. Int. J. Gaming Comput.-Mediated Simul. **5**(4), 1–16 (2013)
13. Gros, B.: Digital games in education. J. Res. Technol. Educ. **40**(1), 23–38 (2007)
14. Rupp, A.A., Gushta, M., Mislevy, R.J., Shaffer, D.W.: Evidence-centered design of epistemic games: measurement principles for complex learning environments. J. Technol. Learn. Assess. **8**(4), 3–41 (2010)
15. Kiili, K.: Evaluations of an experiential gaming model. Hum. Technol. **2**(2), 187–201 (2006)

16. Ash, J.: Attention, videogames and the retentional economies of affective amplification. Theory Cult. Soc. **29**(6), 3–26 (2012)
17. Shute, V., Ventura, M.: Stealth Assessment: Measuring and Supporting Learning in Video Games. The MIT Press, Cambridge (2013)
18. Watson, C.S., Kewley-Port, D.: Advances in computer-based speech training: aids for the profoundly hearing impaired. Volta Rev. **91**(5), 29–45 (1989)
19. Bench, R.J.: Communication Skills in Hearing-Impaired Children. Wiley, London (1992)
20. Hsieh, D.-L., Liu, T.-C.: Effect of computer-assisted speech training on speech recognition and subjective benefits for hearing aid users with severe to profound prelingual hearing loss. J. Commun. Disord. Deaf Stud. Hear. Aids, **3**(4) (2015)
21. Aldaz, G., Puria, S., Leifer, L.J.: Smartphone-based system for learning and inferring hearing aid settings. J. Am. Acad. Audiol. **27**(9), 732–749 (2016)
22. Sztahó, D., Kiss, G., Vicsi, K.: Computer based speech prosody teaching system. Comput. Speech Lang. **50**, 126–140 (2018)
23. Lin, P.G.: Language disorders and articulation problems of the hearing impaired. Bull. Spec. Educ. **1**(7), 141–164 (1985)
24. Liu, J.X.: A study on articulation ability of mandarin phonemes and its related factors for the first grade hearing-impaired the first grade hearing-impaired children in Taipei city. Bull. Spec. Educ. **2**(7), 127–162 (1986)
25. Santhanam, R., Sasidharan, S., Webster, J.: Using self-regulatory learning to enhance e-learning-based information technology training. Inf. Syst. Res. **19**(1), 26–47 (2008)
26. Arbaugh, J.B.: Virtual classroom characteristics and student satisfaction with internet-based MBA courses. J. Manag. Educ. **24**(1), 32–54 (2000)

Exploring Student Discussion Topics in STEAM Hands-On Collaborative Activity

Chia-Ju Lin[1], Ting-Ting Wu[2], Tzu-Heng Wang[1], Margus Pedaste[3], and Yueh-Min Huang[1](✉)

[1] Department of Engineering Science, National Cheng Kung University, Tainan, Taiwan
huang@mail.ncku.edu.tw

[2] Graduate School of Technological and Vocational Education, National Yunlin University of Science and Technology, Yunlin, Taiwan

[3] Institute of Education of the University of Tartu, Tartu, Estonia

Abstract. The STEAM transdisciplinary education method is crucial in the K-12 educational framework. Collaborative learning strategies are often used in STEAM transdisciplinary education to train students' problem-solving and communication skills. In the process of collaborative learning, hands-on teaching activities can be more effective for students' learning interests, and can also help them to understand and remember knowledge. In the teaching process, except for the application of teaching strategies that affect student learning, the discussion content during collaborative activities can facilitate instructors' understanding of the situation and the process of learning so that they can adjust the course content and teaching mode. We conduct a pilot study to explore the discussion process during collaborative learning. We also develop a topic classification system to focus on the discussion topics of students during hands-on collaborative teaching activities. The accuracy rate of this system exceeds 80%. We classify the discussion content into three topic categories to observe the relationship between the discussion topics of each group and the learning effect. The results show that students who discuss more coding syntax exhibit improved learning effectiveness and outcomes.

Keywords: STEAM hands-on · Collaborative learning · Natural language processing

1 Introduction

Learning materials are now often accompanied by technological improvements. Transdisciplinary education has become a teaching framework in STEAM (science, technology, engineering, the arts, and mathematics) education. Transdisciplinary education means interacting and communicating in different subjects.

Modern teaching strategies such as project-based learning, design thinking, inquiry-based learning, and collaborative learning have been applied in many learning activities for STEAM transdisciplinary education [1]. Various studies show that compared with traditional teaching classes, inquiry-based learning combined with collaborative hands-on learning activities can be more effective for students' transdisciplinary ability.

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 13–21, 2022.
https://doi.org/10.1007/978-3-031-15273-3_2

The literature largely focuses on features such as emotion or behavior as correlates with learning performance or other dimensions. However, few studies investigate the discussion content of students during collaborative hands-on activities [2]. Likewise, due to the complexity and difficulty of higher education courses, few studies take higher education as the object of discussion and observe the process of its learning and discussion [3].

In the past, instructors were obliged to pay constant attention to learners' learning situations during this kind of hands-on collaborative learning activity, which sometimes slowed down the teaching progress. This proved to be an opportunity to use natural language processing (NLP), a well-known technology in artificial intelligence. NLP can be used to solve this kind of problem in e-learning, and can help instructors to simultaneously keep track of multiple student discussions.

Given these problems and suggestions from the literature, we conducted a pilot study on teaching STEAM hands-on collaborative activities in higher education. We created a topic classification system using speech recognition and topic classification technology, and collected data from the discussion content of learners during the collaborative process. In this study, the classification categories are self-defined. This research evaluates the effectiveness of the proposed topic classification system and also explores the relationship between the topics discussed by students and their learning performance.

2 Literature Review

2.1 STEAM Education

In the 1990s, the National Science Foundation recognized science, mathematics, engineering, and technology (STEM) as a high impact factor on economic development [4]. According to Bequette and Bequette [5], art education facilitates STEM learning, enhances learning engagement, and may even reduce barriers and limitations between subjects. Therefore, in K-12 education, art education has been added to STEM education, which is accordingly renamed STEAM. The main purpose of STEAM education is to educate students to apply what they have learned to real life, so that they can explore critical thinking, creativity, and problem-solving.

Many studies address the effectiveness and importance of STEM or STEAM educational activities. For instance, Graham and Brouillette [6] describe a quasi-experiment to explore the influence of primary school students on the learning of STEAM physical and chemical science lessons. Kant, Burckhard, and Meyers [7] explore the impact of STEAM cultural activities in the United States. Lee, Chien, Chang, Hooshyar, and Huang [8] observe students' learning behavior during STEAM learning activities.

Although many studies attempt to design learning activities based on the STEAM education framework, still more is needed. As Herro, Quigley, and Cian [9] state, in a STEAM curriculum, hands-on learning activities should be discussed more, so that learners can organize theoretical knowledge.

2.2 Collaborative Learning

Collaboration has been defined broadly as "a kind of coordinated and synchronized activity. It is a result of continuing to construct and maintain a common concept of the problem" [10]. According to Boice, Jackson, Alemdar, Rao, Grossman, and Usselman [11], fostering transdisciplinary ability in STEAM education brings instructors more challenges. In particular, the production of projects enables the planning of teaching activities based on STEAM. Given that many learners prefer collaborative learning to reduce knowledge barriers between professional disciplines, for teachers this may result in challenges or situations beyond their expertise in evaluating collaborative projects for students. Herro, Quigley, Andrews, and Delacruz [12] indicate that although many educational institutions follow the STEAM education scaffold for related curriculum planning and experimental activities, the effectiveness of these teaching methods as well as collaborative problem-solving skills remains to be evaluated.

Many studies focus on teaching strategies for STEAM curriculum integration and collaborative learning. Lin, Yu, Hsiao, Chu, Chang, and Chien [13] develop an evaluation system for STEM education courses to evaluate learner ability to collaborate on problem-solving skills. Kelton and Saraniero [14] emphasize the necessity of sharing visions in collaborative activities, as this can yield positive effects such as fostering professional development and motivating learning engagement. In their study, using museum partnerships as an example, they observe researchers' performance in designing STEAM activities collaboratively. The results confirm that professional development ability can be promoted through STEAM interdisciplinary collaboration.

2.3 Natural Language Processing in Education

The purpose of NLP—the processing of natural language by computers—is to use machines to process and use natural language, including cognition, understanding, and generation [15]. Language processing not only increases the convenience in daily life, but also helps instructors to teach knowledge by using technology, resulting in more effective learning.

Among NLP technologies, speech recognition is in particular widely used. Evers and Chen [16] show that speech recognition in NLP technology can be used to help learners in reading, speaking, and communicating skills: applying speech recognition technology to convert speech into text helps learners absorb non-native language courses [17]. Also, Hwang, Shadiev, Kuo, and Chen [18] apply speech-to-text recognition (STR) in synchronous online courses to evaluate the effectiveness and relevance when investigating students' learning processes and their behavioral intentions. Smith, Haworth, and Žitnik [19] focus on the automatic grading of student responses via NLP technology. They observe the grading of open-ended questions in web-based eBooks to examine students' understanding of the course. Somers, Cunningham-Nelson, and Boles [20] apply NLP technology in an e-learning environment to automatically assess students' conceptual understanding during short question-and-answer sessions in digital analysis courses. Sullivan and Keith [21] leverage NLP technology to analyze speaking content during collaborative group discussions by using part-of-speech data to process and classify text.

Most studies demonstrate the difficulty and deficiency of relevant NLP literature. For instance, phrases, repetitive words, and specific emphasize words often do not follow established grammatical structures, such that there remain considerable challenges in the development of text recognition and analysis technology.

NLP applications are common in language learning, where speech is recognized, converted into text, and then compared with student behaviors or classroom learning situations. However, studies seldom address the content of discussion in STEAM hands-on collaborative activities to determine whether discussion topics affect learning. In this study, we attempt to bridge this gap in the literature.

3 Methodology

3.1 Participants

Given the importance of STEAM transdisciplinary education in collaborative learning, we describe a pilot study conducted to explore the discussion process in collaborative learning. This workshop was held in a high school in Taiwan with a class of 36 participants to whom Python programming on a Raspberry Pi device was taught using hands-on collaborative activities.

3.2 Experimental Process

In this study, hands-on collaborative learning activity was carried out in randomly-divided groups of two to three people. Figure 1 shows the arrangement of the experimental procedure of this study.

Before starting the Python programming tutorial, the participants took a pre-test on Python programming skills and embedded board knowledge. The pre-test results revealed that students had no prior knowledge of programming and embedded boards; thus the workshop materials concerned basic logic and applications.

During the basic Python tutorial, small quizzes were included after each sub-topic to ensure that students understood the teaching content, after which the teacher introduced the functions and applications of Raspberry Pi. After that, learners were taught how to connect and control hardware elements using Python code taught previously in the class. This was followed by hands-on activities.

At the end of the courses, a post-test on Python programming skills and embedded board knowledge was administered to evaluate students' learning results.

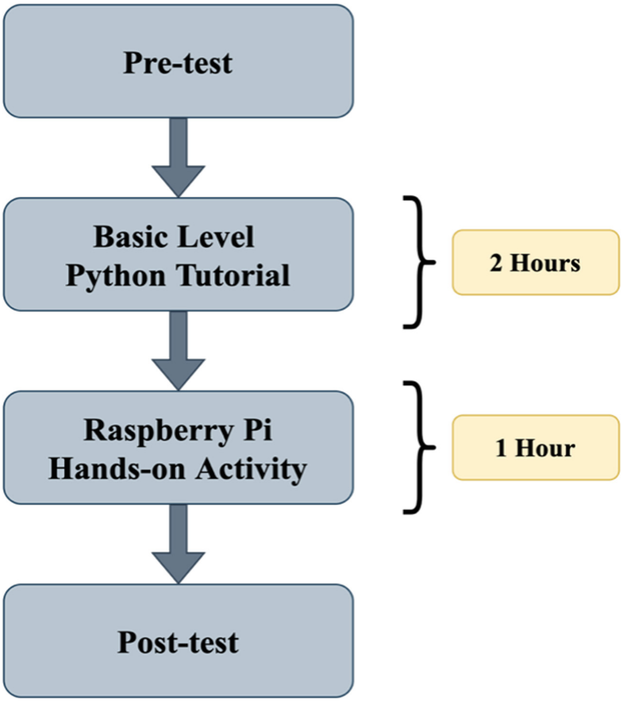


Fig. 1. Experimental procedure

3.3 Topic Classification System

In this study, we developed a topic classification system for STEAM hands-on collaborative activities using NLP speech-to-text recognition technology. System testing and evaluation demonstrated an accuracy of over 80% for the topic classification system. This indicates that the proposed matching of equipment and settings are suitable for advanced courses. In addition, according to the classification criteria for the C programming language of Sosnovsky and Gavrilova [22], the classification criteria of C language learning were modified to reflect the content in the Python programming and Raspberry Pi hands-on courses. The discussion content was classified according to these categories and content, as shown in Table 1.

The workshop consisted mainly of hands-on collaborative learning, and there were a total of 36 students who were randomly divided into 16 groups of 2 or 3 students each.

Table 1. Classification categories

Category	Description
Coding syntax	Words about Python programming e.g., define, print, import, if … else, for, while
Learning environment	Words related to the environment or learning equipment installed for learning e.g., Google, install, google, Colab, Raspberry Pi
Project assignment	Tasks or assignments related to classroom implementation e.g., isosceles triangle, leap year, LED flicker

Due to the large number of groups, teachers and assistants were not able to keep up with everyone. Therefore, the proposed topic classification system provided a statistical basis for student discussions in the workshop, as shown in the system page depicted in Fig. 2. This topic classification page was updated every three minutes, and the proportion of the three categories was calculated by group and then visualized as a pie chart. The five most recent words of each category in each group were listed below the pie chart to help teachers and assistants understand the content of each group's discussion.

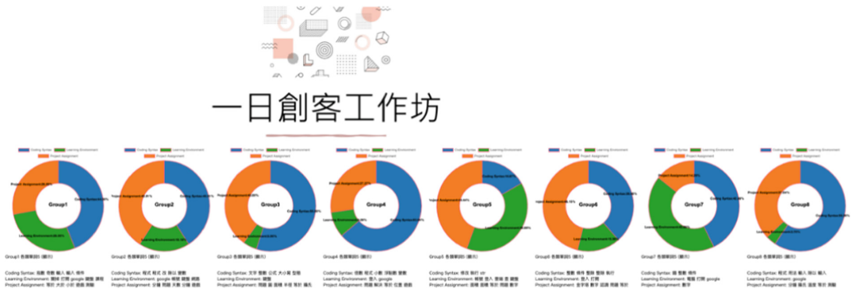


Fig. 2. Topic classification system page

4 Results

We propose a topic classification system to identify speech and extract keywords. This helps instructors to understand each group's discussion process and further explore the relationship between the discussion topics of each group and the learning effect. The classification accuracy of the purposed topic classification system reached 70% in practice.

The t-test statistics of the pre- and post-tests are shown in Table 2. There is no significant difference in the pre-test ($p = 0.99$), but there is a significant difference in the post-test. Also, the average post-test score (M) is significantly improved.

Table 2. Pre-test and post-test significance

	M	*SD*	*t* (*p*)
Pre-test ($N = 16$)	12.9	10.7	7.91 (<.001) ***
Post-test ($N = 16$)	53.5	15.4	

Note: H_a $\mu > 29.2$, *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$.

To better understand the relationship between the discussion contents and topics and the students' final learning results, we conducted a Spearman correlation coefficient statistical analysis on the self-defined classification criteria and post-test scores. The results in Table 3 show that post-test scores are highly positively correlated with the coding syntax category discussed in the collaborative discussion process ($p < .001$) and that their learning outcomes are highly negatively correlated with the learning environment ($p < .001$).

Table 3. Spearman correlation coefficient of topic categories

		Post-test	Coding syntax	Learning environment	Project assignment
Spearman's rho coefficient	Post-test	–			
	Coding syntax	**.828*****	–		
	Learning environment	**−.801*****	−.905**	–	
	Project assignment	−.234	−.481	.132	–

Note: *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$.

5 Conclusion

In this study we use speech recognition technology to build a topic classification system, for which we consulted the literature to define the classification categories. The accuracy of the system exceeded 80%. To evaluate the effectiveness of the system, we conducted a pilot experiment involving hands-on collaborative activity.

Apart from the system effectiveness, we also explore the relationship between what the students discuss and their learning outcomes. The results show that students made good improvements after the basic Python tutorial and the Raspberry Pi implementation. We also evaluated learners' speech by self-defined topic categories, finding that the classification accuracy of this study reached 70%. *Coding syntax* and *learning environment* both had significant impacts, whereas *project assignment* had no significant impact. Perhaps this is because project assignment is a more subjective category and differs by course or assignment; thus it is not possible to evaluate learning performance based on project assignments. In summary, we find that students who discuss coding syntax more show improved learning effectiveness and outcomes.

References

1. Wickson, F., Carew, A.L., Russell, A.W.: Transdisciplinary research: characteristics, quandaries and quality. Futures **38**, 1046–1059 (2006)
2. Kastrati, Z., Dalipi, F., Imran, A.S., Pireva Nuci, K., Wani, M.A.: Sentiment analysis of students' feedback with NLP and deep learning: a systematic mapping study. Appl. Sci. **11**, 3986 (2021)
3. Rybinski, K.: Are rankings and accreditation related? examining the dynamics of higher education in Poland. Qual. Assur. Educ. **28**(3), 193–204 (2020)
4. Bybee, R.W.: The Case for STEM Education: Challenges and Opportunities. NSTA press (2013)
5. Bequette, J.W., Bequette, M.B.: A place for art and design education in the STEM conversation. Art Educ. **65**, 40–47 (2012)
6. Graham, N.J., Brouillette, L.: Using arts integration to make science learning memorable in the upper elementary grades: a quasi-experimental study. J. Learn. Through Arts **12**, n1 (2016)
7. Kant, J., Burckhard, S., Meyers, R.: Engaging high school girls in native American culturally responsive STEAM activities. J. STEM Educ. **18**(5) (2018)
8. Lee, H.-Y., Chien, Y.-C., Chang, P.-Y., Hooshyar, D., Huang, Y.-M.: Use object-detection to identify materials and tools for STEAM hands-on activity. In: Huang, Y.-M., Lai, C.-F., Rocha, T. (eds.) Innovative Technologies and Learning: 4th International Conference, ICITL 2021, Virtual Event, November 29 – December 1, 2021, Proceedings, pp. 39–48. Springer International Publishing, Cham (2021). https://doi.org/10.1007/978-3-030-91540-7_5
9. Herro, D., Quigley, C., Cian, H.: The challenges of STEAM instruction: lessons from the field. Action Teach. Educ. **41**, 172–190 (2019)
10. Roschelle, J., Teasley, S.D.: The construction of shared knowledge in collaborative problem solving. In: O'Malley, C. (ed.) Computer supported collaborative learning, pp. 69–97. Springer Berlin Heidelberg, Berlin, Heidelberg (1995). https://doi.org/10.1007/978-3-642-85098-1_5
11. Boice, K.L., Jackson, J.R., Alemdar, M., Rao, A.E., Grossman, S., Usselman, M.: Supporting teachers on their STEAM journey: a collaborative STEAM teacher training program. Educ. Sci. **11**, 105 (2021)
12. Herro, D., Quigley, C., Andrews, J., Delacruz, G.: Co-measure: developing an assessment for student collaboration in STEAM activities. Int. J. STEM Educ. **4**, 1–12 (2017). https://doi.org/10.1186/s40594-017-0094-z
13. Lin, K.-Y., Yu, K.-C., Hsiao, H.-S., Chu, Y.-H., Chang, Y.-S., Chien, Y.-H.: Design of an assessment system for collaborative problem solving in STEM education. J. Comput. Educ. **2**(3), 301–322 (2015). https://doi.org/10.1007/s40692-015-0038-x
14. Kelton, M.L., Saraniero, P.: STEAM-y partnerships: a case of interdisciplinary professional development and collaboration. J. Mus. Educ. **43**, 55–65 (2018)
15. Winograd, T.: Understanding natural language. Cogn. Psychol. **3**, 1–191 (1972)
16. Evers, K., Chen, S.: Effects of automatic speech recognition software on pronunciation for adults with different learning styles. J. Educ. Comput. Res. **59**, 669–685 (2021)
17. Shadiev, R., Hwang, W.-Y., Huang, Y.-M., Liu, C.-J.: Investigating applications of speech-to-text recognition technology for a face-to-face seminar to assist learning of non-native English-speaking participants. Technol. Pedagog. Educ. **25**, 119–134 (2016)

18. Hwang, W.-Y., Shadiev, R., Kuo, T.C., Chen, N.-S.: Effects of speech-to-text recognition application on learning performance in synchronous cyber classrooms. J. Educ. Technol. Soc. **15**, 367–380 (2012)
19. Smith, G.G., Haworth, R., Žitnik, S.: Computer science meets education: natural language processing for automatic grading of open-ended questions in ebooks. J. Educ. Comput. Res. **58**, 1227–1255 (2020)
20. Somers, R., Cunningham-Nelson, S., Boles, W.: Applying natural language processing to automatically assess student conceptual understanding from textual responses. Australas. J. Educ. Technol. **37**, 98–115 (2021)
21. Sullivan, F.R., Keith, P.K.: Exploring the potential of natural language processing to support microgenetic analysis of collaborative learning discussions. Br. J. Edu. Technol. **50**, 3047–3063 (2019)
22. Sosnovsky, S., Gavrilova, T.: Development of educational ontology for C-programming (2006)

Combining Deep Learning and Computer Vision Techniques for Automatic Analysis of the Learning Process in STEM Education

Hsin-Yu Lee, Wei-Cyun Chang, and Yueh-Min Huang(✉)

Department of Engineering Science, National Cheng Kung University, Tainan City, Taiwan
huang@mail.ncku.edu.tw

Abstract. STEM education has been a focus in recent years, evidenced by the increasing number of studies conducted on STEM education to enhance the future competitiveness of learners. Compared with traditional teaching methods, learning outcomes in STEM education focus on what is learned during the process of collaboration and problem-solving rather than on the score of the final exam or final project. However, most assessment tools measure learning outcomes using questionnaires or interviews, which lack objective standards and require time for data processing. We address these problems with a system that combines deep learning and computer vision techniques to automatically recognize the learner's learning process in STEM education. System verification reveals an average precision of 87.1% and an average recall of 86.4%, which is sufficient to keep track of the learning process.

Keywords: STEM education · Deep learning · Computer vision · Automatic assessment tool

1 Introduction

STEM education, proposed by the National Science Foundation (NSF), integrates science, technology, engineering, and mathematics to address the shortage of R&D talent caused by the challenges of the future economy [1]. STEM education cultivates problem-solving skills and critical thinking by integrating knowledge from different fields [2]. Learners use what they learn in these fields to identify and solve problems that cannot be solved by a single-disciplinary approach [3]. Hsiao, Chen, Chen, and Lin [4] characterize STEM education as developing learners' problem-solving, collaborative, and creative thinking skills through a student-centered approach. In contrast to the traditional teacher-centered teaching model, learners in student-centered STEM education combine cross-disciplinary knowledge with personal experience and construct their own knowledge actively by using hands-on work or experiments [5]. Such differences make the traditional approach to assessing final learning outcomes (midterms and final exams) increasingly inappropriate for student-centered STEM education. Gao, Li, Shen, and Sun [6] argue that assessing only these final outcomes in STEM education may result in the

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 22–32, 2022.
https://doi.org/10.1007/978-3-031-15273-3_3

loss of important information about learners' knowledge building processes, including problem solving, interdisciplinary reasoning, and collaboration; they also mention the importance of assessing the learning process.

One increasingly important issue in STEM education assessment is how to effectively understand the learning process of learners in STEM activities. According to a systematic review of STEM assessment tools by Gao, Li, Shen, and Sun [6], past studies use self-reporting and observation to assess STEM education. Self-reporting is measured primarily through traditional subjective measures such as questionnaires or interviews to help learners to express their motivational beliefs and their experiences and feelings during the learning process [7]. Researchers and experts use the observation method to measure the learning process and performance by coding classroom data [8, 9]. However, both methods have limitations, including the vulnerability of self-reporting to subjective consciousness, memory limitations, and interference by social expectations [10]. In addition, D'Mello, Dieterle, and Duckworth [11] note that the observation method is time- and labor-intensive to code and label and is not observable in some learning environments (e.g., the learner's home). To address these challenges, in this study we combine deep learning and computer vision technologies to develop an automated STEM activity behavior recognition system to aid teachers and researchers in understanding learning processes in STEM activities in a more objective and automated way.

2 Related Work

2.1 STEM Education Assessment

In a systematic review by Gao, Li, Shen, and Sun [6], self-reporting and the observation method are the main ways to measure the learning performance and processes of STEM education learners. Self-reporting is a traditional subjective measure that allows learners to express their motivational beliefs and their experiences and feelings during the learning process through questionnaires or interviews [7]. For instance, Ekatushabe, Kwarikunda, Muwonge, Ssenyonga, and Schiefele [12] use self-reporting questionnaires to measure learners' levels of teacher autonomy support, self-efficacy, and boredom while participating in STEM activities. Sahin and Yilmaz [13] use a questionnaire on attitudes toward science and a questionnaire on attitudes toward AR use to understand changes in learners' attitudes toward science and AR after using AR technology in STEM activities. However, one study indicates that self-reporting is susceptible to subjectivity, subject memory limitations, and interference by social expectations [10].

To ameliorate these disadvantages, many studies use the observation method as a fairer way to measure learners' performance in the classroom [8, 9]. The observation method is a method of assessing learners' learning processes and performance by coding classroom data by researchers and experts [8, 9]. For example, Chen, Huang, Lin, Chang, Lin, Lin, and Hsiao [14] propose four behavioral indicators for hands-on STEM activity, hiring two experts to code images to understand the learners' learning process. Sun, Ouyang, Li, and Zhu [15] invite two experts to code learners' behaviors in video of unplugged STEM activity, finding differences in learners' processes and behaviors during traditional classroom and unplugged STEM activity. However, D'Mello, Dieterle, and Duckworth [11] indicate that the observation method is time- and labor-intensive to code and label and is not observable in some learning environments (e.g., the learner's home).

In recent years, as technology has developed, more and more studies have been conducted on the use of deep learning and related technologies for automated recognition to reduce the time and human costs of the observation method [16]. Barbadekar, Gaikwad, Patil, Chaudhari, Deshpande, Burad, and Godbole [17] use cameras to capture learners' facial expressions as a basis for determining learner engagement. Kim, O'Sullivan, Kolykhalova, Camurri, and Park [18] use computer vision techniques to analyze learner movements at various keypoints and investigate the effect of aromatherapy on learner movements.

In summary, although many recent studies have been conducted on the use of deep learning techniques in educational assessment, few studies have been conducted to systematically model and explore student-centered STEM activities. To address the limitations of self-reporting and the observation method and to fill the gaps in STEM education assessment, in this study we combine deep learning and computer vision techniques to identify the interaction between learners' hands and learning materials, which characterize determine learner behaviors in STEM activities and can be used as a basis for the objective assessment of the learning process.

2.2 Human Action Recognition

Human action recognition, a popular research topic in the field of deep learning, has been a focus in the past few years due to its wide range of applications, including human-computer interaction, sports, and healthcare [19, 20]. Common approaches to recognize human action can be classified by data type: video-based human action recognition [20], wearable device-based human action recognition [21], and wireless network device-based human action recognition [22]. In these studies, greater attention has been paid to video-based human action recognition because of its advantages in terms of higher recognition accuracy and ease of affiliation [23].

With the release of Kinect-related applications by Microsoft in 2011, an increasing number of studies have been conducted on human action recognition using 3D human node images [24], for instance, pace measurement and health monitoring [25]. However, the extraction of 3D human keypoints requires specific sensors and depth cameras for recognition, and overlapping joints may cause inaccurate recognition [25]. Cao, Simon, Wei, and Sheikh [26] propose a system called OpenPose which extracts human keypoints from 2D RGB images in real time, and further use part affinity fields to connect the human keypoints to determine the human body pose. This method not only requires commercially available cameras for keypoint extraction, but also effectively solves the problem of keypoint overlap by convolutional neural networks [26]. For example, Yan, Hu, Chen, and Zhengyuan [27] combine OpenPose with a Kalman filter to track the correctness of patients' rehabilitation movements to understand their recovery. Wu, Tang, Xiong, Wei, Song, and Zhu [28] propose ROpenPose based on OpenPose optimization to detect astronauts' movements and maneuvers in a weightless environment in a space capsule. Considering the speed and accuracy of OpenPose detection, in this study we use OpenPose to extract learners hand keypoints in STEM activities and develop a system to identify learner behaviors in STEM learning activities as a basis for evaluating their learning process.

3 Methodology

Hofstein and Lunetta [29] consider the learning process to be the learner's experience, which includes interaction between the learner and the learning material and the observation of phenomena. Thence, based on this concept, in this study we comprehend the learners' learning process in STEM activity by recognizing interaction between the learners and the learning materials. The system captures images from STEM activity frame by frame, recognizing learners' hand keypoints using OpenPose [26] and learning materials' information with YOLOv4 [30]. Finally, the current behavior of the learner is defined by analyzing the interaction between the hand keypoints and learning materials. The system architecture is shown in Fig. 1.

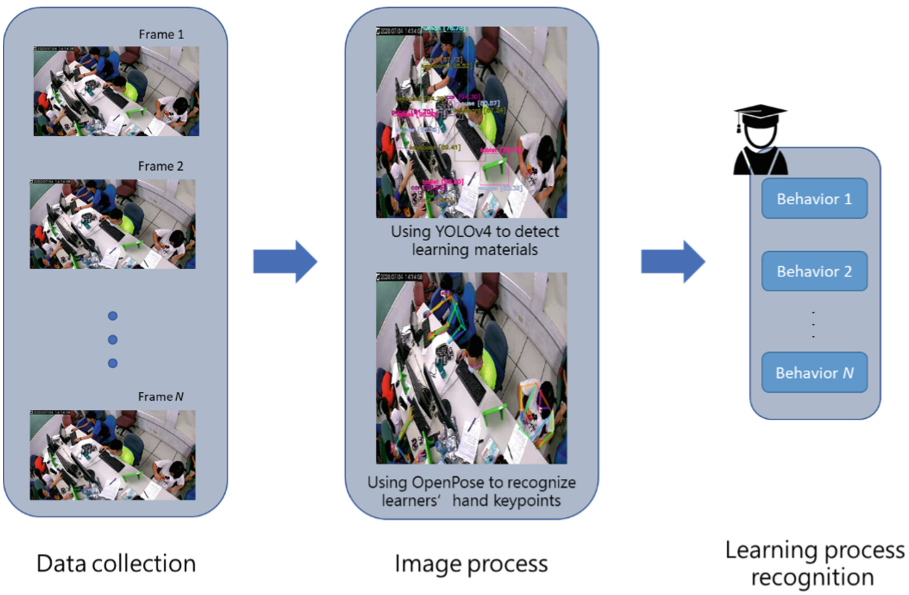


Fig. 1. System architecture

3.1 Data Collection

Three researchers were recruited to simulate behaviors during STEM activity, and two minutes of video was recorded for each behavior type as training and validation data for the system. A total of 21 simulated videos were collected, and all videos were captured every 10 s for model building.

3.2 Image Processing

1. **YOLOv4**

In this study we used the YOLOv4 model proposed by Bochkovskiy, Wang, and Liao [30] to detect objects commonly used in STEM activity. However, most objects frequently used in STEM activities lack native YOLO pretrained weights. That is, these objects were not labeled in the COCO dataset. Therefore, we adopted transfer learning to accurately detect objects used in the STEM activities in this study. Transfer learning used the weight parameters trained in other large datasets as the initial weights for training, freezing the weight parameters in deeper network layers and retraining the network weights in the shallower network layers. With transfer learning, we thus take a neural network originally used for another task and apply it to a completely new domain, inheriting the weights from the pretrained model in another domain to save retraining time and improve model accuracy. The YOLOv4 training parameters are listed in Table 1.

Table 1. YOLOv4 training parameters

Parameter	*batch*	*subdivision*	*max_batch*	*height*	*width*	*class*
Value	64	8	12000	608	608	6

The adjusted parameters of YOLOv4 in this study included setting the batch size to 64, i.e., each time 64 samples were input to the model for training and weight updates; *subdivision* was set to 8 to split the batch into 8 loads when there was not enough memory for the whole batch. As *max_batch* was set to the number of categories multiplied by 2000 in the original paper [30], we set it to 12,000 to ensure that there were enough training epochs for each category. In this study, the *height* and *width* of the model were both set to 608. Note that since objects are generally small in STEM activities, the input height and width should be increased to improve the recognition of small objects.

In this study, the simulated images mentioned in the data collection section were used as training data, and six objects—keyboard, mouse, tablet, car, phone, and pen—were detected in the images. The YOLOv4 output in each frame contained five parameters: the category number, the ratio of the boundbox's center X coordinate to the image width, the ratio of the boundbox's center Y coordinate to the image height, the ratio of the boundbox's width to the image width, and the ratio of the boundbox's height to the image height.

2. **OpenPose**

We used the OpenPose architecture proposed by Cao, Simon, Wei, and Sheikh [26] to extract the hand keypoints of learners with the parameters set in Table 2 below. OpenPose, which uses part affinity fields to learn the connections of human muscles through convolutional neural networks, represents various keypoint connections by 2D vectors, thus significantly increasing the efficiency of human keypoint detection. The final output is a three-dimensional vector of $135 \times 3 \times N$, where 135 is the total number of body keypoints, including 25 keypoints for the trunk and limbs, 70 keypoints for the face, and 40 keypoints for the hands. Each keypoint has 3 attributes: the x- and y-coordinates of the keypoint and the confidence of the keypoint. N is the number of people in the image. After reviewing the source code of OpenPose, we used only hand keypoints 26 to 65 as the basis for subsequent behavioral analysis.

Table 2. OpenPose parameter settings

Parameter	*camera_resolution*	*model_pose*	*net_resolution*	*face_detector*
Value	608×608	BODY_135	-1×480	false

The parameters include *camera_resolution*, which was set to 608x608 to make the output format of OpenPose and YOLOv4 consistent while ensuring the overall detection performance and speed; *model_pose*, which was set to BODY_135 to call the pre-training weight of OpenPose, which output a total of 135 human. *Net_resolution* was set to -1×480 as suggested by Cao, Simon, Wei, and Sheikh [26] as a balance between recognition speed and accuracy. Finally, *face_detector* was set to false because we focus only on hand poses in this study.

3.3 Automatic Learning Process Recognition System

In the image processing stage, input classroom images were input to YOLOv4 to detect the learning material locations and then to OpenPose to extract the hand keypoints of learners in the images. The system output is shown in Fig. 2. In addition, we also took into account the manual coding frequency of Sun, Ouyang, Li, and Zhu [15] to identify learner behaviors at a rate of 5 s. Finally, the automatic STEM behavior recognition system recorded each 5-s behavior in the learning history of each learner and provided visual reports to help teachers understand the distribution of behaviors at different moments during the STEM activity.

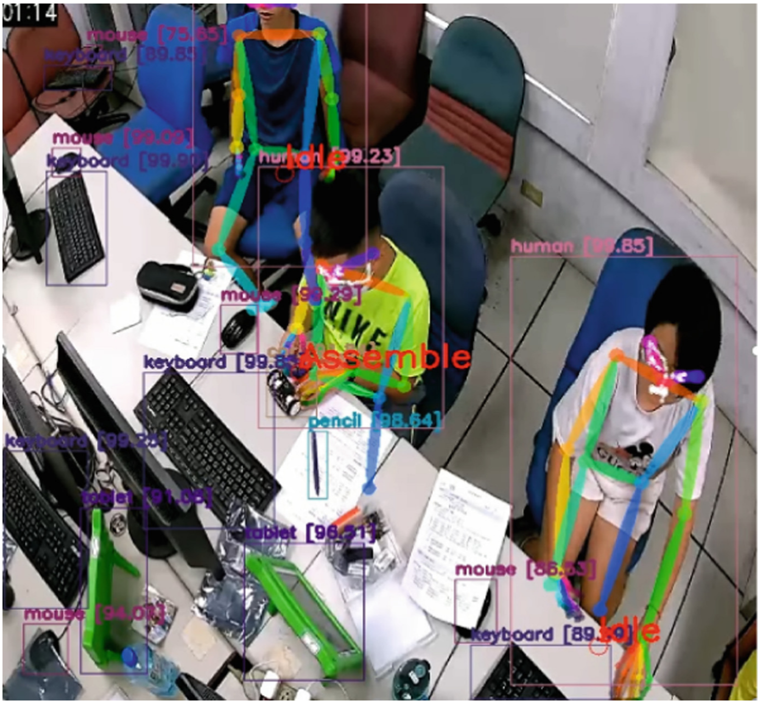


Fig. 2. System output

3.4 Learning Process Indicators

The STEM learning process indicators were defined by the learning materials that YOLOv4 recognized in this study. That is, if learners touched a learning material during the STEM activity, the corresponding learning process indicator was recognized and recorded. A total of seven such indicators were defined: *use computer, read, assemble, use phone, write, idle,* and *error*. These are described in Table 3.

Table 3. STEM learning process indicators

Indicator	Description
use computer	Use keyboard and mouse to operate computer
read	Operate tablet to study learning materials
assemble	Assemble
use phone	Assemble Micro: bit components to finish manufacturing car
write	Use pencil to take notes about what has been learned
idle	Hands are not touching any objects related to STEM activity
error	Cannot recognize keypoints of learners' hands

4 Results and Discussion

The proposed system identifies learning processes in STEM activity by recognizing interaction between hand keypoints and STEM learning materials. We analyzed and validated the accuracy of the system to ensure its accuracy. To measure the accuracy of the system, one-minute images were randomly selected from the collected data for accuracy analysis and compared with expert coding. Finally, a confusion matrix was used as the basis for system evaluation. The analysis results are shown in Fig. 3.

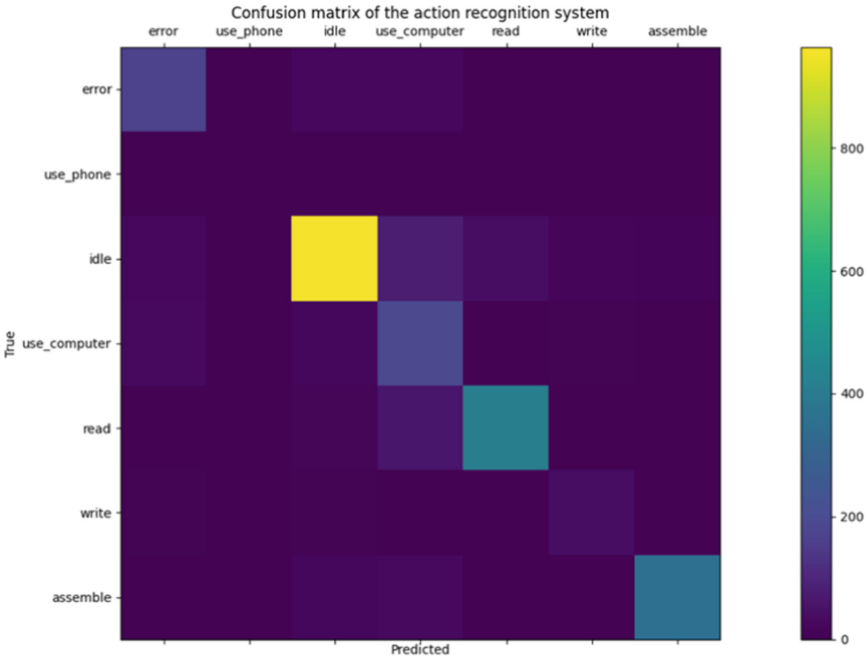


Fig. 3. Confusion matrix for proposed system

In this study, the results were expressed as the precision of each indicator, as described in Table 4. The average precision was 0.871 and the average recall was 0.864. The precision of the *use computer* indicator was worse than the *error* indicator due to the limited camera angle and field size, which caused multiple objects to overlap in the camera's view angle. In addition, the keyboard and mouse, which were used to determine the *use computer* indicator, occupied a large area of the desktop. If small-object recognition failed, these were misjudged as *use computer* because the hands are placed near the keyboard and mouse on the desktop.

Since the objects used to determine *write* and *use phone* were small, both indicators were difficult to recognize. In addition, the fact that the camera captured video at only 20 frames per second (FPS) made it difficult to recognize small learning materials. Also, in many cases OpenPose extracted hand keypoints for the learner even when the hands were

Table 4. Indicator precision

	use computer	*read*	*assemble*	*use phone*	*write*	*idle*	*error*
Precision	84%	91%	94%	79%	86%	94%	82%
Recall	82%	92%	92%	77%	89%	93%	80%

under the table, which degraded the accuracy of the *error* indicator. The performance of the remaining *assemble*, *read*, and *idle* was better.

We thus offer the following observations: as most of the learning process indicators during STEM activities were generated by hand interaction with learning materials, we combined hand keypoints with learning material information to recognize the state of the learning process when completing STEM activities. A few indicators were limited by the size of object and angle of the camera. Hence we believe that combining hand keypoints and STEM learning material location information is a feasible way to keep track of the STEM learning process.

5 Conclusion

In this study we develop a system to measure a learner's learning process in STEM activity by combining deep learning and computer vision techniques. The proposed method yields an average precision of 0.871 and an average recall of 0.864. In recent years, due to COVID-19, large-scale workshops have not been held, which limited the experimental activities and the number of participants in this study, making it difficult to carry out the corresponding STEM activities and planning. Therefore, we used past images of STEM activities to evaluate the system. Thus it was impossible to control field conditions such as intervention by teaching assistants and movement of unrelated personnel, which would normally be needed for proper model development.

The results reveal room for further discussion and improvement. First of all, to complete the implementation of the multi-person learning process tracking algorithm, we could use other more novel human tracking algorithms to record each participant, for instance by using a feature vector instead of tracking each person's specific points. Furthermore, to improve the system efficiency for real-time tutoring of learners, we suggest further optimizing the data flow transfer and adopting a more lightweight model architecture. In addition, to improve the camera's limited view angle, more sensors could be used to collect more data about the learners (e.g., watch-based tri-axis accelerometers, the log file of the platform operation, etc.). Future studies should also add questionnaires to assess more learning outcomes in terms of motivation, participation, and self-efficacy. In this way, the system would more comprehensively analyze the impact of learners in the learning process of STEM activities and conduct a step-by-step investigation of various learning situations in STEM activities using computer vision technology.

References

1. Bybee, R.W.: The Case for STEM Education: Challenges and Opportunities. NSTA Press (2013)
2. Sanders, M.: Integrative STEM education: primer. Technol. Teach. **68**, 20–26 (2009)
3. Martín-Páez, T., Aguilera, D., Perales-Palacios, F.J., Vílchez-González, J.M.: What are we talking about when we talk about STEM education? A review of literature. Sci. Educ. **103**, 799–822 (2019)
4. Hsiao, J.-C., Chen, S.-K., Chen, W., Lin, S.S.: Developing a plugged-in class observation protocol in high-school blended STEM classes: student engagement, teacher behaviors and student-teacher interaction patterns. Comput. Educ. **178**, 104403 (2022)
5. Christensen, R., Knezek, G., Tyler-Wood, T.: Alignment of hands-on STEM engagement activities with positive STEM dispositions in secondary school students. J. Sci. Educ. Technol. **24**, 898–909 (2015). https://doi.org/10.1007/s10956-015-9572-6
6. Gao, X., Li, P., Shen, J., Sun, H.: Reviewing assessment of student learning in interdisciplinary STEM education. Int. J. STEM Educ. **7**(1), 1–14 (2020). https://doi.org/10.1186/s40594-020-00225-4
7. Zimmerman, B.J.: Investigating self-regulation and motivation: historical background, methodological developments, and future prospects. Am. Educ. Res. J. **45**, 166–183 (2008)
8. Harari, G.M., Müller, S.R., Aung, M.S., Rentfrow, P.J.: Smartphone sensing methods for studying behavior in everyday life. Curr. Opin. Behav. Sci. **18**, 83–90 (2017)
9. Lathia, N., Rachuri, K.K., Mascolo, C., Rentfrow, P.J.: Contextual dissonance: design bias in sensor-based experience sampling methods. In: Proceedings of the 2013 ACM International Joint Conference on Pervasive and Ubiquitous Computing, pp. 183–192 (2013)
10. Paulhus, D.L., Vazire, S.: The self-report method. Handbook of research methods in personality psychology, vol. 1, pp. 224–239 (2007)
11. D'Mello, S., Dieterle, E., Duckworth, A.: Advanced, analytic, automated (AAA) measurement of engagement during learning. Educ. Psychol. **52**, 104–123 (2017)
12. Ekatushabe, M., Kwarikunda, D., Muwonge, C.M., Ssenyonga, J., Schiefele, U.: Relations between perceived teacher's autonomy support, cognitive appraisals and boredom in physics learning among lower secondary school students. Int. J. STEM Educ. **8**(1), 1–15 (2021). https://doi.org/10.1186/s40594-021-00272-5
13. Sahin, D., Yilmaz, R.M.: The effect of augmented reality technology on middle school students' achievements and attitudes towards science education. Comput. Educ. **144**, 103710 (2020)
14. Chen, J.C., et al.: Developing a hands-on activity using virtual reality to help students learn by doing. J. Comput. Assist. Learn. **36**, 46–60 (2020)
15. Sun, D., Ouyang, F., Li, Y., Zhu, C.: Comparing learners' knowledge, behaviors, and attitudes between two instructional modes of computer programming in secondary education. Int. J. STEM Educ. **8**(1), 1–15 (2021). https://doi.org/10.1186/s40594-021-00311-1
16. Ashwin, T., Guddeti, R.M.R.: Unobtrusive behavioral analysis of students in classroom environment using non-verbal cues. IEEE Access **7**, 150693–150709 (2019)
17. Barbadekar, A., et al.: Engagement index for classroom lecture using computer vision. In: 2019 Global Conference for Advancement in Technology (GCAT), pp. 1–5. IEEE (2015)
18. Kim, H., O'Sullivan, D., Kolykhalova, K., Camurri, A., Park, Y.: Evaluation of a computer vision-based system to analyse behavioral changes in high school classrooms. Int. J. Inf. Commun. Technol. Educ. (IJICTE) **17**, 1–12 (2021)
19. Khan, M.A., Zhang, Y.-D., Khan, S.A., Attique, M., Rehman, A., Seo, S.: A resource conscious human action recognition framework using 26-layered deep convolutional neural network. Multimedia Tools Appl. **80**(28–29), 35827–35849 (2020). https://doi.org/10.1007/s11042-020-09408-1

20. Majd, M., Safabakhsh, R.: Correlational convolutional LSTM for human action recognition. Neurocomputing **396**, 224–229 (2020)
21. Demrozi, F., Pravadelli, G., Bihorac, A., Rashidi, P.: Human activity recognition using inertial, physiological and environmental sensors: a comprehensive survey. IEEE Access **8**, 210816–210836 (2020)
22. Cui, W., Li, B., Zhang, L., Chen, Z.: Device-free single-user activity recognition using diversified deep ensemble learning. Appl. Soft Comput. **102**, 107066 (2021)
23. Kamel, A., Sheng, B., Yang, P., Li, P., Shen, R., Feng, D.D.: Deep convolutional neural networks for human action recognition using depth maps and postures. IEEE Trans. Syst. Man Cybern. Syst. **49**, 1806–1819 (2018)
24. Lin, K.-C., Ko, C.-W., Hung, H.-C., Chen, N.-S.: The effect of real-time pose recognition on badminton learning performance. Interact. Learn. Environ. 1–15 (2021)
25. Al-Naji, A., Gibson, K., Lee, S.-H., Chahl, J.: Real time apnoea monitoring of children using the Microsoft Kinect sensor: a pilot study. Sensors **17**, 286 (2017)
26. Cao, Z., Simon, T., Wei, S.-E., Sheikh, Y.: Realtime multi-person 2d pose estimation using part affinity fields. In: Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, pp. 7291–7299 (2017)
27. Yan, H., Hu, B., Chen, G., Zhengyuan, E.: Real-time continuous human rehabilitation action recognition using OpenPose and FCN. In: 2020 3rd International Conference on Advanced Electronic Materials, Computers and Software Engineering (AEMCSE), pp. 239–242. IEEE (2020)
28. Wu, E.Q., Tang, Z.-R., Xiong, P., Wei, C.-F., Song, A., Zhu, L.-M.: ROpenPose: a rapider OpenPose model for astronaut operation attitude detection. IEEE Trans. Industr. Electron. **69**, 1043–1052 (2021)
29. Hofstein, A., Lunetta, V.N.: The role of the laboratory in science teaching: neglected aspects of research. Rev. Educ. Res. **52**, 201–217 (1982)
30. Bochkovskiy, A., Wang, C.-Y., Liao, H.-Y.M.: YOLOv4: optimal speed and accuracy of object detection. arXiv preprint arXiv:2004.10934 (2020)

Automatic Topic-Based Lecture Video Segmentation

Peterson Anjunie Co[1](✉), Wesley Ryan Dacuyan[1], Jeremy Giles Kandt[1], Shu-Chen Cheng[2](✉), and Cherry Lyn Sta. Romana[1]

[1] College of Computer Studies, Cebu Institute of Technology-University, Cebu, Philippines
{petersonanjunie.co,wesleyryan.dacuyan,jeremygiles.kandt, cstaromana}@cit.edu

[2] Department of Computer Science and Information Engineering, Southern Taiwan University of Science and Technology, Tainan, Taiwan
kittyc@stust.edu.tw

Abstract. The recent rise in popularity of online learning has completely overhauled the way students consume informative content and how educators provide it. One of the ways teachers can provide more engaging lectures online is by segmenting recorded lectures by topic, which allows students to interact with the video and navigate it. Unfortunately, manually segmenting videos requires time and effort, adding even more to their workload. To address this issue, a system that takes any slide-based lecture videos as input and outputs a list of all the topic transitions contained in the video was developed. Previous research on this topic have placed heavy emphasis on the lecturer's speech to segment the video by topic. However, this research investigates the use of lecture video's presentation slides to determine topics. Topic transitions were determined using a Convolutional Neural Network - based Binary Classification Model trained on an original dataset of lecture videos collected from different educational resources. The video undergoes a series of preprocessing steps that gradually cut down the group of frames to contain only distinct slides before inputting them into the model. The classification model's performance was satisfactory. It obtained 91% accuracy and an 80% F1 score, which is indicative of its reliability in determining whether a slide is a topic transition or not. The system developed in this research provides both lecturers and students with a method to label and segment their videos based on key topics automatically. With further evaluation, this system can potentially be proven to be convenient enough to be introduced as a new tool in the educational industry to supplement online learning.

Keywords: Video segmentation · Information retrieval · Convolutional neural network

1 Introduction

Because of the pandemic due to COVID-19, there was a shift in the education system around the globe. There was a distinctive rise in handling classes in an online setting, also

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 33–42, 2022.
https://doi.org/10.1007/978-3-031-15273-3_4

called e-learning [1]. Included in how online classes are handled are the use of videos in conducting lectures, which have been a rather effective means to deliver informative content and to teach students online [2]. Because of the increased use of lecture videos, a need for more straightforward navigability according to the topics covered in the lecture video arises. To address this issue, some online platforms created a feature that enables one posting a video to place markers in a video to help the user navigate and sift through the needed information. This feature is also known as video segmentation.

Video segmentation identifies key objects in a video scene [3]. Video segmentation has played an important role in digital media processing, pattern recognition, and computer vision [4], which have been crucial in many areas, including autonomous driving, robotics, automated surveillance, social media, and video conferencing, to name a few. In the case of lecture videos, online platforms that have implemented this feature mainly require the manual addition of points in the video to divide it into parts. This research aims to automate the process of video segmentation in a lecture video and provide quick navigation and convenience for users.

The scope of the study is solely on the automation of video segmentation in lecture videos that make use of presentation slides.

2 Literature Review

Automatic Topic-based Lecture Video Segmentation (ATLVS) is increasingly needed in academics as students require quick access and maneuverability of educational materials. Video segmentation by topic requires grouping the video by image frames based on its content similarity and detecting topic transitions that signify the end and start of a topic [5, 6]. There are multiple approaches to segmenting a video by topic. Some of the more common methods include identifying scene changes, processing text used in the video, and analyzing the audio cues of the lecturer.

2.1 Video Segmentation Using Scene Changes

One of the earlier video segmentation methods was detecting scene changes in videos. A certain scene-change detection algorithm [7] used image processing and edge detection algorithms to map out changes in video scenes, detecting points in the video where there is a significant change in scenes. From that, it was possible to segment the video according to scene changes, but this did not necessarily mean that the videos were segmented according to topic, since changes in video scenes do not necessarily signify a shift in the topic of the video.

Another method used in another paper was extracting keyframes in a video with the use of k-means clustering algorithm [8]. Afterward, texture, edge, and motion features were applied to each extracted frame. This algorithm was able to identify unique objects in each frame, thereby making the identification of video scenes according to their content possible.

The two works mentioned used image processing to extract information from a video. These methods may be effective when segmenting videos in general. However, lecture videos usually have little to no scene changes. Thus, with lecture videos, it is necessary to be able to detect small changes occurring within the presentation of the lectures.

To do that, a method called average hashing can be done [9]. This is a type of image hashing that creates a hash from the average of the grayscale pixels from each frame. This method was able to identify slightly different images to their proper categories with around 80 to 100% accuracy when the threshold value was placed at around 75 to 80% similarity.

Yet in most cases, scene changes in lecture videos do not coincide with topic changes [10]. Text extraction may be performed to address this issue. In addition to identifying topic changes in a lecture video, this may also be faster in segmenting a lecture video according to its topic since most lecture videos would most likely convey information that an algorithm can extract as text.

2.2 Video Segmentation Using Text Extraction

Texts found in lecture videos are valuable for detecting topic changes within a video. That is why extracting these texts is one of the approaches to segmenting videos based on their topics [11]. One way of extracting these texts is through Optical Character Recognition (OCR) [6]. The extracted texts from OCR were used as an input for a text-based indexing algorithm. This indexing algorithm aims to be able to segment the lecture video so that each segment will represent a topic. Just like the purpose of an index in a book, indexing a video would provide viewers with faster accessibility and navigability of contents [12]. However, it may be possible that texts extracted from different slides may have similar or the same topics and, thus, similar words used.

Lecture videos contain screen text and speech text, which is the corresponding text of the spoken words in the lecture video. The technology to convert these spoken words into text is called Automatic Speech Recognition (ASR) [13]. Speech text is as valuable as screen text because it contains information that can give topics in a lecture video. For this reason, a study [14] was done to use the speech content of the instructors to obtain textual and acoustic features and use them to segment the lecture video. The study showed more efficiency than other similar systems in Precision, Recall, and F-score.

A study was conducted to investigate which performs better in segmenting a video, whether using screen text or speech text as the input for a text-based indexing algorithm [6]. The study showed that screen text is a better guide in discovering topic changes than speech text. Errors found in speech recognition far exceed the errors in text recognition. Therefore, there would be greater accuracy in segmenting a video when screen text recognition is used instead of speech recognition.

2.3 Video Segmentation Using Machine Learning

Although text extraction is accurate, a comparative study [15] was conducted that shows video indexing where machine learning is involved provided better results. The study revealed that text-based algorithms performed better than non-text-based algorithms and indexing with machine learning algorithms performed better than text-based algorithms. The machine learning algorithms were accurate by around 80%, whereas text-based algorithms were accurate by around 68%. This shows that there is a huge improvement in video indexing accuracy if machine learning algorithms are involved in the process.

Another study uses boosted deep convolutional neural networks (CNNs) to segment lecture videos accurately [16]. In this study, indexing is done by matching high-quality slide images, with either known or extracted text, to lower resolution video frames with possible noise, space distortion, and occlusion. Experimental results of this study showed much more capability in handling features of the video like occlusion, spatial transformations, and other noises compared to other known approaches. Due to that, the indexing of the videos is a lot more accurate.

With these in mind, this research aimed to further improve the accuracy of video segmentation algorithms by combining image processing, text extraction methods, and machine learning. More specifically, the study was based on extracting text seen on the video using video frames and Optical Character Recognition (OCR). The data gathered from these methods were used as input into a convolutional neural network (CNN). Afterward, fine-tuning and testing were done to ensure the accuracy of the results.

3 Methods

A simple web app was used to get or capture lecture videos from the user. The video uploaded were then put through a data pipeline where the output of the process are unique slides found in the video. In the data pipeline, the frames per second of the video were extracted using OpenCV library. While extracting, redundant frames were filtered out using Image Hashing. Both of these processes were done together to make it a little bit faster. Afterwards, using the frames that were filtered out through Image Hashing, similar slides found in the frames were filtered out. This was done using CRAFT text detection and easyocr. These two libraries were able to get the title text of the slides and then using SequenceMatcher, title texts of two consecutive frames were compared by their similarity ratio. The output of this pipeline, which were the frames containing the unique slides in the video, were used as the input to a CNN Model that was created and designed for this purpose. The model identified which of the frames contained Transitional Slides and Non-Transitional Slides. With the Transitional Slides identified, their respective title text and timestamps were then extracted to segment the lecture video using the video player created (Fig. 1).

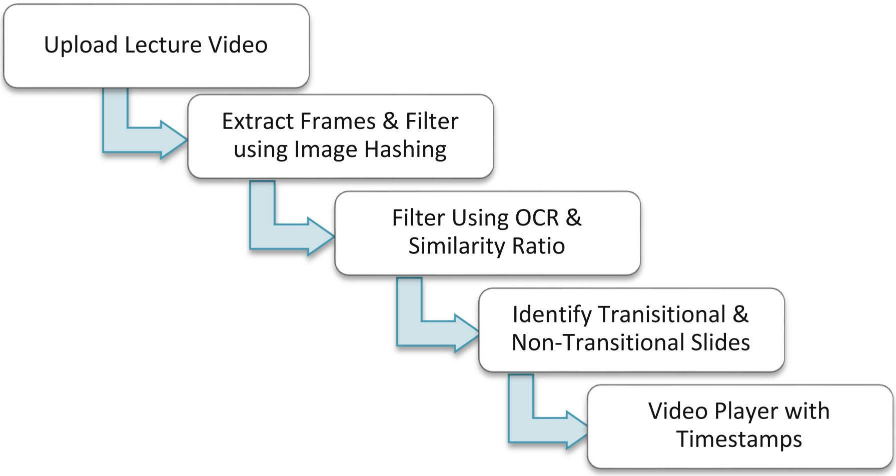


Fig. 1. Automatic topic-based lecture video segmentation flowchart

3.1 Data Pipeline

Frame Extraction. To be able for the system to process the lecture video, the image frames found in the lecture video are extracted first. However, not all image frames are extracted in the lecture video. Only one image frame per second is extracted to make the process faster and at the same time, get all the slides found in the presentation. The OpenCV library was used to read the video file and get the Frames Per Second (FPS) of the lecture video. Then, the FPS was used to get the exact image frame per second of the lecture video. The image frames extracted were used for data collection and input for the model.

Filter Similar Frames through Image Hashing. After extracting the frames per second of the video, redundant frames must be filtered out. This will serve 3 purposes: to narrow down the number of frames to be used as input to the model, ensure there are no consecutive frames that have little to no difference, and allow the next part of the pipeline to distinguish between slides.

To filter out similar frames, the visual similarities and differences of the frames must be considered. To do this, Image Hashing can be applied in which the image structure is analyzed and given numerical values for comparisons. To be more specific, a particular Image Hashing technique called Average Hashing was used. With this algorithm, the images are converted to grayscale then scaled down. The average of all gray values of the image is then calculated and the pixels are examined one by one from left to right. Pixels with gray values larger will lead to a 1 being added to the hash value while a 0 is added otherwise. Once a hash value is given to each image, arithmetic operations can then be applied to the hash values of two images to get a numerical value that represents their visual difference. A difference threshold (the value in which we consider two images to be too different from each other) was determined by comparing the hash values of 1,500 video frames with no similarities with each other and taking the average of all the differences. This value was determined to be 5.98, which means that any difference that falls below the threshold will be considered having too many similarities to be different. The image frame that comes later in the order of frames will be dropped entirely.

Filter Similar Slides through OCR and Similarity Ratio. Extracting every frame per second in the lecture video also captures all the slides that can be found. And after filtering out redundant frames, there are still similar slides found in different frames. Text detection using CRAFT and OCR libraries like easyocr was used to address this. With the help of CRAFT, all the text region or area in the slides were detected, and one of these text areas contains the title text of the slide. After finding the location of the title, easyocr was then used to extract the text in that location to be compared to the text found in the next frame. The basis for comparison used for the two texts will be their similarity ratio. The similarity ratio used was 90% which was able to cover 2–3 letter differences in the texts. This type of comparison was used since there are image frames that were captured during transitioning or going to the next slide, and easyocr cannot easily extract texts from it.

3.2 Dataset

An array of lecture videos that use slides were collected from various resources such as educational YouTube playlists, Free Online Courses, and recorded lectures uploaded by multiple different Universities. There were minor constraints with the kind of lectures being chosen aside from the constraint of having to select only those that made use of presentation slides.

Because the model is a binary classification model that will identify whether a certain slide is a slide that transitions to a new topic or not, the dataset is therefore split into only two classes: Transition Slides and Non-Transition Slides. The labeling of these slides was mainly determined through the uploader's topic segmentation of their videos, and for those videos that were not pre-segmented by their uploader, the content of the presentation itself was considered.

Around 80 lecture videos of varying lengths were collected, and after going through the pipeline and manual labeling, a dataset of 1,200 transition slides and 1,300 non-transition slides was made. Non-transition slides initially only amounted to around 750. However, training with the model with this amount resulted in it being heavily biased towards transition slides; therefore, data augmentation (horizontally flipped) was applied to double the number of non-transition slides. These were then split into train, test, and validation sets with a 80%, 10%, and 10% ratio, resulting in 1750 images for the training set and 250 images each for the validation and test set.

3.3 Image Classification Model

Model Architecture. The proposed system contains a Convolutional Neural Network based Binary Classification Model implemented through Python's Tensorflow Keras Library. It comprises 5 layers that each has one Convolutional Layer, one Max Pooling Layer, and one Dropout Layer. The only variation between these 4 layers is the number of outputs for each Convolutional Layer. The first layer has 16 output filters, 32 for the second layer, and 64 for the next 3 layers. The final group of layers comprises of a Flattening Layer, a Dense layer that outputs 512 units, and another Dense layer that has one output unit, which serves as the final output of the whole model. All layers that require activation functions use the 'relu' activation function except for the final Dense output layer, which uses the 'Sigmoid' activation function since an output range of 0 to 1 is needed.

Hyper-parameter Tuning and Training. Since this is a binary classification task, the model was trained on a Binary Cross Entropy loss function. In addition to this, because initial results of model training resulted in several degrees of overfitting (a validation loss of more than 0.9), multiple regularization techniques were added to circumvent this. First, Max Pooling Layers were added to each group of layers to minimize features and narrow them down to the most important ones that should logically reduce overfitting. Along with this, Dropout layers with 20% dropout rate was added to reduce overfitting, which decreased validation loss by around half (still $0.5 >$). Finally, an Early Stopping Function that monitors a significant increase in the validation loss was applied to the model's training, which further decreased the validation loss by half to around 0.26.

Applying Early Stopping automatically stopped the training at 19 epochs, which was the point where the validation loss started climbing up once again.

3.4 Evaluation of the Model

The model was evaluated on the test set mentioned earlier. Key metrics that were measured are the accuracy, evaluation loss, as well as standard evaluation scores for classification models such as precision score, which quantifies the number of positive class predictions that actually belong to the positive class, recall score, which quantifies the number of positive class predictions that were made out of all the positive examples, and the F-1 score, which takes the weighted average of both precision and recall scores. The equations for the three scores are displayed below:

$$\text{Precision} = \frac{\text{Number of Correctly Labeled Transition Slides}}{\text{Number of All Slides Labeled as Transition Slides}} \tag{1}$$

$$\text{Recall} = \frac{\text{Number of Correctly Labeled Transition Slides}}{\text{Number of All Transition Slides in Dataset}} \tag{2}$$

$$\text{F1 Score} = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}} \tag{3}$$

3.5 Web Application

A simple web application was implemented to demonstrate the functions of the system created. The web application can accept any video file of standard format. This video file is then be fed into the data pipeline explained above. After the unique slides are extracted, they will be used as input for the Binary Classification Model. The model will then label each frame, and the ones that have been labeled as being topic transition slides will have their topic title extracted using Optical Character Recognition. Since the filename of the image frames is their frame number, timestamps can be extracted in seconds by dividing the frame number to its FPS. When this is completed, the results are then displayed in the web interface where they can be interacted with by the user. Clicking on the timestamp on any topic of their interest will skip the video player ahead to that timestamp. The web application was made using Flask and Bootstrap as the framework and HTML Video for the video player.

4 Results and Discussion

The model's performance on key metrics was the basis used to evaluate the system's performance itself.

After evaluating the model on a test set containing 250 slides resulted in an evaluation loss of 0.19 and an accuracy of 0.91. Among 121 total Transition Slides and 131 Non-Transition Slides in the dataset, 119 were correctly labeled as Transition Slides while 76 were correctly labeled as Non-Transition Slides. When the detailed results of the evaluation are plotted in a confusion matrix, the results are shown below (Table 1):

Table 1. Confusion matrix of evaluation results on the test set

Heading level	True transition	True non-transition
Predicted transition	119	55
Predicted non-transition	2	76

The model had a Precision Score of 0.70, a Recall Score of 0.98 and an F1 Score of 0.80.

Overall, the model has a satisfactory result in its F1 Score, which is the benchmark score used for classification. A few inferences can be made about the model by breaking down the score even further. First, a very high Recall Score means that the model returns a high number of results including a few false negatives. A 0.70 Precision Score indicates that the model mistakes non-transition slides to be transition slides quite a bit. These two scores highly suggest that the model might still have a bit of a bias toward transition slides despite it decreasing. However, most of the time, after a lecture video is processed through the data pipeline where only its unique slides remain, the transition slides often outnumber the non-transition slides by a factor of 2. So, perhaps this bias is unavoidable and generally harmless in the application. Another reason might be because transition slides generally follow a visual layout with a degree of similarity from each other such as large bold titles at the center or at the top. Non-transition slides do not generally follow any pattern and are therefore much harder to distinguish.

A web application was implemented where a video was used as input. The application was able to output timestamps that were detected by the model as transition slides, along with their corresponding topics. Though there were a few errors in text extraction, the model was able to get important topics throughout the video. These strings of topics were extracted from detected topic transition slides, as mentioned earlier in the Methods section of this paper. Figure 2 shows how the timestamps help the user's navigability in the video. Each timestamp is a link that skips the video on the left to the specified timestamp when clicked, allowing for instant jumping to the specified transition slide in the video.

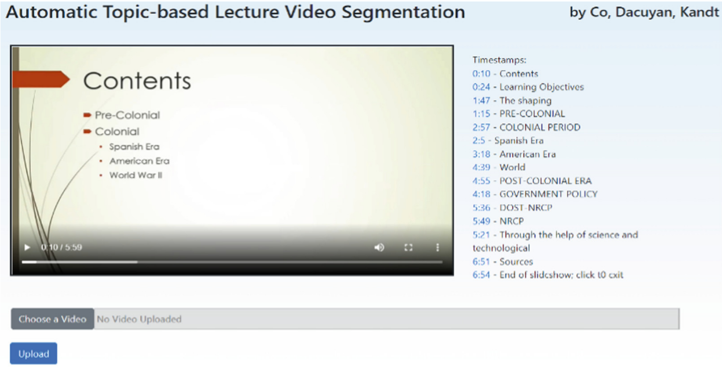


Fig. 2. An image of the video player after a timestamp was clicked.

5 Conclusion

The shift to online learning has increased the workload of teachers to compensate for the decrease in interactivity and engagement in lectures. One of the ways they can achieve this is to provide students with recorded lecture videos that have been pre-segmented by topic. However, teachers have so far only been able to do this manually. This study aimed to develop an AI system where lecture videos that made use of presentation slides could be uploaded then the timestamps of the start of essential topics could be identified and then outputted. The technique used to preprocess the raw video before being inputted into the model involved several techniques. First, image hashing was used to eliminate similar image frames effectively. And then, this filtered group of frames will have their text content extracted through Optical Character Recognition. Finally, the similarity ratio between slides is analyzed to determine if two image frames contain the same slide. The CNN-based binary classification model trained on a sample of 1750 lecture slides achieved satisfactory benchmark scores and has been integrated into a web-based video player platform. This research has created a system that could take in lecture videos of any duration and automatically segment them by topic with no human input. It should be noted that although system performance is satisfactory and the preprocessing techniques used were quite effective, the system itself has not been tested beyond system evaluation or its technical performance. Before a system like this can be formally introduced for use in any educational institution, more feedback must be taken from significant stakeholders in the academe.

References

1. Pokhrel, S., Chhetri, R.: A literature review on impact of COVID-19 pandemic on teaching and learning. High. Educ. Future **8**(1), 133–141 (2021)
2. Scagnoli, N.I., Choo, J., Tian, J.: Students' insights on the use of video lectures in online classes. Br. J. Edu. Technol. **50**, 399–414 (2019)
3. Wang, W., Zhou, T., Porikli, F., Crandall, D., Van Gool, L.: A survey on deep learning technique for video segmentation. arXiv:2107.01153 (2021)
4. Li, H., Ngan, K.N.: Image/Video segmentation: current status, trends, and challenges. In: Ngan, K.N., Li, H. (eds.) Video Segmentation and Its Applications, pp. 1–23. Springer, New York, NY (2011). https://doi.org/10.1007/978-1-4419-9482-0_1
5. Ağzıyağlı, V.S., Oğul, H.: Multi-level lecture video classification using text content. In: 2020 IEEE 14th International Conference on Application of Information and Communication Technologies (AICT), pp. 1–5. IEEE, New York (2020)
6. Tuna, T., Joshi, M., Varghese, V., Deshpande, R., Subhlok, J., Verma, R.: Topic based segmentation of classroom videos. In: 2015 IEEE Frontiers in Education Conference. IEEE, New York (2015)
7. Huang, C., Liao, B.: A robust scene-change detection method for video segmentation. In: IEEE Transactions on Circuits and Systems for Video Technology. IEEE, New York (2001)
8. Ravinder, M., Venugopal, T.: Content-based video indexing and retrieval using key frames texture, edge and motion features. Int. J. Curr. Eng. Technol. **6**(2), 672–676 (2016)
9. Haviana, S.F.C., Kurniadi, D.: Average hashing for perceptual image similarity in mobile phone application. J. Telematics Inf. **4**(1), 12–18 (2016)
10. Lin, M., Chau, M., Cao, J., Nunamaker, J.F., Jr.: Automated video segmentation for lecture videos: a linguistic based approach. Int. J. Technol. Hum. Interact. **1**(2), 27–45 (2005)
11. Gaikwad H., Hapase, A., Kelkar, C., Khairnar, N.: News video segmentation and categorization using text extraction technique. Int. J. Eng. Res. Technol. (2013)
12. Gayathri, N., Mahesh, K.: A systematic study on video indexing. Int. J. Pure Appl. Math. **118**(8), 425–428 (2018)
13. Arora, J., Singh, R.: Automatic speech recognition: a review. Int. J. Comput. Appl. **60**, 34–44 (2012)
14. Chand, D.: Lecture video segmentation using speech content. Østfold University College (2020)
15. Tuna, T.: Automated Lecture Video Indexing With Text Analysis and Machine Learning. Thesis. University of Houston (2015)
16. Ma, D., Zhang, X., Ouyang, X., Agam, G.: Lecture video indexing using boosted margin maximizing neural networks. arXiv:1712.00575 (2017)

Exploring the Relationship Between Learning Achievement and Discussion Records in Remote Maker Activities

Yu-Cheng Chien[1,2], Pei-Yu Cheng[3], Lin-Tao Csui[1], Yeongwook Yang[4], Danial Hooshyar[5], and Yueh-Min Huang[1(✉)]

[1] Department of Engineering Science, National Cheng Kung University, Tainan City, Taiwan
huang@mail.ncku.edu.tw
[2] Department of Information Management, National Chin-Yi University of Technology, Taichung City, Taiwan
[3] Department of Information Management, Tamkang University, New Taipei City, Taiwan
[4] Division of Computer Engineering, Hanshin University, Osan-si, South Korea
[5] School of Digital Technologies, Tallinn University, Tallinn, Estonia

Abstract. Maker's popularity worldwide has led to numerous studies on maker education to enhance learner competitiveness. One important research topic in educational research is how to effectively measure learning performance. Given the rapid development of science and technology, it is now possible to use learner discussion data to measure learning outcomes. We propose using natural language processing (NLP) technology to analyze learner discussion records by using speech-to-text technology to convert audio files into text files and using NLP technology exploring the resultant discussion texts. Experimental results reveal significant relationships between learner discussion and learning effectiveness, participation, and teamwork. This analysis also shows that high-achieving learners often discuss programming-related keywords. The proposed method can be used to analyze learner discussions and thus to measure their learning achievements.

Keywords: Maker education · Natural language processing · Speech-to-text · Discussion analysis

1 Introduction

Maker education adheres to the concept of "learning by doing" via the learner's learning process and connecting the acquired knowledge with the real world [1]. Compared with traditional, teacher-centered instruction, in which learners typically passively accept knowledge and find it more difficult to apply what they have learned [2], maker education is learner-centered, allowing learners to learn by hands-on practice and problem-solving, and also placing a greater emphasis on cultivating the learner's creativity and promoting problem solving, critical thinking, and collaborative sharing [3].

The success of learners in maker activities depends on whether they actively participate as teams during the learning process [4]; Riikonen, Seitamaa-Hakkarainen, and

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 43–51, 2022.
https://doi.org/10.1007/978-3-031-15273-3_5

Hakkarainen [5] emphasize the importance of students working as teams during maker activities. Teamwork thus plays an important role in maker education and is a key factor in maker success [6]. Therefore, it is important to determine how to assess the learning process and learning effectiveness when a learner works within a team. This has attracted several researchers to shift their attention to the course discussion records of maker activities.

The rise of the maker culture has caused educators to turn their attention to makers and has multiplied the opportunities for students to participate in design and hands-on practice [7]. Tofel-Grehl, Fields, Searle, Maahs-Fladung, Feldon, Gu, and Sun [8] show that bringing the idea of makers into traditional classrooms can promote interest in science. However, due to the impact of COVID-19, traditional face-to-face learning is limited, making it necessary to conduct remote maker courses via online video conferencing. Therefore, this study records the discussion content generated when learners participate in remote maker activity. We use latent Dirichlet allocation (LDA) to mine semantic information from textual data and understand the focus of the discussion and related vocabulary, which helps researchers and classroom teachers better understand learner discussions in maker courses.

2 Related Work

2.1 Social Learning

The demand for collective thinking and collaborative problem solving in society has increased, and collaboration has slowly become a key skill in today's society [9]. The pedagogical philosophy of adopting cooperation in teaching activities to promote student learning and the ability to work in groups has led to its wide use around the world [10, 11]. As collaboration becomes more and more important, educators also incorporate the idea of collaboration into curriculum teaching.

Social learning is the process by which individuals or groups acquire relevant environmental information and change their behavior through interaction with others [12]. In the process of collaborative knowledge construction, learners share knowledge and ideas and exchange opinions [13]; this is also an important motivation for learners [14]. In discussions, learners engage in debate, critical thinking, elaboration, and reasoning in small groups [15], an interactive process in which learners share ideas and opinions with their peers, thereby gaining knowledge from different viewpoints and promoting their understanding of the course content [16].

Participating in discussion activities during the learning process can improve their learning results, and learners who actively participate in discussions criticize, correct, or supplement the opinions of others so as to reach consensus with peers and solve problems [17]; in addition to helping to understand and apply what they have learned in the course [18], classroom discussions lead to more critical thinking and better learning outcomes for learners [19, 20].

2.2 Discourse Analysis

Discourse analysis first appeared in the field of linguistics [21]. In the field of education, discourse analysis can be used (1) to detect students' contributions and learning attitudes when participating in discussions, (2) to reveal how knowledge is constructed by learners, and (3) to gain a deeper understanding of how learners interact with each other [22]. In recent years, due to the advancement of science and technology, discussion-based teaching activities have received increasing attention; in particular, researchers have begun to develop artificial intelligence (AI) based discussion and analysis techniques for educational research. This is a key technology to promote the practical application of learning analysis and educational data mining [23], the most typical data source of which is discussion text derived from the learning process [12].

The discourse keywords of learners in discussions are gradually being valued by researchers, as these can be used to analyze and understand the key and focus of the discussions [24]; topic modeling has thus become increasingly popular in education [12, 25]; LDA, an unsupervised topic modeling algorithm based on machine learning, mines semantic information from textual data and can be used to understand the focus of discussion and related vocabulary. Ezen-Can, Boyer, Kellogg, and Booth [25] use K-medoids clustering to classify learner discussion posts in MOOC online forums, and further adopt an LDA model to observe topics of interest to learners. Peng and Xu [12] use LDA in a behavior-emotion topic model (BETM) to evaluate the semantic content of comments between two learning achievement groups (an "academic completion" group and an "academic incompletion" group), including topics discussed among learners as well as related affective and behavioral characteristics. Their results reveal differences in the discourse behavior between the two groups, in particular the subject category, subject emotion, and subject behavior. The researchers also found that the academic incomplete group tends to respond to comments unrelated to the course.

3 Methodology

3.1 Participants

We offered an "Online Maker Class" as an experimental course for remote maker activities. To ensure that the experimental subjects had basic computer and programming experience, a total of 18 volunteers participated in this experiment from elementary schools in southern Taiwan, including 12 boys and 6 girls. The 18 students were randomly divided into 6 groups of 3 people.

3.2 Online Learning Environment

Due to the COVID-19 epidemic, this study used Google Meet and Google Classroom as the learning platforms for online courses and online discussions.

Google Meet is an online video conferencing platform which helps teachers implement learning activities such as online synchronous teaching courses or oral presentations in an online environment; teamwork and sharing of creative results are part of the creative process, and functions provided by Google Meet provide effective support for remote maker activities. In Google Meet, learners display programming results by sharing the screen, and share implementation results with peers via video. Google Meet also provides a breakout room function, using which learners can join different breakout rooms so that they can discuss and share without interference from other groups. Figure 1 is a screenshot of the Google Meet breakout room. In the distance maker course activity of this research, as there were six groups of participants in the experiment, we established six breakout rooms.

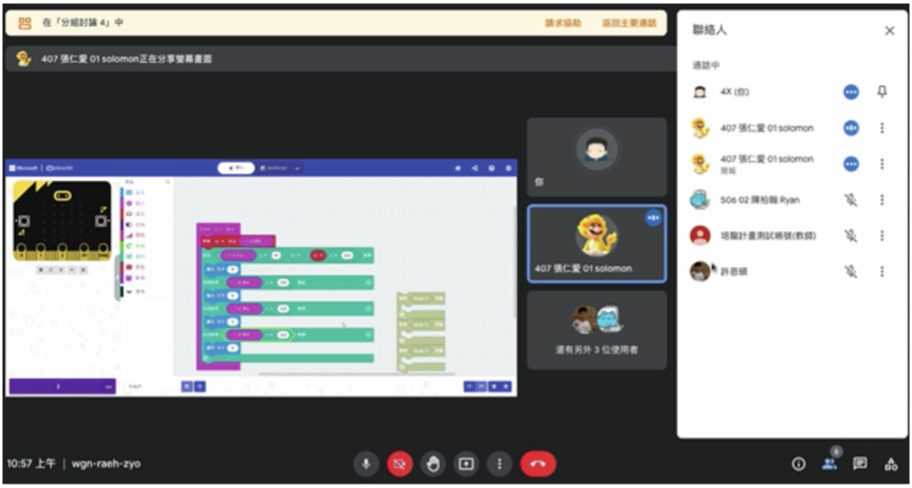


Fig. 1. Google Meet breakout rooms

Using Google Classroom, an online learning management platform, course managers or teachers invite students to participate in courses; they also share courses, assign homework, and check homework submission status through this platform. Figure 2 shows the list of learners in a maker activity, the activity task list, and the completion and submission status of their homework assignments (tasks) for this study. When experiment participants were engaged in online maker activities, they could view the handouts, the task content, the assignment submission (task upload), and the course comments through Google Classroom at any time.

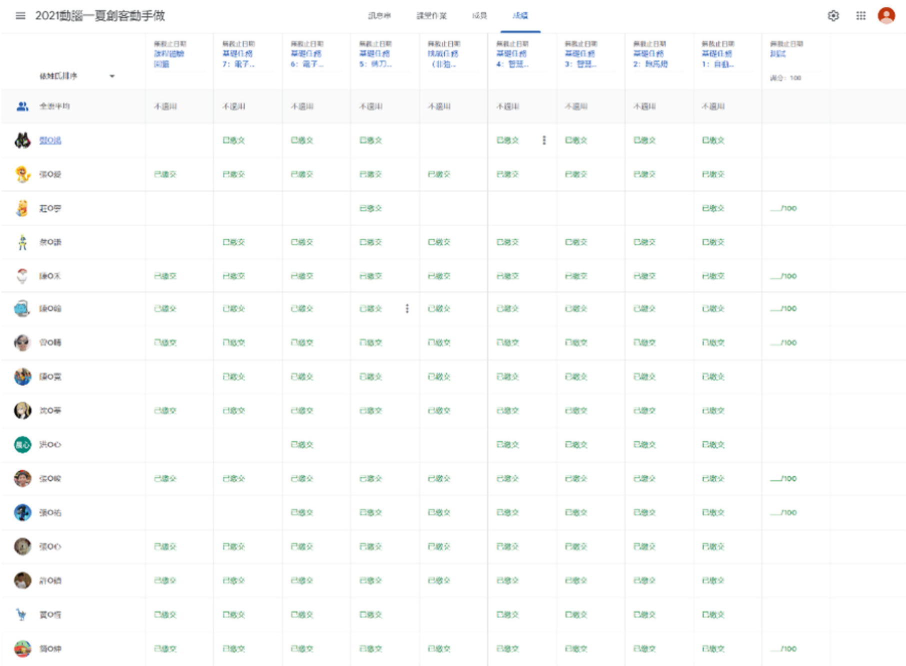


Fig. 2. Google Classroom

3.3 Maker Activity

For the remote maker activity of this study, we adopted micro:bit as the theme of the experiment. The activity was divided into four stages, including an introduction of micro:bit, the makecode platform, the variables and operations, and logical judgment. All tasks were designed with reference to Microsoft [26]. The tasks and learning objectives in this study are described in Table 1. This experimental activity was designed with a total of seven basic tasks and one challenge task.

To ensure that all participants in the experiment were able to successfully complete the remote maker activities, we briefly explained Google Meet, the online video conferencing platform, and Google Classroom, the online course platform. Then, the teacher introduced each staged course and tasks and demonstrated the operation thereof, after which participants were to complete the corresponding phased course tasks. After explaining each stage of the course, the participants were asked to use the micro:bit development board to complete the activity tasks using the course handout and study sheet.

Table 1. Micro:bit tasks in maker activity

Learning stage	Task
Micro:bit introduction	N/A
Makecode platform	Basic task #1: Automatic countdown
	Basic task #2: Marquee
Variables and operations	Basic task #3: Smart thermometer
	Basic task #4: Smart light sensor
Logical judgment	Basic task #5: Finger-guessing game
	Basic task #6: Electronic dice
	Basic task #7: Electronic compass
	Challenge mission: Night lights

4 Results

We explore the proposed use of natural language processing technology in the analysis of discussion records to evaluate the relevance and feasibility of the learning outcomes of maker education. Based on the text data collected in the remote maker activities, we summarize and sort the LDA analysis results to understand the differences in the discussion process of learners with different achievements participating in the maker activities.

In this study, students were divided into groups based on their learning performance. This grouping resulted in 9 high-achievement students and 9 low-achievement students (Table 2).

Table 2. Learning achievement groups

	Product score		Testing score	
	Mean	*SD*	*Mean*	*SD*
High achievement ($N = 9$)	9.85	0.71	9.62	0.94
Low achievement ($N = 9$)	7.09	3.58	3.13	4.19

For the discussion analysis, we used LDA for text topic analysis, seeking to analyze the discussion data generated by learners during their maker activities. Since the experimental activity was a remote maker activity designed around micro:bit; during the activity, the learners discussed the learning platform, learning materials, programming design, as well as content unrelated to the course. Thus we classified subject words extracted by LDA into 1) online operation; 2) activity theme; 3) programming; and 4) other. Table 3 categorizes and describes the discussion categories of maker activities in this study.

Table 3. Maker activity discussion categories

Discussion category	Description	Example
Online operation	Problems encountered in Google Meet and Google Classroom	"I'll project it" "How to download" "How to upload"
Task theme	Discuss course content and worksheet content	"How to write the fifth question"
Programming	Discuss the problems encountered when writing programs on the makecode platform	"Like this with an array of numbers" "Use the if-then-else"
Other	Discuss content not related to the activity	"I wrote it" "Wait a minute it will be ready"

To explore differences in the discussion categories between different achievements, a Kruskal–Wallis one-way analysis of variance (ANOVA) was conducted on high and low achievements. Shown in Table 4, the analysis results indicate a significant difference in programming between achievements ($p = 0.010$).

Table 4. Differences between students of different achievement and discussion categories

	High achievement		Low achievement		Kruskal–Wallis test (p)
	Mean	*SD*	*Mean*	*SD*	
Online operation	1.75	1.67	3.67	3.28	0.241
Task theme	14.0	11.1	6.89	6.62	0.111
Programming	12.9	8.46	3.00	3.12	0.010*
Other	3.13	3.83	4.56	3.57	0.265

5 Conclusion

This study uses natural language processing technology to analyze the discussions of learners participating in distance-learning maker activities. In these discussions, learners with different achievements exhibit significant differences in the discussion of programming writing; there are no significant differences in online operations, activity themes, and the three other aspects. Programming is a discussion-oriented task in which one puts into practice the knowledge learned, ultimately achieving a higher learning level. In this study we used the system to analyze the recorded audio files of the course so that teachers can understand the current learning status of learners and assist low-achieving learners.

References

1. Schön, S., Ebner, M., Kumar, S.: The maker movement. Implications of new digital gadgets fabrication tools and spaces for creative learning and teaching. eLearning Pap. **39**, 14–25 (2014)
2. Kollöffel, B., de Jong, T.: Conceptual understanding of electrical circuits in secondary vocational engineering education: combining traditional instruction with inquiry learning in a virtual lab. J. Eng. Educ. **102**, 375–393 (2013)
3. Hsu, Y.-C., Baldwin, S., Ching, Y.-H.: Learning through making and maker education. TechTrends **61**, 589–594 (2017). https://doi.org/10.1007/s11528-017-0172-6
4. Scardamalia, M., Bereiter, C.: Knowledge building and knowledge creation: theory, pedagogy, and technology. Camb. Handb. Learn. Sci. **2**, 397–417 (2014)
5. Riikonen, S., Seitamaa-Hakkarainen, P., Hakkarainen, K.: Bringing maker practices to school: tracing discursive and materially mediated aspects of student teams' collaborative making processes. Int. J. Comput.-Support. Collab. Learn. **15**, 319–349 (2020). https://doi.org/10.1007/s11412-020-09330-6
6. Shan, J., Wang, W.: Making and sharing in asynchronous discussion: exploring the collaboration process in online maker community. Interact. Learn. Environ. 1–15 (2021)
7. Martin, L.: The promise of the maker movement for education. J. Pre-Coll. Eng. Educ. Res. (J-PEER) **5**(1), 4 (2015)
8. Tofel-Grehl, C., et al.: Electrifying engagement in middle school science class: improving student interest through e-textiles. J. Sci. Educ. Technol. **26**, 406–417 (2017). https://doi.org/10.1007/s10956-017-9688-y
9. Laal, M., Laal, M., Kermanshahi, Z.K.: 21st century learning; learning in collaboration. Procedia Soc. Behav. Sci. **47**, 1696–1701 (2012)
10. Howe, C.: Peer Groups and Children's Development. Wiley, Hoboken (2009)
11. Mercer, N., Littleton, K.: Dialogue and the Development of Children's Thinking: A Sociocultural Approach. Routledge (2007)
12. Peng, X., Xu, Q.: Investigating learners' behaviors and discourse content in MOOC course reviews. Comput. Educ. **143**, 103673 (2020)
13. Roschelle, J., Teasley, S.D.: The construction of shared knowledge in collaborative problem solving. In: O'Malley, C. (ed.) Computer Supported Collaborative Learning, pp. 69–97. Springer Berlin Heidelberg, Berlin, Heidelberg (1995). https://doi.org/10.1007/978-3-642-85098-1_5
14. Sharples, M., Taylor, J., Vavoula, G.: A theory of learning for the mobile age. In: Bachmair, B. (ed.) Medienbildung in Neuen Kulturräumen, pp. 87–99. VS Verlag für Sozialwissenschaften, Wiesbaden (2010). https://doi.org/10.1007/978-3-531-92133-4_6
15. Stegmann, K., Wecker, C., Weinberger, A., Fischer, F.: Collaborative argumentation and cognitive elaboration in a computer-supported collaborative learning environment. Instr. Sci. **40**, 297–323 (2012). https://doi.org/10.1007/s11251-011-9174-5
16. Noroozi, O., Weinberger, A., Biemans, H.J., Mulder, M., Chizari, M.: Facilitating argumentative knowledge construction through a transactive discussion script in CSCL. Comput. Educ. **61**, 59–76 (2013)
17. Weinberger, A., Fischer, F.: A framework to analyze argumentative knowledge construction in computer-supported collaborative learning. Comput. Educ. **46**, 71–95 (2006)
18. Hübscher, R.: Assigning students to groups using general and context-specific criteria. IEEE Trans. Learn. Technol. **3**, 178–189 (2010)
19. Smith, D.G.: College classroom interactions and critical thinking. J. Educ. Psychol. **69**, 180 (1977)

20. Rathakrishnan, M., Ahmad, R., Suan, C.L.: Online discussion: Enhancing students' critical thinking skills. In: AIP Conference Proceedings, p. 020120. AIP Publishing LLC (2017)
21. Harris, Z.S.: Discourse analysis. In: Harris, Z.S., Hiż, H. (eds.) Papers on Syntax, pp. 107–142. Springer Netherlands, Dordrecht (1981). https://doi.org/10.1007/978-94-009-8467-7_7
22. Knight, S., Littleton, K.: Discourse-centric learning analytics: mapping the terrain. J. Learn. Analytics **2**, 185–209 (2015)
23. Chung, C.K., Pennebaker, J.W.: Using computerized text analysis to track social processes. In: Handbook of Language and Social Psychology. Oxford, New York, vol. 12 (2013)
24. Chien, Y.-C., Liu, M.-C., Wu, T.-T.: Discussion-record-based prediction model for creativity education using clustering methods. Thinking Skills Creativity, **36**, 100650 (2020)
25. Ezen-Can, A., Boyer, K.E., Kellogg, S., Booth, S.: Unsupervised modeling for understanding MOOC discussion forums: a learning analytics approach. In: Proceedings of the Fifth International Conference on Learning Analytics and Knowledge, pp. 146–150 (2015)
26. Microsoft. Makecode. https://microbit.org/projects/make-it-code-it/. Accessed 15 May 2022

A Sentiment Analysis Based Approach for Exploring Student Feedback

Rdouan Faizi(✉) and Sanaa El Fkihi

ENSIAS, Mohammed V University in Rabat, Rabat, Morocco
{rdouan.faizi,sanaa.elfkihi}@um5.ac.ma

Abstract. Student feedback is commonly used as a reliable source of information to evaluate learning outcomes and teaching quality. This feedback has proven to provide faculty not only with valuable insights into how students are learning, but also with an ideal opportunity to reflect on teaching resources and instructional strategies. However, given the increasing massive amounts of feedback that is available online, collecting and analyzing this data manually is not usually an easy task. The aim of this work is, therefore, to put forward a sentiment analysis classifier that is capable of categorizing student feedback as being either positive or negative. To this end, students' reviews posted about online courses were automatically extracted, preprocessed and then fed into various machine learning algorithms. The findings of this analysis revealed that the Support Vector Machines (SVM) algorithm achieves the highest accuracy score (93.35%) and, thus, outperforms other implemented models.

Keywords: Education · Student feedback · Sentiment analysis · Machine learning · SVM

1 Introduction

Student feedback has always been used as a valuable source of information that can be used to assess learning outcomes and the quality of teaching. By collecting and analyzing this feedback, faculty can get information into how students are learning and how they are engaged with content. In fact, teachers can see what specific areas students are strong at and what parts of the course they are weak at. This formative feedback, thus, gives faculty an ideal opportunity to reflect on both the teaching resources as well as on their instructional strategies and approaches [1, 2].

This feedback is generally collected from students through discussions that are held during or after face-to-face classes or through rating scale surveys or a mixture of closed-ended and open-ended questionnaires. However, given the increasing proliferation of online courses over the last couple of years, the internet has become an optimal space in which students post massive amounts feedback about the various learning resources that they have used. Nevertheless, extracting and analyzing this feedback manually is time consuming. Therefore, our purpose in this work is to propose a sentiment analysis

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 52–59, 2022.
https://doi.org/10.1007/978-3-031-15273-3_6

approach that automatically identifies the perceptions and opinions of students towards the learning resources and classifies them as being positive or negative.

The rest of this article is structured as follows. In Section Two we review the major studies that have addressed student feedback using sentiment analysis. In Section Three we propose our sentiment-based approach. Section Four presents the results of the experiments that have been carried out. Finally, Section Five summarizes the findings of this article.

2 Review of the Literature

Due to the huge amounts of data that have been produced online in the past few years, sentiment analysis has drawn much attention from researchers. Sentiment analysis applications are currently used in various domains [3–5]. These include e-commerce, marketing and hospitality. Nonetheless, these applications have recently found their way into other fields, one of which is education [6–9]. In fact, due to the growing proliferation of online tutorials over the last two decades, the platforms hosting these resources have become an ideal space where students or learners post comments about the courses as well as questions/answers about issues that need clarification. Once retrieved, this formative feedback can be beneficially made use of to enhance the teaching and learning experiences [10–14].

To extract value from this student feedback, many studies have been carried out using different sentiment techniques. In this vein, Giang et al. [15] collected Vietnamese university students' feedback and manually organized it into three main classes, namely positive, negative and neutral. On the basis of this annotated dataset, they trained and tested three classifiers. These include Naïve Bayes, Maximum Entropy and Support Vector Machine. After evaluation they found out that Maximum Entropy is better than the two other algorithms as it is associated with the highest accuracy score (i.e. 91.36%).

Within the same context, Altrabsheh et al. [16] trained Naive Bayes, Complement Naive Bayes (CNB), Maximum Entropy as well as Support Vector Machines (SVM) using students' feedback. Two classifiers were found out to do well at learning sentiment. The first is SVM, which has the best accuracy score (i.e. 94%) followed by CNB (84%). The authors also attempted to make use of the neutral class but their findings demonstrated that both classifiers generally perform better in terms of accuracy when this class is excluded.

In his attempt to design a model that can classify lecturer-student reviews, Rakhmanov [17] undertook a comparative study of different vectorization and classification methods. In this context, TF-IDF and Count Vectorizer, as vectorization methods, were compared, and Random Forest, Support Vector Machines, Naive Bayes, Gradient boosting and artificial neural networks were evaluated as classification algorithms. The results of the experiments showed that the classifier designed using Random Forest was the most proficient as it has an accuracy of around 97% for a 3-class classification while TF-IDF performed better than Count Vectorizer.

In [18] Kandhro et al. evaluated the use of Multinomial Naive Bayes, Stochastic Gradient Decent, Support Vector Machines, Random Forest and Multilayer Perceptron on the dataset they collected from various universities in Karachi. The results of their analysis showed that the performances of MNB and MLP was more effective compared to those of the other classifiers.

For their parts, Nasim et al. [19] presented a hybrid approach that combines both machine learning and lexicon-based methods. The best performing approach was the one using TF-IDF and the domain-specific sentiment lexicon. As opposed to lexicon-based techniques, using a sentiment lexicon together with machine learning models can correctly predict the sentiment of the feedback although opinion words are not present in the lexicon.

Using roughly the same set of machine learning algorithms, Dsouza et al. [20] collected student feedback via Google forms and used Support Vector Machine, Multinomial Naive Bayes Classifier, and Random Forest to perform sentiment analysis. A comparative analysis of these machine learning techniques approaches revealed that Multinomial Naïve Bayes algorithm performs much better than Support Vector Machine and Random Forest algorithms.

3 Proposed Model

In this section we detail the different steps that we went through during the sentiment classification of student feedback.

3.1 Data Extraction and Sentiment Annotation

To carry out sentiment analysis on student feedback, we extracted reviews that have been written on YouTube educational videos. Our choice of this social media platform is not at random. In fact, though YouTube has widely been recognized as an entertainment outlet, through which the internet user can view, upload and share an extremely large array of multimedia content, this video sharing website has recently turned into an ideal venue which students resort to so as to improve their learning experience in a variety of disciplines [21–24]. However, just like other social networks, this platform serves not only as a means to watch video tutorials but also as a forum in which learners can leave feedback [25–27].

Once the learners' feedback has been extracted, we firstly deleted duplicated comments well as those that are written in languages other than in English. The resulting reviews were then manually assigned sentiment labels namely, positive or negative. Once all comments have been annotated, we got 5969 reviews: 3340 positive and 2629 negative.

3.2 Data Preprocessing

After the reviews have been extracted and labelled, our dataset had got to go through the pre-processing phase. The latter is, actually, a critical step in any natural language processing operation. Indeed, since raw YouTube comments usually contain irrelevant or meaningless data that can negatively impact model accuracy, we had to clean them up. The pre-processing or cleaning phase includes the following tasks:

- Removing noise such as special characters, numbers, hyperlinks, white spaces, tags, punctuation, etc.
- Lowercasing: convert all letters to lower case so as to avoid lower and upper case differences between words.
- Deleting stop words such as articles, pronouns, conjunctions, preposition as these items do not affect sentiment analysis.
- Normalization, that is converting words into a canonical form.
- Tokenization: split a piece of text into individual words or tokens.
- Stemming: reducing words to their stems by deleting affixes.
- Lemmatization: returning words to their dictionary basic unit.

3.3 Feature Extraction

After the pre-processing phase, the data must be converted into features for machine learning models to process it. In fact, since no model can understand human natural languages, our preprocessed data should be turned into numeric or vector representation. To this end, we used TF-IDF. This feature extraction technique takes into consideration the occurrence of a word not just in a single document but in the entire corpus. This method works by assigning higher weights to rarer words or phrases which are more important and by allocating lower weights to common words.

3.4 Model Classification

Once the data was preprocessed and turned into vectors, it was split into two: a training set (80%) for fitting and tuning the model and a testing set (20%) for creating predictions on and evaluating the classifier at the end. The next task was to fed our data into machine learning models. Yet, for our particular problem in this work, we used supervised learning algorithms, which are characterized by two important stages: a learning phase where the model is trained on the data, and an evaluation stage where the performance of that approach is tested. In this respect, the dataset prepared beforehand was used with four machine learning classifiers, namely Support Vector Machines (SVM), Naive Bayes (NB), Logistic Regression (LR) and Random Forest (RF). These models are detailed below.

- NB is a probabilistic classifier which is based on the Bayes Theorem [28] that assumes that the presence or absence of a given feature of a class is absolutely independent of that of the other features. This algorithm predicts the likelihood of an incident based on some prior knowledge of certain conditions related to that event.
- LR is a classification rather than a regression model despite its name. Logistic regression basically uses a logistic function to model a binary output variable [29]. It is commonly made use of in cases in which the data in question is associated with a binary output (e.g. “spam/ham” or “true/false”).
- SVM is a non-probabilistic classification model that is based on the notion of decision planes which define decision boundaries. SVM conducts classification by identifying the best hyperplane that divides a particular dataset into two classes using support vectors. Intuitively, the most appropriate decision boundary or hyperplane is the one that has the largest distance to the most adjacent training data point of any class.

- RF is an ensemble classifier that makes estimates on the basis of multiple different decision trees. RF fits a set of decision trees on subsets of data that are randomly selected. The prediction of the random forest is attained via a majority vote over the predictions of every individual decision tree.

To evaluate the performance of these machine learning algorithms after their implementation on our dataset, we made use of accuracy as an evaluation metric. The latter is a measure of the number of correctly predicted instances of the global number of predictions.

4 Results and Discussion

Based on a set experiments that were conducted on the dataset using three language models of n-grams, namely unigram, bigram and trigram, we got the following findings (Table 1).

Table 1. Findings based on testing accuracy

Model	N-Grams	Accuracy (stemming)	Accuracy (lemmatization)
NB	Unigram	91.83%	92.00%
	Unigram-bigram	92.34%	91.49%
	Unigram-trigram	92.00%	91.41%
LR	Unigram	91.32%	90.40%
	Unigram-bigram	90.82%	89.89%
	Unigram-trigram	90.74%	89.81%
SVM	Unigram	93.09%	93.35%
	Unigram-bigram	92.67%	92.84%
	Unigram-trigram	92.67%	92.76%
RF	Unigram	89.64%	88.88%
	Unigram-bigram	89.22%	88.72%
	Unigram-trigram	89.98%	88.97%

As the table clearly displays, SVM performs better than the other algorithms in classifying student feedback. Indeed, despite the fact that its implementation seems to be more time-consuming, this model actually achieved the highest accuracy score with all three combinations of n-gram language models, namely unigrams (93.35%), unigrams-bigrams (92.84%) and unigrams-trigrams (92.76%) when only lemmatization is taken into consideration. Equally, this supervised machine learning model outperforms other algorithms when stemming is opted for rather than lemmatization. In this vein, the tests that were performed have proven that SVM got the best accuracy score when using unigrams (93.09%) as well as with combinations of unigrams-bigrams and unigrams-trigrams (92.67%).

With scores that are not distant from those of SVM, the NB classifier exhibited an accuracy of 92.34% for unigrams and bigrams. Besides SVM and NB, LR has similarly been demonstrated to yield good results. As for RF, the findings of the experiments have shown that this classifier is associated with the lowest accuracy scores (around 89%) for all cases.

Taking into account the good performance of SVM in classifying our dataset, it can be deduced that this model can efficiently process student feedback and can provide faculty and educators with the students' perceptions and attitudes towards the learning materials and teaching methodologies in real-time or near real-time. This valuable information can, thus, help improve the students' learning experience and teaching strategies.

5 Conclusion

Our aim in this work was to put forward a sentiment analysis model that is capable of classifying student feedback as being positive or negative. In this context, on the basis of the implementation of various supervised machine models on the students' reviews that have been posted about YouTube educational videos, it has been demonstrated that SVM performs better in comparison with other machine learning models. Thus, the sentiment analysis approach we proposed can efficiently predict students' perceptions and sentiments towards learning resources and can, thus, allow faculty to get an idea on the different parts of the course that the learners master as well as information on the learning difficulties that students encounter.

References

1. Blair, E., Valdez Noel, K.: Improving higher education practice through student evaluation systems: is the student voice being heard? Assess. Eval. High. Educ. **39**(7), 879–894 (2014)
2. Johnson, S.D., Aragon, S.R., Shaik, N.: Comparative analysis of learner satisfaction and learning outcomes in online and face-to-face learning environments. J. Interact. Learn. Res. **11**(1), 29–49 (2000)
3. Faizi, R., El Fkihi, S., Ezzahid, S.S., El Afia, A.: Using sentiment analysis to derive business value. In: Proceedings of the 32nd International Business Information Management Association (IBIMA), pp. 15–16, November 2018, Seville, Spain (2018). ISBN: 978-0-9998551-1-9
4. Faizi, R., El Fkihi, S., El Afia, A.: Leveraging big data to improve customer experience. In: Proceedings of the 30th International Business Information Management Association Conference, IBIMA 2017 - Vision 2020: Sustainable Economic development, Innovation Management, and Global Growth (2017)
5. Faizi, R., El Fkihi, S., El Afia, A.: Exploring the potentials of big data analytics in marketing. In: Proceedings of the 31st International Business Information Management Association Conference, IBIMA 2018: Innovation Management and Education Excellence through Vision 2020 (2018)
6. Colace, F., Casaburi, L., De Santo, M., Greco, L.: Sentiment detection in social networks and in collaborative learning environments. Comput. Hum. Behav. **51**, 1061–1067 (2015)

7. Barrón Estrada, M.L., Zatarain Cabada, R., Oramas Bustillos, R., Graff, M.: Opinion mining and emotion recognition applied to learning environments. Expert Syst. Appl. **150**, 113265 (2020)
8. Zhou, J., Ye, J.M.: Sentiment analysis in education research: a review of journal publications. Interact. Learn. Environ. 1–13 (2020)
9. El Fkihi, S., Ezzahid, S.S., Faizi, R., Chiheb, R.: Formative assessment in the era of big data analytics. In: Proceedings of the 32nd International Business Information Management Association (IBIMA), pp. 15–16 November 2018, Seville, Spain (2018). ISBN: 978-0-9998551-1-9
10. Menaha, R., Dhanaranjani, R., Rajalakshmi, T., Yogarubini, R.: Student feedback mining system using sentiment analysis. IJCATR **6**, 1–69 (2017)
11. Eng, T.H., Ibrahim, A.F., Shamsuddin, N.E.: Students' perception: student feedback online (SuFO) in higher education. Procedia-Soc. Behav. Sci. **167**, 109–116 (2015)
12. Sangeetha, K., Prabha, D.: Sentiment analysis of student feedback using multi-head attention fusion model of word and context embedding for LSTM. J. Ambient. Intell. Humaniz. Comput. **12**(3), 4117–4126 (2020). https://doi.org/10.1007/s12652-020-01791-9
13. Singh, L.K., Devi, R.R.: Student feedback sentiment analysis: a review. Mater. Today Proc. (2021)
14. Faizi, R.: A sentiment-based approach to predict learners' perceptions towards YouTube educational videos. In: Abraham, A., et al. (eds.) Innovations in Bio-Inspired Computing and Applications: Proceedings of the 12th International Conference on Innovations in Bio-Inspired Computing and Applications (IBICA 2021) Held During December 16–18, 2021, pp. 549–556. Springer, Cham (2022). https://doi.org/10.1007/978-3-030-96299-9_52
15. Giang, N.T.P., Dien, T.T., Khoa, T.T.M.: Sentiment analysis for university students' feedback. In: Arai, K., Kapoor, S., Bhatia, R. (eds.) FICC 2020. AISC, vol. 1130, pp. 55–66. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-39442-4_5
16. Altrabsheh, N., Cocea, M., Fallahkhair, S.: Learning sentiment from students' feedback for real-time interventions in classrooms. In: Bouchachia, A. (ed.) adaptive and intelligent systems, pp. 40–49. Springer, Cham (2014). https://doi.org/10.1007/978-3-319-11298-5_5
17. Rakhmanov, O.: A comparative study on vectorization and classification techniques in sentiment analysis to classify student-lecturer comments. Procedia Comput. Sci. **178**, 194–204 (2020)
18. Kandhro, I.A., Chhajro, M.A., Kumar, K., Lashari, H.N., Khan, U.: Student feedback sentiment analysis model using various machine learning schemes: a review. Indian J. Sci. Technol. **12**(14), 1–9 (2019)
19. Nasim, Z., Rajput, Q., Haider, S.: Sentiment analysis of student feedback using machine learning and lexicon based approaches. In 2017 International Conference on Research and Innovation in Information Systems (ICRIIS), pp. 1–6. IEEE (2017)
20. Dsouza, D.D., Deepika, D.P.N., Machado, E.J., Adesh, N.D.: Sentimental analysis of student feedback using machine learning techniques. Int. J. Recent Technol. Eng. **8**(14), 986–991 (2019)
21. Faizi, R.: Moroccan higher education students' and teachers' perceptions towards using Web 2.0 technologies in language learning and teaching. Knowl. Manag. E-Learn. Int. J. (KM&EL) **10**(1), 86–96 (2018)
22. Snelson, C.: The benefits and challenges of YouTube as an educational resource. In: Hobbs, R. (ed.) The Routledge Companion to Media Education, Copyright, and Fair Use, pp. 203–218. Routledge (2018)
23. Vieira, I., Lopes, A.P., Soares, F.: The potential benefits of using videos in higher education. In: Proceedings of EDULEARN14 Conference, pp. 0750–0756. IATED Publications (2014)
24. Faizi, R.: Teachers' perceptions towards using Web 2.0 in language learning and teaching. Educ. Inf. Technol. **23**(3), 1219–1230 (2017)

25. Faizi, R., Rudneva, M.: Higher education students' perceptions towards using Facebook as a learning platform. In: Huang, Y.-M., Lai, C.-F., Rocha, T. (eds.) ICITL 2021. LNCS, vol. 13117, pp. 548–554. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-91540-7_56
26. Faizi, R., El Fkihi, S.: Investigating the role of social networks in enhancing students' learning experience: Facebook as a case study. Int. Assoc. Dev. Inf. Soc. (2018)
27. Faizi, R., El Fkihi, S.: Incorporating Web 2.0 technologies in education: opportunities and challenges. In: Proceedings of the 28th IBIMA conference on Vision 2020: Innovation Management, Development Sustainability, and Competitive Economic Growth, pp. 3242–3248 (2016)
28. Lewis, D.D.: Naive (Bayes) at forty: the independence assumption in information retrieval. In: Nédellec, C., Rouveirol, C. (eds.) ECML 1998. LNCS, vol. 1398, pp. 4–15. Springer, Heidelberg (1998). https://doi.org/10.1007/BFb0026666
29. Tolles, J., Meurer, W.J.: Logistic regression: relating patient characteristics to outcomes. JAMA **316**(5), 533–534 (2016)

VR/AR/MR/XR in Education

AR Compiler: A Visualization Data Structured Program Learning System

Wei-Tsung Lin[1](✉), Ting-Yu Kuo[2], Chao-Chun Chen[1], and Yong-Ming Huang[2](✉)

[1] Department of Institute of Manufacturing Information and System, National Cheng Kung University, Tainan, Taiwan, R.O.C.
p96091123@gs.ncku.edu.tw, chaochun@mail.ncku.edu.tw

[2] Department of Multimedia and Entertainment Science, Southern Taiwan University of Science and Technology, Tainan, Taiwan, R.O.C.
mb0k0105@stust.edu.tw

Abstract. Data structure is an important educational issue because it could help us write efficient programs. However, the traditional teaching materials in data structure courses make it difficult for students to understand because students usually learn data structures through paper textbooks, which usually use abstract graphics to represent data structures, making it difficult for students to understand the concept of data structures. In addition, augmented reality has been shown by many scholars to improve students' understanding because it could visualize abstract concepts, and therefore many scholars have applied it in education. Therefore, based on these findings, this study developed an augmented reality learning system for data structure programming called AR Compiler for students to learn the concepts of data structure programming. Finally, most of the students have positive comments about AR Compiler after using it, but it still has some improving points which are listed at the end of this paper.

Keywords: Augmented reality · Data structure · Visualization learning system

1 Introduction

Data structure is an important educational topic because it could help us write efficient programs. Specifically, the data structure is a collection of data with specific relationships that help us save program space and promote program efficiency. In other words, data structures can organize data systematically and logically among them. In addition, there are four types of data structures [1], namely, set, linear, hierarchical, and graphical. Set data do not have an order problem, but only a question of whether the data belong to the set. Linear data are organized in a one-to-one relationship, and there is an order of sequence between the data, such as an array. Hierarchical data is a one-to-many organization relationship and has the concept of upper and lower levels, such as a tree. Graphical data is a many-to-many organization, and the access to the data depends on specific rules, such as shortest path. In addition, data structures can help us to write efficient programs. For instance, if we have two strings of data called rhinoceros and

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 63–67, 2022.
https://doi.org/10.1007/978-3-031-15273-3_7

zebra, we can store them in an array called animal, so that when we want to access them in the future, we can access them in animals, because they are all animals. In addition, the concept of array is very similar to bookcase. For instance, if there is a bookcase with numbered order, then we could use the number of the bookcase to read the data in the bookcase, so that the access to the data would be faster. Therefore, the data structure is an important factor if we want to write good programs [2, 3].

However, traditional data structure courses usually teach abstract theoretical knowledge, which makes it difficult for students to understand the concepts [6]. Specifically, data structure courses have many topics, including introduction, arrays, linked lists, stacks, queues, tree structures, graphical structures, sorting, searching, etc. [4]. In the introduction, the basics of data structure are usually introduced. In arrays, data storage in continuous space is usually introduced. In linking lists, discontinuous data storage is introduced. Stacks usually introduce LIFO (Last In First Out) data processing, such as recursion. In queue, the FIFO method is usually introduced. Tree structures usually introduce hierarchical data organization, such as binary search trees. The graphical structure usually introduces many-to-many data organization, such as an adjacent matrix. Sorting usually introduces data ordering, such as bubble sorting. Searching usually introduces how to find data, such as binary search. However, the data structure is not visible in our life because it is stored in computer memory [5], so it is a very abstract concept, but data structure courses are usually taught in a descriptive way [6], which is so abstract that students often have difficulty in understanding the concept of data structure, and then encounter learning challenges in future related courses [3, 7–9]. More importantly, students often try to remember this knowledge without understanding them [10], e.g., data processing in stacks is last-in-first-out (LIFO), data processing in columns is first-in-first-out (FIFO), so students may think that data structures just require learning about data structures (LIFO and FIFO), but they do not know that their concepts are important. Therefore, some students may be able to describe the knowledge of data structures but start to have difficulties in introducing the concepts of data structures because they learn them by rote [9].

Based on this, this study found that the current problem in data structure education is that students have difficulty understanding the concept of data structure. Therefore, this study developed an augmented reality visualization learning system, called AR Compiler, to try to improve students' understanding.

2 Related Studies

Because of the problems with traditional data structure materials, many scholars have tried to develop applications to solve them. Venigalla, Lakkundi, and Chimalakonda suggested that the traditional data structured materials made it difficult for students to understand the concept of the pointer. Although students can understand the concept by drawing a flowchart of the pointer, drawing the pointer on paper is boring [11]. Therefore, they proposed PointerViz, a web suite that visualizes the pointer code and allows students to see the flowchart of the pointer while writing a program. The results showed that the students thought that PointerViz could help them understand the concept of pointer easily [11]. Su, Zhang, and Giacaman pointed out that the data structure is abstract and boring, so many students have difficulty understanding its concepts. Although visualization tools are available to help students understand the concept of data structure, they generally lack an interactive environment, resulting in a lack of motivation [6], and game-based learning can promote students' motivation [6]. Therefore, they developed Decode, a data structure learning system based on game-based learning. The results showed that most of the students thought that Decode not only enhanced their motivation but also helped them to understand the concept of a data structure [6]. Narman et al. proposed ARCSE, as shown in Fig. 1, which is a training tool for novice programmers to learn data structure, and it contains a system (ARCSE) and diagram cards. During the learning process, students use the system to scan the cards, and then the system displays the data structure models (Linked List, Array List, and Stack), and then students can use the buttons in the system to control the models, such as adding or deleting data. The results showed that although most of the students liked ARCSE, two improvements could be made to ARCSE. The first is that the content on the ARCSE picture cards is meaningless (the school logo). The second is that the ARCSE extended data structure model is still abstract (square) [12].

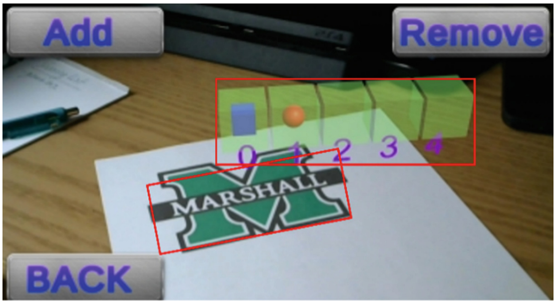


Fig. 1. Data structure visualization learning system (ARCSE)

Thus, this study finds that there are some problems in the past data structure learning system (ARCSE), so this study proposes a new learning system called AR Compiler based on this, and the details are as follows.

3 AR Compiler

The AR Compiler development environment is divided into two parts, the first is software, and the second is hardware. Specifically, in terms of software, this study uses Unity 2020.3.0f1 C# (.net 4. x), Vuforia 9.8.8, Adobe Illustrator, and Blender to develop the AR Compiler. Specifically, Unity is responsible for system integration, Vuforia is responsible for supporting augmented reality, Illustrator is responsible for the interface design, and Blender is responsible for the model design. In terms of hardware, this study uses Google Pixel 4, thick snow tungsten paper, and a cell phone stand. In addition, the AR Compiler was installed on the Google Pixel 4, and the paper used for the program cards was thick snow tungsten. The Google Pixel 4 was installed on the phone stand, as this allowed students to have their hands free to use the program cards. Finally, the system is shown in Fig. 2, where the student has to write a program using a card, and the conceptual model of that program would appear in the center of the screen. The conceptual model of that program would appear in the center of the screen. In addition, the purpose of the card in Fig. 2 is to create an array, and the length of the array is five, which means that it could hold five data, and the type of those data is string, so it could hold some text.

Fig. 2. Data structure visualization learning system (AR Compiler)

4 Conclusion

In conclusion, this study found that the current data structure courses make it difficult for students to understand the concept of data structure, so this study developed AR Compiler to help students understand data structure. In addition, there is some improvement potential for AR Compiler. The first one is that there are too few augmented reality related data structure learning systems, so in the future, we could develop related types of data structure learning systems, such as linked list, Queue, Stack, etc. The second one is that this study uses smartphone to develop AR Compiler, so it could be developed using tablets in the future, because tablets could make the system more flexible because it can scan more cards. The third one is that this study uses smartphones to develop AR Compiler, so students need to use a tripod to support the phone, so in the future, we could consider using smart glasses to develop teaching materials, because smart glasses can free up students' hands to use the cards, but we need to pay attention to whether the smart glasses can handle the performance required by the teaching materials. The fourth one is that the AR Compiler developed in this study is a data structure visualization learning system, so it may be a good direction to integrate other factors such as gamification into the system in the future, which is the Augmented Reality Gamification Learning (ARGBL) system.

Acknowledgments. The authors would like to thank the Ministry of Science and Technology of the Republic of China, Taiwan, for financially supporting this research under Contract No. 109–2511-H-218 -004 -MY3.

References

1. McDonnell, M.: Data types and data structures (2019). https://www.integralist.co.uk/posts/data-types-and-data-structures/#data-structures
2. Langdon, W.B.: Genetic Programming and Data Structures: Genetic Programming+ Data Structures= Automatic Programming. Springer, Cham (1998). https://doi.org/10.1007/978-1-4615-5731-9
3. Yang, X.: Integrated teaching content design of programming courses based on ability of algorithm thinking and program application. In: 2021 4th International Conference on Information Systems and Computer Aided Education, pp. 759–761. Dalian, China: ACM Publications (2021). https://doi.org/10.1145/3482632.3483011
4. Porter, L., Zingaro, D., Lee, C., Taylor, C., Webb, K. C., Clancy, M.: Developing course-level learning goals for basic data structures in CS2. In: Proceedings of the 49th ACM technical symposium on Computer Science Education, pp. 858–863. New York, United States, ACM Publications (2018). https://doi.org/10.1145/3159450.3159457
5. Mäsker, M., Süß, T., Nagel, L., Zeng, L., Brinkmann, A.: Hyperion: building the largest in-memory search tree. In: Proceedings of the 2019 International Conference on Management of Data, pp. 1207–1222. New York, United States. AMC Publications (2019). https://doi.org/10.1145/3299869.3319870
6. Su, S., Zhang, E., Denny, P., Giacaman, N.: A game-based approach for teaching algorithms and data structures using visualizations. In: Proceedings of the 52nd ACM Technical Symposium on Computer Science Education, pp. 1128–1134 (2021). https://doi.org/10.1145/3408877.3432520
7. de Moraes, P.H.S., Teixeira, L.M.: Willow: a tool for interactive programming visualization to help in the data structures and algorithms teaching-learning process. In: Anais Estendidos do XXXIII Brazilian Symposium on Software Engineering, pp. 553–558. New York, United States. ACM Publications (2020). https://doi.org/10.1145/3350768.3351303
8. Liu, X.J.: Exploration on the key issues of teaching reform of the data structure course. DEStech Trans. Soc. Sci. Educ. Hum. Sci. (aeme) (2017). https://doi.org/10.12783/dtssehs/aeme2017/18512
9. Yidan, X.: The application and study of PBL teaching mode in data structure course (2018).https://doi.org/10.2991/essaeme-18.2018.21
10. Bowen, R.S., Flaherty, A.A., Cooper, M.M.: Investigating student perceptions of transformational intent and classroom culture in organic chemistry courses. Chem. Educ. Res. Pract. (2022).https://doi.org/10.1039/D2RP00010E
11. Venigalla, A.S.M., Lakkundi, C.S., Chimalakonda, S.: PointerViz-towards visualizing pointers for novice programmers. In: Proceedings of the 53rd Hawaii International Conference on System Sciences, pp. 118–126 (2020). https://aisel.aisnet.org/hicss-53/cl/teaching_and_learning_technologies/14/
12. Narman, H.S., et al.: Augmented reality for teaching data structures in computer science. In: 2020 IEEE Global Humanitarian Technology Conference, pp. 1–7 (2020). https://doi.org/10.1109/GHTC46280.2020.9342932

A Semi-systematic Literature Review of Holoportation in Education: The Potential of Immersive Technology

Satu-Maarit Korte(✉) and Janne Väätäjä

University of Lapland, 96300 Rovaniemi, Finland
{satu-maarit.korte,janne.vaataja}@ulapland.fi

Abstract. The ongoing digital revolution in education and learning is the focus of many research studies due to the significant potential of technology-mediated learning. However, the integration of holoportation as an immersive technology in educational contexts is still somewhat unexplored. In this semi-systematic literature review, we seek to assess the emerging literature on teachers' and learners' experiences using Microsoft HoloLens as a teaching and learning medium. The objective is to identify the benefits, challenges, and future development needs related to the use of the HoloLens in education. We limited our review to empirical studies published in international peer-reviewed journals during the last five years. The review was not limited by discipline, educational context, or theoretical perspectives. The findings of this meta-analysis highlight the lack of research on the use of mixed reality (MR) in education. Possible directions for future development of pedagogical approaches that take advantage of innovative immersive learning environments and research in this area are also outlined; these suggestions can benefit researchers and industrial developers.

Keywords: Microsoft HoloLens · Mixed reality (MR) · Education · Immersive technology · Semi-systematic literature review

1 Introduction

Immersive experiences with three-dimensional (3D) holographic technology can offer an unparalleled tool for learning, both in face-to-face and remote educational contexts, as this technology can enable collaboration and interaction among learners in different locations. This is due to the fact that holoportation offers an immersive telepresence form of communication in which augmented reality (AR) and virtual reality (VR) are combined in a real-time 3D system [9]. In this mixed reality (MR), the real environment is combined with digital elements, as users are able to see their surroundings but also interact and communicate with a virtual but tangible holographic environment or with an object or person that is visible through a headset or head-mounted display (HMD) [10, 11]. Microsoft developed the HoloLens MR holographic glasses in 2016. These glasses incorporate a real-time functioning central processing unit, a graphic processing unit, and a holographic processing unit [16]; they can also monitor the wearer's movements. The

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 68–78, 2022.
https://doi.org/10.1007/978-3-031-15273-3_8

HoloLens is mostly used to aid medical and surgical procedures, in medical education (for simulations), in architecture, and in engineering [11].

The objective of the present semi-systematic literature review (SSLR) is to analyze existing empirical academic papers that explore the use of the HoloLens as a learning tool in educational contexts. Since little research has been done in this area, we did not limit the educational context to any particular level of education. This review seeks to contribute to a broader understanding of the potential of holoportation in education, to investigate the benefits and challenges of holoportation in education, to identify the needs for development in holoportation technology involved education, and to map the possibilities of holoportation in education to support future research on and development of this technology.

2 Research Methodology

2.1 Research Questions

Literature reviews are useful for mapping current research and development trends in a given educational field independent of discipline [15] and type of learning [4]. A semi-systematic literature review method was chosen for this study for three reasons. First, this enabled the inclusion of qualitative and quantitative articles from diverse disciplines. Second, this best matches the study's goal of obtaining an overview of the research area. Third, this approach enables the present review to contribute to the state of knowledge in the research area and create an agenda for future research (Snyder, 2019). This SSLR on the use of holoportation—specifically, holoportation using the Microsoft HoloLens—in education was conducted to provide evidence of the potential of holoportation, one tool of digital pedagogy, for enhancing learning. This study also sought to identify the needs for development of this technology to improve the usefulness of holoportation in education. To achieve these research objectives, the following research questions were used:

1. What benefits does the HoloLens experience offer for learners?
2. What challenges do learners experience while using the HoloLens?
3. What future research directions do existing papers suggest?

2.2 Literature Search Procedure

This section describes the papers' selection process; the eligibility, inclusion, and exclusion criteria; the information sources and search strategy; the data items collected; and method of analysis. To identify scientific publications on the chosen topic, we used the following literature review steps, as recommended by Creswell and Creswell [2]:

1. Identify keywords
2. Choose databases
3. Begin searching
4. Locate related articles and books
5. Identify useful literature
6. Design a literature map
7. Assemble the literature review

First, the search keywords were identified. For this study, the keywords "HoloLens" and "education" were used. Searches were conducted on the Web of Science (Clariative database), Scopus (Elsevier database), and the Taylor and Francis Social Science and Humanities Library (Taylor & Francis database) online retrieval systems for scientific articles.

2.3 Identification and Screening Process

The following selection criteria were used to reduce the number of included papers (Table 1).

Table 1. Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
• Peer reviewed • Written in English • Published 2016 – April 2022 • Presents empirical research • Includes implementation of the HoloLens in education	• Does not focus on an educational implementation of the HoloLens • Participants not specified • Book chapters, reviews, editorials and essays

Since the HoloLens was first introduced in 2016, the search was limited to papers published between January 2016 and April 2022. Only peer-reviewed empirical studies published in English were considered. The initial search identified a total of 195 articles, including 79 from Web of Science, 53 from Scopus, and 63 from Taylor and Francis. Four of the 195 articles were identified immediately as duplicates, leaving 191 for further filtering (Fig. 1).

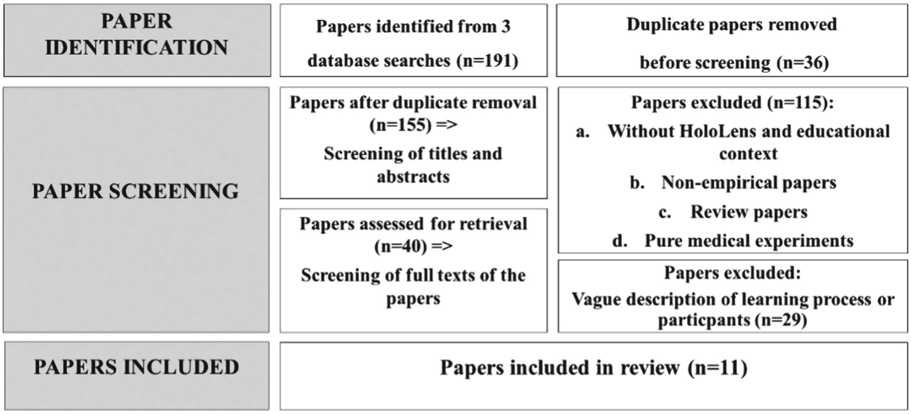


Fig. 1. The identification and screening process for selecting papers for this study.

After manually found duplicates (36) were removed, the abstracts of 155 papers were examined to exclude studies that did not focus on the use of the HoloLens in an educational context. Non-empirical and review papers, as well as those reporting pure medical experiments, were also excluded, leaving 40 papers for further screening. The full texts of these 40 papers were assessed, and an additional 29 papers were excluded due to vague information on the learning process or the participants in the study. A total of 11 papers were then included in the final literature review.

2.4 Data Analysis

These 11 papers were analyzed, and the contents were classified and interpreted. A thematic analysis method was used to identify themes in the papers that related to the research questions of the present literature review. In the first phase, the research method, topic or aims, participants, generation of HoloLens used, and the field in which the study was executed were identified for each paper (Table 2).

Table 2. Description of the included 11 studies.

Study	Method	Topic/Aims	Participants	Field
Brunzini et al. (2022) [1]	Quantitative (1st-gen. HoloLens)	Measure stress and workload to confirm the simulation's enhanced realism and to ensure that the simulation does not lead to cognitive overload during medical training	20 sixth-year students in medicine and surgery	Medical
Gnanasegaram et al. (2020) [3]	Quantitative (1st-gen. HoloLens)	Learn the anatomy of the ear	29 first- and second-year medical students	Medical
Kwon & Kim (2019) [5]	Quantitative (1st-gen. HoloLens)	Measure the positive effects on learning of adding tactile senses to a training system that uses augmented reality (AR) to teach the use of an automated external defibrillator (AED) during CPR	24 university students	Medical/Engineering
Lauer et al. (2021) [6]	Quantitative (HoloLens 2)	Assess the usability of Microsoft's HoloLens 2 (the latest HMD-AR-device) for elementary school children	47 second- to sixth-grade children	Humanities
Leonard & Fitzgerald (2018) [7]	Mixed methods (1st-gen. HoloLens)	Identify the design and research problems, establish design framework	73 secondary school students	Humanities

(*continued*)

Table 2. (*continued*)

Study	Method	Topic/Aims	Participants	Field
Moro et al. (2021) [8]	Quantitative (1^{st}-gen. HoloLens)	Learn the anatomy of the brain	38 pre-clinical medical students	Medical
Peterson et al. (2020) [12]	Quantitative (1^{st}-gen. HoloLens)	Learn complex, three-dimensional (3D) macromolecule structures	83 biology or biochemistry majors	Medical
Robinson et al. (2020) [13]	Quantitative (1^{st}-gen. HoloLens)	Learn about gross and microscopic respiratory anatomy	10 first-year medical students	Medical
Schoeb et al. (2020) [14]	Quantitative (1^{st}-gen. HoloLens)	Learn to place a bladder catheter on a male catheterization training model	164 medical students	Medical
Wolf et al. (2021) [17]	Quantitative (HoloLens 2)	Investigate the benefits of AR-based, contextual instruction in ECMO cannulation training to fight the persistently high mortality rate of ECMO interventions	21 medical students	Medical
Wyss et al. (2021) [18]	Mixed methods (1^{st}-gen. HoloLens)	Investigate the use of the Microsoft HoloLens for learning molecular structures, focusing on a didactic perspective	18 student teachers	Humanities

In the second phase, the contents of the learning processes and users' experiences while using the HoloLens were analyzed. In particular, benefits, challenges, and suggested future research directions related to the HoloLens mentioned in each paper were identified.

3 Results

3.1 What Benefits Does the HoloLens Experience Offer for Learners?

The main advantages of the device that users mentioned were the perception of realistic three-dimensionality and the visual feedback, particularly regarding human anatomical structures, histology, the circulatory system, and macromolecular structures. These features of the HoloLens can reinforce learning [1, 3, 7, 12, 13]. In medical education, the HoloLens enables visual access to structures that were previously inaccessible [18]. In one study [5], this sense of realism was further enhanced by an experiment that added tactile sensory experiences to the visual features of the HoloLens. Several studies mention that the use of the HoloLens stimulated participant engagement through interactive and collaborative learning, enhancing participants' motivation to learn about the topic [3, 6–8, 12, 13, 17, 18]. Several participants also reported that engagement with the content through exploration and individual discovery positively impacted their learning [7, 8, 13, 18]. In addition, participants appreciated the possibilities for collaborative work [18], supporting the conclusion that the positive emotions related to achievement are one benefit of using the HoloLens in educational contexts [6]. Furthermore, one study confirmed that children experienced increased enjoyment and decreased frustration and boredom during learning when using the HoloLens; this occurred even when the children used the technology for the first time [6]. This finding further confirms this technology's positive impact on learning, even when learners experience some difficulties using the HoloLens; such difficulties may be due to unfamiliarity [7]. In all included studies, learners' performance levels and skills improved satisfactorily when they learned using the HoloLens; this means that learning outcomes with the HoloLens were equal to or better than the outcomes of learning with other learning methods.

One attractive feature of the HoloLens in educational contexts is the option of recording activities. This offers an excellent opportunity for learners, teachers, and researchers to analyze and reflect on the learning process [18]. Furthermore, for adult learners, instructions can be provided with video- and audio-based guidance, allowing learners to proceed independently without direct interaction with teaching personnel or fixed time schedules. This highlights the flexibility and cost-effectiveness of the HoloLens for supporting self-directed learning [13, 14] as well as to the efficiency of HoloLens for information acquisition and ease of learning [17]. Several studies also conclude, however, that the use of 3D technologies should supplement, not replace, applied instructional methods to obtain the best learning outcomes [6, 8, 18]. Another positive aspect of the HoloLens is that the wearer of the device can perceive the holographic objects but also interact with paper documents at the same time [18]. Although several studies mention the high cost of the HoloLens as a disadvantage that may limit its possible applications, working with it can help teachers and learners become more familiar with digital media, which could increase their motivation to use and comfort in using new technologies in their future work. Overall, participants were highly motivated to work with the HoloLens [18].

3.2 What Challenges Do Learners Experience While Using the HoloLens?

The challenges that learners faced while using the HoloLens related to the available applications, uncomfortable equipment, the technology's dependability, and teachers' self-efficacy [7, 12, 14, 17, 18]. The limited number of applications available for the HoloLens limits the use of the HoloLens in educational contexts. One study mentions that the HoloLens currently does not have educational applications for every desired subject or topic [12, 18]. This means that teachers who would like to use the HoloLens in the classroom need to first determine whether suitable applications exist before acquiring the HoloLens equipment.

Another challenge to using the HoloLens in educational contexts is the fit of the HoloLens equipment, which may be uncomfortable [14, 17]. One study acknowledges this issue, emphasizing the need to include real-life interactions in the educational setting and to avoid using AR elements exclusively to present visual material such as pictures or videos [18].

Another challenge relates to the technical issues of the HoloLens. One study reports that learners slightly preferred conventional instructions to those provided with the HoloLens because of the possibility of technical difficulties [17]. The HoloLens also requires significant infrastructure, such as fast and reliable internet and technical support, to be utilized successfully [14].

The reviewed studies also identify several challenges related to teachers' self-efficacy. In one study, teachers expressed concern because they could not fully control the teaching process while learners were using the HoloLens [7]. Another study emphasizes the need for teachers to be experienced in and comfortable with technology in general and the HoloLens specifically to successfully utilize this technology in an educational context [18]. One study also points out that learners need some time to become accustomed to using the HoloLens [12].

3.3 What Future Research Directions Do Existing Papers Suggest?

3D technologies are an effective teaching method, particularly for teaching and learning anatomy [3, 8, 13]. However, many assessment methods are still two-dimensional [3], determining the relative effectiveness of teaching and learning. This opens the question of whether traditional assessment methods are optimal or whether new methods should be developed [3]. Future studies could also assess learning outcomes and long-term memory a number of weeks after participants have learned new material using the HoloLens, as existing studies have only assessed immediate recall [8]. Since the experiment with the HoloLens 2 triggered strong positive emotions and excitement in participants, future studies should investigate the impact of affective processes on learning using the HoloLens 2 [6] as well as this technology's potential for promoting embodied learning [7]. In addition, future research could explore new theoretical directions using theories on the social nature of knowledge creation and related theories that focus on the roles, rules, and tools of specific learning environments [7]. The use of the HoloLens in learning should also be tested and evaluated in many contexts, courses, and disciplines to identify and assess the overall usefulness of 3D technologies in teaching and learning.

These evaluations should also assess cognitive load, engagement, and non-verbal communication through video recording, in addition to assessing self-reported perceptions [8, 18]. Furthermore, several iterations of research using the same instructional materials, methods and participants could elucidate long-term performance improvement [3, 17].

4 Discussion, Limitations and Conclusion

This literature review has sought to identify the benefits, challenges, and possible future research directions related to the use of the HoloLens in educational contexts. Our overall aims were to paint a picture of a new, developing topic; to identify current research trends; and to provide some suggestions for future research directions. The literature review included 11 articles in the fields of humanities, medicine, and engineering. A larger sample might have enabled comparisons among different fields of study. However, the authors wanted to focus this meta-analysis on the use of the HoloLens as an educational tool.

First, overall, the reviewed articles consistently agree that the HoloLens is a valuable tool for teaching and learning 3D structures. Second, several of the included studies provided information about the use of hardware and software applications with the HoloLens but did not provide an overall description of or conclusion regarding the pedagogical significance of using the HoloLens in educational contexts. Thus, there is a need for more research on the pedagogical use of the HoloLens and development of immersive technology-enhanced pedagogy. Third, we observed a marked trend in research methods: Most included studies are quantitative; the only two exceptions are studies in the humanities that used mixed-methods approaches. No qualitative studies have been conducted on the use of the HoloLens in educational contexts, pointing to the need for additional research using this approach. The video recordings of the activities would provide a rich source of qualitative data for evaluating the entire teaching and learning process.

The results of this literature review clearly indicate the potential of the HoloLens for supporting education at all levels. Participants particularly appreciated the possibility for collaborative as well as individualized learning. Our results also show that learners' needs for traditional instruction and support vary depending on their age and prior experience with the HoloLens.

This literature review sets the foundation for future research on the use of the HoloLens in education. This study has provided useful insights about the use of the HoloLens in educational contexts. We argue that thorough assessments of learning processes and learning experiences with the HoloLens can contribute knowledge that can then be used to develop innovative immersive learning environments that use meaningful, tailored pedagogical approaches and assessment methods to achieve the best possible learning outcomes. This can ensure that the potential of the HoloLens in educational contexts is maximized.

References

1. Brunzini, A., Papetti, A., Messi, D., Germani, M.: A comprehensive method to design and assess mixed reality simulations. Virtual Reality (2022). https://doi.org/10.1007/s10055-022-00632-8
2. Creswell, J.W., Creswell, J.D.: Research Design: Qualitative, Quantitative, and Mixed Methods Approaches. Sage Publications, Thousand Oaks (2017)
3. Gnanasegaram, J.J., Leung, R., Beyea, J.A.: Evaluating the effectiveness of learning ear anatomy using holographic models. J. Otolaryngol.—Head N. **49**(1), 1–8 (2020). https://doi.org/10.1186/s40463-020-00458-x
4. Hwang, G.J., Tsai, C.C.: Research trends in mobile and ubiquitous learning: a review of publications in selected journals from 2001 to 2010. Br. J. Educ. Technol. **42**(4), E65–E70 (2011)
5. Kwon, C., Kim, D.H.: A comparative study on the effectiveness of the training system of an augmented reality-based automated external defibrillator with an added tactile sense. Int. J. Innov. Technol. Explor. Eng. **8**(8), 1091–1096 (2019)
6. Lauer, L., et al.: Investigating the usability of a head-mounted display augmented reality device in elementary school children. Sensors **21**(19), 6623 (2021). https://doi.org/10.3390/s21196623
7. Leonard, S.N., Fitzgerald, R.N.: Holographic learning: a mixed reality trial of Microsoft HoloLens in an Australian secondary school. Res. Learn. Technol. **26** (2018). https://doi.org/10.25304/rlt.v26.2160
8. Moro, C., Phelps, C., Redmond, P., Stromberga, Z.: HoloLens and mobile augmented reality in medical and health science education: a randomised controlled trial. Br. J. Educ. Technol. **52**(2), 680–694 (2021). https://doi.org/10.1111/bjet.13049
9. Orts-Escolano, S., et al.: Holoportation: virtual 3D teleportation in real-time. In: Proceedings of the 29th Annual Symposium on User Interface Software and Technology, pp. 741–754 (2016)
10. Osmers, N., Prilla, M., Blunk, O., Brown, G., Janßen, M., Kahrl, N.: The role of social presence for cooperation in augmented reality on head mounted devices: a literature review. In: Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems, pp. 1–17 (2021)
11. Park, S., Bokijonov, S., Choi, Y.: Review of Microsoft HoloLens applications over the past five years. App. Sci. **11**(16), 7259 (2021)
12. Peterson, C.N., Tavana, S.Z., Akinleye, O.P., Johnson, W.H., Berkmen, M.B.: An idea to explore: use of augmented reality for teaching three-dimensional biomolecular structures. Biochem. Mol. Biol. Educ. **48**(3), 276–282 (2020). https://doi.org/10.1002/bmb.21341
13. Robinson, B.L., Mitchell, T.R., Brenseke, B.M.: Evaluating the use of mixed reality to teach gross and microscopic respiratory anatomy. Med. Sci. Educ. **30**(4), 1745–1748 (2020). https://doi.org/10.1007/s40670-020-01064-2
14. Schoeb, D.S., et al.: Mixed reality for teaching catheter placement to medical students: a randomized single-blinded, prospective trial. BMC Med. Educ. **20**(1), 1–8 (2020). https://doi.org/10.1186/s12909-020-02450-5
15. Snyder, H.: Literature review as a research methodology: an overview and guidelines. J. Bus. Res. **104**, 333–339 (2019)
16. Wang, W., Wu, X., Chen, G., Chen, Z.: Holo3DGIS: leveraging Microsoft HoloLens in 3D geographic information. ISPRS Int. J. Geoinf. **7**(2), 60 (2018)

17. Wolf, J., Wolfer, V., Halbe, M., Maisano, F., Lohmeyer, Q., Meboldt, M.: Comparing the effectiveness of augmented reality-based and conventional instructions during single ECMO cannulation training. Int. J. Comput. Assist. Radiol. Surg. **16**(7), 1171–1180 (2021). https://doi.org/10.1007/s11548-021-02408-y
18. Wyss, C., Bührer, W., Furrer, F., Degonda, A., Hiss, J.A.: Innovative teacher education with the augmented reality device Microsoft HoloLens—results of an exploratory study and pedagogical considerations. Multimodal Technol. Interact. **5**(8), 45 (2021)

Facilitating Geometry Learning Through Real-Time Collaborative Activities with Augmented Reality in Authentic Context

Wu-Yuin Hwang[1(✉)], Yi-Jing Lin[1], Anh Hoang[1], Rio Nurtantyana[1], and Oscar Lin[2]

[1] No. 300, Zhongda Rd., Zhongli Dist., Taoyuan City 32001, Taiwan (R.O.C.)
sss2004101280@gmail.com
[2] Athabasca University, Athabasca, Canada

Abstract. In this study, a smart Ubiquitous Geometry (Smart-UG) system with smart mechanisms support was developed to facilitate learners' geometry learning through measuring objects in authentic context. Further, we designed a real-time collaborative measuring function based on the augmented reality (AR) in the mobile device. Learners were required to measure objects collaboratively with their peers, calculate the surface area and perimeter of the objects in authentic contexts, and discuss. In order to facilitate meaningful collaboration, interaction and socialization among peers, we designed the smart mechanisms that provided learners with a way to ask others for help if they face difficulty. Participants were fifth-grade learners from two classes that were assigned into different groups. The experimental group (EG) consists of 26 learners and the control group (CG) consists of 26 learners with/without smart mechanisms support, respectively. The results revealed that EG with assistance of smart mechanisms like peer help significantly improved geometry ability and got higher scores than CG. In addition, EG who completed more practices, made fewer mistakes, and asked others for help had a better understanding of geometry concepts. Moreover, learners showed a positive attitude and high intention toward Smart-UG. Therefore, our Smart-UG with the smart mechanism support could facilitate learners to learn geometry smartly in authentic context and enhance their geometry ability.

Keywords: Geometry learning · Authentic context · Augmented reality · Smart mechanisms · Collaboration

1 Introduction

Geometry is one main area of mathematics and it is essential to connect with real-life problems [1]. However, in conventional mathematics education, learners often fail to understand and apply geometry concepts in their daily life since they usually learn geometry through paper-based approaches [2]. Several studies showed that learning in authentic context allowed learners to create meaningful outcomes and it could improve their abilities, including geometry ability, spatial ability and estimation ability [3].

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 79–87, 2022.
https://doi.org/10.1007/978-3-031-15273-3_9

In the recent years of research, there is an evolution of "smart" in education. A smart learning environment provides learners with tailored and personalized learning services [4]. In addition, collaborative learning is also an effective approach that can be used to support smart learning and enhance socialization among learners [5]. As a result, it can increase learners' self-efficacy and intrinsic value of the learning tasks, such as problem solving, and discussion [6].

Regarding measurement in authentic context, the previous study mentioned that AR could be empowered to facilitate geometry learning individually through measuring the real objects in their surroundings [7]. However, few studies addressed these issues of collaborative learning in authentic context with the smart mechanisms and augmented reality to support geometry learning.

Based on the aforementioned above, we developed a system using augmented reality technology (AR) in mobile devices and designed collaborative learning activities to facilitate geometry learning in authentic context. The following are the research questions in this study:

1. Are there any significant differences in learning achievement between the experimental group (EG) with smart mechanisms support and the control group (CG) without smart mechanisms support?
2. What are the relationships between learning achievement and behaviors in EG?
3. What is the learners' perception of the system and the smart mechanisms in EG?

2 Literature Review

2.1 Geometry Learning in Authentic Context

Geometry is an important knowledge in our daily life [1]. Geometric terminology is used to describe the shapes of objects, such as point, line, angle, curve, rectangle, which indicates that having knowledge of geometry is critical to daily life [8].

Applying geometry in a real situation like daily life can consolidate understanding of geometry concepts. However, most learners learn geometry through paper-based approaches which only emphasize the calculating process.

On the other hand, collaborative learning approach is an effective strategy that can be used to enhance achievement and socialization among learners [5]. Several studies showed that technology supported collaborative learning in authentic context has a positive effect on learners' learning achievement [9]. Augmented reality (AR) allows multiple users to share physical space surrounding them and a virtual space merged with the physical one, which makes it possible for users to design something collaboratively [10]. It can also be used to enhance face to face collaboration seamlessly [11].

Since there have been few studies regarding the development of social-aware applications for learners to improve geometry learning through collaboration, we designed collaborative learning activities with AR technology support for geometry learning in authentic context and provide more chances to connect the learning content with real-life experiences.

2.2 Smart Mechanisms for Geometry Learning in Authentic Context

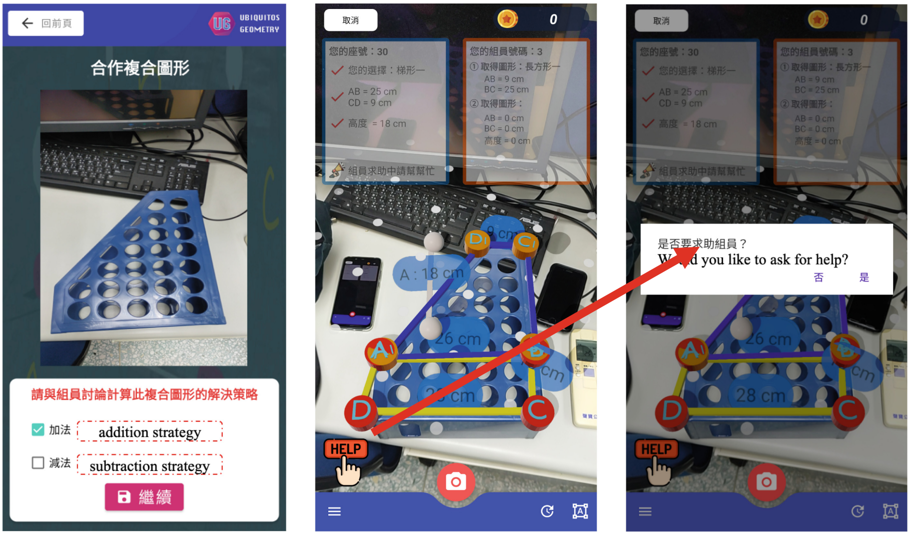
A smart learning environment can provide learners with tailored and personalized learning services (e.g. context awareness, collaborative tool, or real-time feedback) [3]. A smart learning environment enables learners to access ubiquitous resources and also provides learning guidance, suggestions or supportive tools without limitations of time and place [12]. Based on the suggestions on the smart learning environment, we developed smart mechanisms with advanced technology to support smart collaborative learning and assist learners' geometry learning in authentic context. For example, the smart mechanism "Ask for Help Among-groups" allows learners to ask other groups for help if they face difficulty taking object measurements in a learning environment.

3 System Design

In this study, the innovative mobile app called Smart-UG with augmented reality was developed to facilitate real-time collaboration for geometry learning in authentic contexts. In the learning activities, two collaborative learning topics were provided, such as single shape and compound shape. During learning activities, learners work in pairs and they are required to measure the same object collaboratively in real-time with augmented reality. In the compound shape activity, learners are required to discuss the strategy of calculating area with their peers before measuring objects in their surroundings.

In detail, before collaborating on measurement, the learner in the within-group would discuss first about the object and the strategy that will be used to measure it together (Fig. 1a). Afterwards, they collaborated to measure the real object that used augmented reality technology for measuring in Smart-UG (Fig. 1b). For example, in the first time, they chose an additional strategy, later the first student measured the bottom side of the box as a rectangle shape, which indicated in yellow color. At the same time, their mobile screen synchronously displays the real-time object measurement after the first student pressing the "get shape" button. Then the peers would help to measure the upper side of the box as a trapezoid, which is indicated in blue color. By doing so, they could measure different shapes on the same real object in surrounding them with our proposed Smart-UG. Besides asking for help within-group by pressing "help" (Fig. 1c), they could ask assistance from the other groups to measure the object collaboratively by pressing the "help among-groups" button (Fig. 2a) when they have difficulty measuring the object in their surroundings.

After completing the collaborative measurement with augmented reality in Smart-UG, learners have to calculate the surface area and perimeter of the measured object. Finally, the learners were encouraged to discuss the results with their peers in order to complete the geometry learning activities.



(a) Discuss to choose the strategy

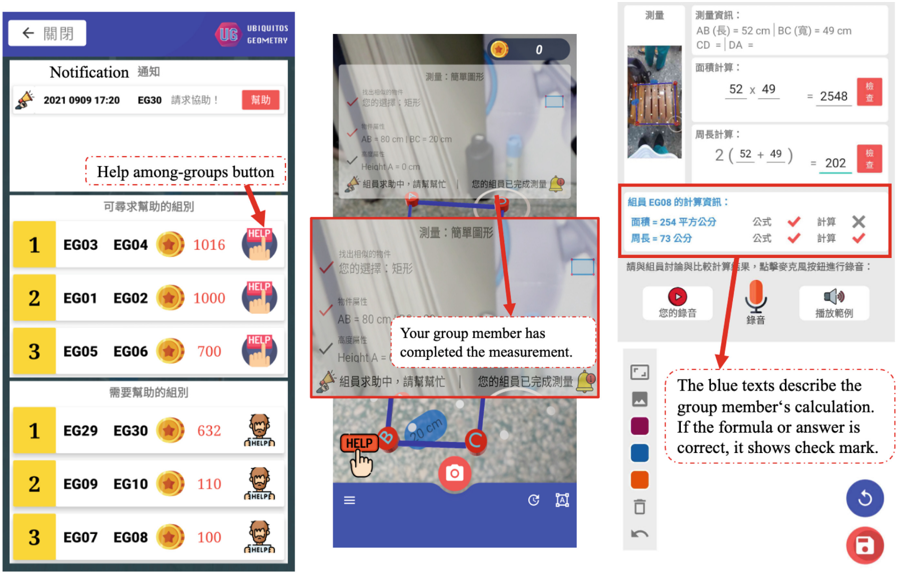
(b) The measurement process

(c) Ask for help within-group

Fig. 1. The real-time collaboration of measurement process using our proposed Smart-UG with augmented reality between learners and the peers as follows: a) the group discuss the measurement strategy, b) the within-group object measurement, and c) ask for help within-group

Since learners might face difficulty when they explore real objects in the real environment, the researchers provided learners with the smart mechanisms and peer help. So, they could get help from peers when they have difficulties. During these activities, the learners were facilitated by our proposed smart mechanisms in Smart-UG, as follows:

1. Ask for Help Within-group, it refers that when learners have difficulty when measuring the objects, they can ask their peers for help by pressing the help button. Later, the notification of the seeker will be displayed on their mobile screen. (Fig. 1b).
2. Ask for Help Among-groups, it refers learners could ask other groups as seekers for help by pressing the help-seeking button. Later, the other learners in other groups who receive the notification can look at the previous problems from the seekers and give them help by pressing the help-giving button (Fig. 2a).
3. Member Learning Status, it refers that in order to make the collaborative process more smoothly and provide learners with their group member's learning situation in the collaborative learning activity, the system sends the notification to their group member when learners complete measuring (Fig. 2b).
4. Member Answer and Correct Status, it refers to learners who can see if their group member's answers are correct or not. Which helps learners understand their group member's learning situation in order to motivate them to help each other (Fig. 2c).



(a) interface of Among-Groups Assist

(b) Member Learning Status

(c) Member Answer and Correct Status

Fig. 2. The smart mechanisms in Smart-UG are as follows: a) the among-groups assist b) the learning status of each member, and c) the feedback from their peers when calculating the surface area or perimeter of the measured object.

4 Methodology

In this study, a total of fifty-two learners from the fifth-grade elementary school participated in the experiment. They were from two classes that were assigned into two different groups. One was the experimental group ($n = 26$) using Smart-UG with the smart mechanisms support and the other was the control group ($n = 26$) without the smart mechanisms support.

The experiment conducted one month including pretest, learning activities, posttest, questionnaire and interview. In the 1st week, the teacher gave the pretest, introduced the learning activities, and introduced the Smart-UG for the all groups. In the 2nd until 3nd weeks, learners used Smart-UG to explore and measure the single and compound shapes of objects in their surroundings. In the 4th week, the posttest for all groups, questionnaire and interview for the experimental group were conducted.

The topics for this study were based on their curricula, such as measuring single shape and compound shape of the objects. The shapes that were measured were rectangle, triangle, parallelogram, and trapezoid. Table 1 shows the research variables for this study, such as learning behavior, and learning achievement to measure geometry ability.

The ANCOVA analysis was used in this study to examine whether there were significant differences or not in learners' prior knowledge and learning achievement between two groups Pearson correlation was used to evaluate the relations between learning behavior and learning achievement in the experimental group only. In addition, the technology acceptance model (TAM) questionnaire was used to investigate learners' perceptions of Smart-UG. Further, the Cronbach's alpha coefficient was used to verify the reliability of pretest, posttest and the questionnaires.

Table 1. Research variables

Variables	Description
Learning achievement	
1. Geometry ability	Ability to calculate area and perimeter of single and compound shape
Learning behavior	
2. Error rate	The ratio of the number of erroneous calculations to the total completed practice
3. Number of practices	The number of completed practice
4. Number of asking for help within-groups	The number of asking group member for help
5. Number of asking for help among-groups	The number of asking other groups for help

5 Results and Discussion

5.1 Learning Achievement Between Groups

The descriptive statistics of learning achievement in pretest and posttest were shown in Table 2. It shows that both two groups had improvement of geometry ability from the pretest to the posttest. Moreover, the experimental group with support of smart mechanisms gained mean scores (M = 83.46) higher than the control group (M = 72.96) without support of smart mechanisms.

Table 2. Descriptive statics of pretest and posttest

Group	N	Pretest		Posttest	
		Mean	*SD*	Mean	*SD*
EG	26	72.54	11.700	83.46	6.525
CG	26	71.54	10.331	72.96	11.718

In addition, the homogeneity of variance for two groups was tested. The hypothesis of homogeneity of regression coefficients in the covariate analysis was allowed to continue in this study (F = 1.268, $p > 0.05$). The ANCOVA result shows that there was no significant difference in the pretest (F = 1.834, $p > 0.05$). However, the results in Table 3 showed that there was a significant difference in the posttest (F = 15.667, $p < 0.001$)

between two groups. It indicates that the prior knowledge between two groups was not significantly different before the experiment. However, after the experiment, learners significantly improved their geometry ability, especially the experimental groups after using the Smart-UG app.

The potential reason is that Smart-UG app with the smart mechanisms support for collaborative learning facilitated learners to give/get help for/from others, which promoted learners' meaningful interaction by exchanging information and ideas when solving the tasks. Therefore, it could effectively enhance the learning achievement, especially their geometry ability.

Table 3. Comparison of posttest between groups

Source	ss	df	MS	F	Sig.
Pretest	162.240	1	162.240	1.834	0.182
Group	1386.083	1	1386.083	15.667	0.000
Error	4335.183	49	88.473		
Total	324017.000	52			

Dependent Variable: *Posttest*

5.2 Relationship Between Learning Behaviors and Learning Achievement

The correlation analysis revealed that there was a negative correlation between the error rate and geometry ability as learning achievement ($r = -.705, p < .01$). It indicates that learners who got higher scores made fewer mistakes in the calculation process. It was also found that there was a positive correlation between the number of practices and geometry ability ($r =-.495$, $p < .05$), which implied that the more measurements they took, the better the learning achievement was.

In addition, the number of asking for help within-groups ($r = .611$, $p < .01$) and among-groups ($r = -.583$, $p < .01$) have significant correlation in learning achievement, which implied those who asked others for help more frequently could get higher scores. The possible reason is because the smart mechanisms provided learners with opportunities for seeking help and getting useful information from peers, so they had better learning achievement.

5.3 Learners' Perception of Smart-UG

The TAM results indicate that learners in the experimental groups felt useful ($M = 4.39$, $\alpha = 0.96$) and easy to use Smart-UG for geometry learning in collaborative activities ($M = 4.29$, $\alpha = 0.93$). They had a positive attitude on the system and the smart mechanisms ($M = 4.32$, $\alpha = 0.97$). In addition, according to the interview content, learners have a high willingness to continue to use Smart-UG in geometry learning in the future. The possible reason is they felt satisfaction using the Smart-UG ($M = 4.31$, $\alpha = 0.95$). One learner said that *"I like to use Smart-UG to measure a big object because it is more convenient than using a ruler."*

According to the feedback by learners on the smart mechanisms "Ask for help within-group" and "Ask for help among-groups", these two mechanisms provided learners with opportunities for seeking help and getting useful information from peers. One learner said that *"If I cannot find a suitable object to measure, I will click the help button to ask peers for help. Then, my classmate would come to help me and I don't waste too much time looking for measurable objects."*

On the other hand, the smart mechanisms "Member Learning Status" and "Member Answer and Correct Status" also helped learners understand peers' learning situation so that they could teach each other and solve problems together. As a result, Smart-UG with the smart mechanisms not only help learners' geometry learning in authentic context, but also enhance meaningful interaction among peers.

6 Conclusion

Regarding research question one, the results revealed that there was a significant difference between experimental group (EG) with the smart mechanisms support and control group (CG) without the smart mechanism support. The learners of EG outperform in posttest compared with CG since they could be guided well by the smart mechanism in our innovative "Smart-UG."

Regarding research question two about the relationship between learning behavior and learning achievement. The results found that those who made fewer mistakes, practiced more and asked others for help more frequently could get better scores in learning achievement, which improved their geometry ability.

Regarding research question three, learners had a positive attitude on Smart-UG with the smart mechanisms. Learners generally think that using Smart-UG for geometry learning is useful and simple, and satisfied with the help of smart mechanisms and peers.

The limitation of this study is that the real-time collaborative measuring function in the Smart-UG takes a longer time to scan the environment and the real objects, which might be implied to reduce learners' practicing time. This problem will be improved in the future Smart-UG and the researchers will improve the design of the function in a more convenient and efficient way. In addition, the future study needs a deep analysis about their learning behavior, especially their collaboration process to construct their cognitive skill or other skills when learning geometry.

References

1. Sherard, W.H.: Why is geometry a basic skill? Math. Teach. **74**(1), 19–60 (1981)
2. Hwang, W.Y., et al.: Exploring effects of multi-touch tabletop on collaborative fraction learning and the relationship of learning behavior and interaction with learning achievement. Educ. Technol. Soc. **18**(4), 459–473 (2015)
3. Hwang, W.Y., Hoang, A., Lin, Y.H.: Smart mechanisms and their influence on geometry learning of elementary school students in authentic contexts. J. Comput. Assist. Learn. **37**(5), 1441–1454 (2021)

4. Zhu, Z.-T., Yu, M.-H., Riezebos, P.: A research framework of smart education. Smart Learn. Environ. **3**(1), 1–17 (2016). https://doi.org/10.1186/s40561-016-0026-2
5. Newman, D., et al.: Evaluating the quality of learning in computer supported co-operative learning. J. Am. Soc. Inf. Sci. **48**(6), 484–495 (1997)
6. Lowyck, J., Poysa, J.: Design of collaborative learning environments. Comput. Hum. Behav. **17**(5–6), 507–516 (2001)
7. Hwang, W.-Y., Nurtantyana, R., Putra, M.T.M.: Facilitating 3D geometry learning with augmented reality in authentic contexts. In: Huang, Y.-M., Lai, C.-F., Rocha, T. (eds.) ICITL 2021. LNCS, vol. 13117, pp. 67–73. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-91540-7_8
8. Hwang, W.-Y., et al.: An investigation of the effects of measuring authentic contexts on geometry learning achievement. IEEE Trans. Learn. Technol. **12**(3), 291–302 (2019)
9. Huang, Y.-M., Jeng, Y.-L., Huang, T.-C.: An educational mobile blogging system for supporting collaborative learning. J. Educ. Technol. Soc. **12**(2), 163–175 (2009)
10. Ohshima, T., et al.: AR/sup 2/Hockey: a case study of collaborative augmented reality. In: Proceedings of the IEEE 1998 Virtual Reality Annual International Symposium (Cat. No. 98CB36180). IEEE (1998)
11. Billinghurst, M., et al.: Mixing realities in shared space: an augmented reality interface for collaborative computing. In: Proceedings of 2000 IEEE International Conference on Multimedia and Expo. ICME2000. Latest advances in the fast changing World of multimedia (Cat. No. 00TH8532). IEEE (2000)
12. Lee, J., Zo, H., Lee, H.: Smart learning adoption in employees and HRD managers. Br. J. Edu. Technol. **45**(6), 1082–1096 (2014)
13. Di Paolo, E., Rohde, M., De Jaegher, H.: Horizons for the enactive mind: values, social interaction, and play. In: Enaction: Towards a New Paradigm for Cognitive Science (2010)

Designing STEM Learning Activity Based on Virtual Reality

Wei-Sheng Wang[1], Margus Pedaste[2], and Yueh-Min Huang[1](✉)

[1] Department of Engineering Science, National Cheng Kung University, Tainan, Taiwan
huang@mail.ncku.edu.tw

[2] Institute of Education, University of Tartu, Tartu, Estonia

Abstract. As teaching materials continue to develop and improve, learners have gradually shifted from abstract learning methods such as learning formulas and understanding images to hands-on learning. Learners apply the acquired knowledge and skills to practical STEM hands-on experiential courses to verify the formulas and knowledge they have acquired. Hands-on learning effectively helps learners transform abstract knowledge into conceptual skills and practical abilities and apply these in practical fields. In a traditional STEM hands-on learning experiment environment, learners verify knowledge through experiments. However, in the experimental fields set up at many schools and laboratories, there is often a lack of experimental equipment. Also, in experiments such as fire drills and medical experiments, learners may not be permitted to perform actual operations and practices in laboratories due to safety factors. Learners lack a safe and secure learning environment where they can study anytime, anywhere. Therefore, we design and develop a virtual reality system which we apply to embedded electronic circuit learning activities, creating for learners a virtual environment for immersive learning. The effectiveness of the system is verified through a pilot study using the technology acceptance model (TAM) to measure learner acceptance. The results of this study and the analysis of the TAM data show that the system was well-accepted by participants.

Keywords: Virtual reality · STEM · Technology acceptance model · Pilot study

1 Introduction

Recent years have witnessed an increasing demand for science, technology, engineering, and mathematical (STEM) skills in the teaching field, but it is often difficult for learners to understand complex scientific phenomena from theoretical knowledge and mathematical formulas [1]. Baird and Penna [2] show that teaching and learning science is a challenging task. Traditional teaching methods only provide learners with solutions and knowledge concepts, but may not really teach learners how to solve problems. This is confirmed by Hake [3], who finds that learners have difficulty understanding the concept of formulas even after memorizing them. Practical knowledge relies on hands-on practice, without which there is no knowledge; knowledge is the collection of hands-on experience [4].

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 88–96, 2022.
https://doi.org/10.1007/978-3-031-15273-3_10

Today, the integration of hands-on learning in education has proven to be an effective teaching method [5].

The use of hands-on teaching environments has spread widely, and teaching materials have also evolved rapidly with the development of science and technology in recent years. With traditional blackboard teaching, students only absorb teaching content from teachers in one direction. Now, however, many teachers are abandoning traditional teaching methods. When designing courses, more learning methods are available, giving learners more opportunities for interaction and communication in the learning process, especially in traditional hands-on experiment courses. Teachers also use digital teaching materials such as PowerPoint presentations, multimedia 2D/3D, and other diverse content to create a richer learning experience for students [6].

Problems encountered in traditional hands-on experiments include limited equipment supplies, difficult access to experimental equipment, a lack of immediate assistance, and even safety factors. The experimental equipment and parts that the learner is exposed to during the experiment are limited, and what is available cannot be used by the learner freely or indefinitely. The learner may even be afraid to conduct the experiment for fear of damaging the equipment [7]; a lack of equipment may also make it impossible for every student to have experimental equipment. Students may be obliged to conduct experiments in groups, resulting in an uneven allocation of time for each student to obtain practical hands-on experience while learning and thus fully participate in the experiments. Some scientific disciplines require the use of large and expensive experimental equipment such as large X-ray machines or tomography machines for medical training and lathes for mechanical departments. However, such large-scale equipment is typically difficult to procure and is not easy for general learners to operate and use, to the end that learners are unable to verify previously-learned knowledge using actual experiments. Learners must resort to "imagining" real-world scenarios for experiments [8]. Practical experiment courses cover a wide range of fields, some of which may be dangerous fields. Students may not be able to fully experience areas such as fire training and ambulance training in real emergency situations due to safety concerns. Hands-on courses do not allow learners to train or learn at any time.

In summary, given the difficulties encountered in traditional hands-on experiments, conducting experiments in the above situations using virtual reality (VR) would reduce the obstacles and limitations of students in the learning process [9, 10]. VR uses computer vision technology to generate a three-dimensional virtual environment on the computer screen, immersing users in the virtual world and making it possible for them to observe the objects in the space instantly and without limitations. In recent years, VR has not only been used for entertainment but has also found wide use in education [11, 12]. VR provides an immersive equipment which is suitable for hands-on experimental courses. The VR laboratory can create many environments that traditional laboratories cannot provide for learners, so that learners need not worry about equipment being too expensive, about there not being enough equipment to go around, and about not having a chance to conduct experiments, because the VR environment can provide learners with unlimited experimental equipment, giving them the opportunity to experiment freely. For fire drills, medical experiments, blasting experiments, or other high-risk fields, VR provides learners the opportunity to conduct experiments in a safe environment [13, 14]. Using VR, learners can instantly apply the theoretical knowledge they have learned.

In this study we develop a VR system and apply it to embedded electronic circuit learning activities so that learners can learn about embedded development in a safe and secure virtual environment. We conduct a pilot study and use the technology acceptance model (TAM) [15] questionnaire to measure the acceptance of the subjects to verify the feasibility of the curriculum system.

2 Literature Review

2.1 STEM Hands-On Learning

STEM education provides teachers with a novel and comprehensive approach to teaching, which is designed to teach different subjects without deliberate division of subject content, and is seen as dynamic, adjustable teaching [16, 17]. Many advocates believe that STEM education can improve learners' systemic thinking and problem-solving skills [18, 19]; by integrating STEM subject knowledge, learners can develop hands-on skills. Chien [20] integrates 3D printers to develop a novel STEM CO2 high-speed car design course in which the experimental group which integrates STEM 3D printers clearly outperformed traditional hands-on groups in terms of both the novelty and complexity of the finished products. Fan and Yu [21] investigate the respective performance of learners of STEM engineering modules compared with students of technology modules, and show that learners of STEM engineering modules were significantly better than those of technology education modules in terms of knowledge, concepts, and higher-order thinking skills. Gao, Li, Shen, and Sun [22] point out that the effectiveness and reliability of interdisciplinary learning in STEM over the past two decades remains a challenge in terms of knowledge, skills, experimentation, and affective domains. In the various subjects, it is easy for students to lose interest and enthusiasm due to the poorly-designed curricula, which leads to a decrease in learning effect.

Therefore, it is necessary to improve teaching methods and the learning environment for different subjects so that learners can achieve greater gains and effects in the learning process.

2.2 Virtual Reality

Olson and Riordan [23] find that past learners had a high failure rate in learning scientific STEM subjects, which may be related to their difficulties in understanding scientific theoretical concepts and knowledge. Teachers have therefore integrated traditional course content into virtual simulations or animations and interactive teaching materials to help learners better understand the knowledge concepts of the subject. Zhang and Zhou [24] believe that teaching methods of 2D/3D simulation teaching situations lack interactivity and timely feedback on student behavior, and thus cannot be considered real-time interactive teaching. To solve this problem, it is necessary to import traditional simulation courses into VR. Although VR technology has been around since the late 1950s, its use in the education sector has been limited due to high equipment costs, difficult access to technology, availability issues, and a lack of proper educational content and educator training. Today, technological advancements in science and technology have reduced the cost of equipment, thus greatly reducing the restrictions on applications in education. In addition, the operability and popularity of current mainstream VR devices on the market have yielded amazing results, highlighting the potential of this technology for educational purposes [25]. VR is expected to play a pivotal role in transforming teaching and learning in higher education; there is no doubt that novel content and full immersion in a virtual environment enhance user attention.

When VR is used as an augmentation tool for traditional learning methods, learners' comprehension and knowledge concept performance are significantly improved [26]. Çakiroğlu and Gökoğlu [27] propose a virtual reality-based behavioral skills training method to teach basic behavioral skills in fire safety. They design and implement a virtual reality-based environment in the context of design-based research, with results that show that using VR-based training significantly improves learners' fire safety behavioral skills, such that most students are able to transfer their behavioral skills to the real world. Pellas, Dengel, and Christopoulos [28] survey various approaches to the instructional design and implementation of VR in K-12 and higher education over the past decade. This includes the characteristics of all participants, teaching methods, teaching uses, and applications. Their results demonstrate the strong potential of using VR applications to enhance or design different teaching environments, with significant improvements in student attitudes, engagement, learning outcomes, achievement, and performance across different STEM domains. They show that the application of VR technology in the teaching field effectively improves the learning effect of students.

3 Method

In this study we seek to use VR technology in STEM learning activities by designing a set of VR course activities for embedded electronic circuit activities. We invited college students and graduate students to participate in a pilot study, and administered the TAM questionnaire to participants to determine the perceived usability and ease of use of the system for use by students.

3.1 Design

This study concerns a set of VR activities for embedded electronic circuit development boards, the content of which is to help participants learn and familiarize themselves with five embedded development board tasks: connecting GPIO and sensors, connecting the mouse and keyboard via USB, connecting the network cable to the LAN, connecting the HDMI video output, and connecting the micro USB power.

Participants were to wear a HTC VIVE head-mounted display (HMD) (Fig. 1) at the start of the experiment, after which the teaching assistant helped to start the course, and the activity started. In the virtual embedded course environment, the scene was a general electronic circuit laboratory with all the equipment required for the experiment, including the virtual embedded development boards, mice and keyboards, DuPont cables, sensors, and HDMI cable. In the virtual environment, an experimental schedule was included in the virtual reality screen (Fig. 2) so that participants could determine their progress and unfinished tasks. In the virtual environment, there was also a prompt function which could be used to bring up detailed descriptions of the embedded development board and peripheral equipment and the connection methods and positions so that learners could familiarize themselves with the embedded development board and operations.

In the course participants were guided step by step to perform each task. After a participant successfully completed a task, an eye-catching prompt would appear (Fig. 3), and was noted in the task progress table. Conversely, if the participant connected the wrong component to the wrong port, an error message appeared (Fig. 4). When the participant had completed all tasks, he/she was informed on the screen and guided to other scenes to continue the other tasks (Fig. 5).

Fig. 1. Participants operating the system

Fig. 2. Initial task screen

Fig. 3. Task success message

Fig. 4. Task failure message

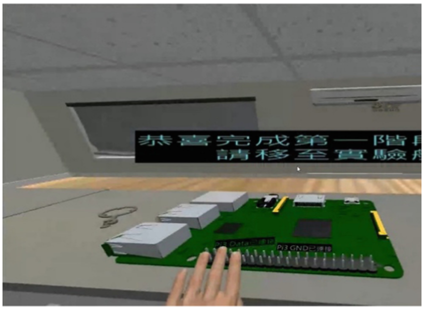


Fig. 5. Task completion message

3.2 Procedure

The participants in this study were undergrad and graduate students who had no understanding of embedded development boards: there were 15 participants in total. The experimental process is shown in Fig. 6. Before beginning the experiment, the teaching assistant explained to the participants how to use the VR equipment, demonstrating how to move and pick up the equipment and change the VR scene. Because the learners wore the HMDs throughout the experiment, they could not operate computer equipment. Therefore, after the learner was familiar with how to use the VR equipment, could move smoothly between the activity scenes, pick up the equipment needed for the experiment, and change the scene, the teaching assistant operated the computer equipment and started the activity course.

The activity lasted for about 45 min, and its content included a number of learning tasks. The purpose of the tasks was to help participants familiarize themselves with the operation and connection methods of the embedded development version. After the activity was performed, the participants filled out the TAM questionnaire for analysis.

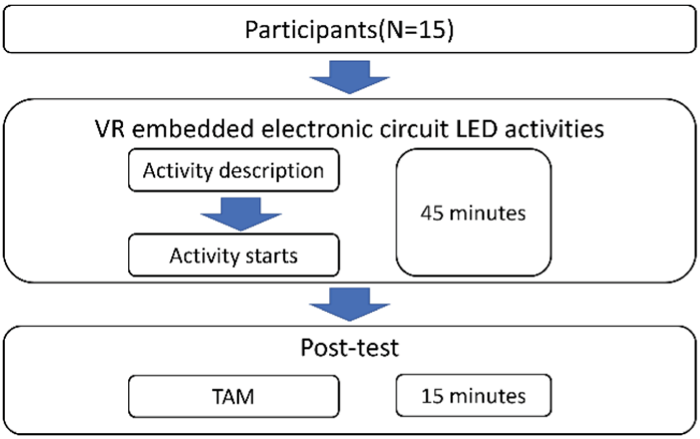


Fig. 6. Experimental procedure

4 Results and Discussion

This study was conducted using an adapted TAM to collect participants' learning experiences of VR activities for embedded electronic circuits. We used a 5-point Likert scale for measurement, divided into *very satisfied, satisfied, average, dissatisfied*, and *very dissatisfied*. The results are shown in Table 1. The scale consisted of six items for perceived usefulness and six items for perceived ease of use. The reliability analysis of the questionnaire is shown in Table 2.

Table 1. Descriptive statistics

	Mean	*SD*
TAM	4.1975	.45004

The average TAM score of the participants in the VR activities with embedded electronic circuits developed here was 4.1975 (Table 1), which indicates that students exhibited a good level of technology acceptance when using VR for the embedded electronic circuit activities. Moreover, the device and its virtual environment were also easy for students to operate, making them feel that it was helpful to use the VR system to complete the required design activities.

Because none of the subjects in this study had any experience using VR headsets, after the activity was explained, participants spent time familiarizing themselves with the functions of the device. During the experiment, some participants asked whether they could suspend the activity due to discomfort from the head-mounted device, which may have prevented the participants from fully experiencing the course using the VR device.

Table 2. TAM reliability analysis

Cronbach's alpha	Items
.817	12

5 Conclusion

The VR activity system for embedded electronic circuits that we developed include correct and incorrect prompts, task schedules, and step-by-step task guidance. The purpose of the system was to avoid the need for participants to conduct traditional experiments. During the course of the experiment, due to unfamiliarity with the operation methods and formulas it was necessary to pause the experiment to review notes and class briefings, which may have reduced the effectiveness of the experiment.

In the virtual experiment environment, participants were able to use as many resources and materials as needed to repeatedly practice the connections, and they could also gain a deeper understanding of embedded electronic circuits through the many visual components designed by the system, and do so in a safe and secure environment. The participants exhibited a high degree of acceptance of the system designed in this study.

However, this study also has some limitations. Due to equipment and environmental factors, this experiment was limited to a space of less than one square meter, so that while performing the experiment, some participants exceeded the range of the device sensor, interrupting the experiment. We suggest that in the future, when performing virtual reality activities, participants should be allowed a range of motion of at least one square meter before the experiment can be carried out smoothly.

References

1. Holly, M., Pirker, J., Resch, S., Brettschuh, S., Gütl, C.: Designing VR experiences-expectations for teaching and learning in VR. Educ. Technol. Soc. **24**, 107–119 (2021)
2. Baird, J.R., Penna, C.: Challenge in learning and teaching science. Res. Sci. Educ. **26**, 257–269 (1996). https://doi.org/10.1007/BF02356938
3. Hake, R.R.: Interactive-engagement versus traditional methods: a six-thousand-student survey of mechanics test data for introductory physics courses. Am. J. Phys. **66**, 64–74 (1998)
4. Rorty, R.: Human rights, rationality and sentimentality. In: The Politics of Human Rights, vol. 67 (1999)
5. Freeman, S., et al.: Active learning increases student performance in science, engineering, and mathematics. Proc. Natl. Acad. Sci. **111**, 8410–8415 (2014)
6. Khotimah, K., Hastuti, U.S.: Developing microbiology digital handout as teaching material to improve the student's science process skills and cognitive learning outcome. Eurasian J. Educ. Res. 80–97 (2021)
7. Chen, J.C., et al.: Developing a hands-on activity using virtual reality to help students learn by doing. J. Comput. Assist. Learn. **36**, 46–60 (2020)
8. Saab, M.M., Hegarty, J., Murphy, D., Landers, M.: Incorporating virtual reality in nurse education: a qualitative study of nursing students' perspectives. Nurse Educ. Today **105**, 105045 (2021)
9. Chang, C.-C., Hwang, G.-J.: An experiential learning-based virtual reality approach to fostering problem-resolving competence in professional training. Interact. Learn. Environ. 1–16 (2021)
10. Tang, F.M.K., et al.: A simulation design of immersive virtual reality for animal handling training to biomedical sciences undergraduates. Front. Educ. **239** (2021)
11. Allcoat, D., Hatchard, T., Azmat, F., Stansfield, K., Watson, D., von Mühlenen, A.: Education in the digital age: learning experience in virtual and mixed realities. J. Educ. Comput. Res. **59**, 795–816 (2021)
12. Sharma, R.C., Sharma, Y.P.: Designing virtual reality experiences in education. Bull. Tech. Committee Learn. Technol. (ISSN: 2306-0212) **21**, 19–22 (2021)
13. Cavalcanti, J., Valls, V., Contero, M., Fonseca, D.: Gamification and hazard communication in virtual reality: a qualitative study. Sensors **21**, 4663 (2021)
14. de Lama, C., González-Gaya, C., Sánchez-Lite, A.: An experimental test proposal to study human behaviour in fires using virtual environments. Sensors **20**, 3607 (2020)

15. Davis, F.D.: Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q. 319–340 (1989)
16. Brown, R., Brown, J., Reardon, K., Merrill, C.: Understanding STEM: current perceptions. Technol. Eng. Teach. **70**, 5 (2011)
17. Le, Q., Le, H., Vu, C., Nguyen, N., Nguyen, A., Vu, N.: Integrated science, technology, engineering and mathematics (STEM) education through active experience of designing technical toys in Vietnamese schools. Br. J. Educ. Soc. Behav. Sci. **11**, 1–12 (2015)
18. Barr, V., Stephenson, C.: Bringing computational thinking to K-12: what is involved and what is the role of the computer science education community? ACM Inroads **2**, 48–54 (2011)
19. Gonzalez, H.B., Kuenzi, J.J.: Science, technology, engineering, and mathematics (STEM) education: a primer. Congressional Research Service, Library of Congress, Washington, DC (2012)
20. Chien, Y.-H.: Developing a pre-engineering curriculum for 3D printing skills for high school technology education. Eurasia J. Math. Sci. Technol. Educ. **13**, 2941–2958 (2017)
21. Fan, S.-C., Yu, K.-C.: How an integrative STEM curriculum can benefit students in engineering design practices. Int. J. Technol. Des. Educ. **27**(1), 107–129 (2015). https://doi.org/10.1007/s10798-015-9328-x
22. Gao, X., Li, P., Shen, J., Sun, H.: Reviewing assessment of student learning in interdisciplinary STEM education. Int. J. STEM Educ. **7**(1), 1–14 (2020). https://doi.org/10.1186/s40594-020-00225-4
23. Olson, S., Riordan, D.G.: Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics. Report to the President. Executive Office of the President (2012)
24. Zhang, J., Zhou, Y.: Study on interactive teaching laboratory based on virtual reality. Int. J. Contin. Eng. Educ. Life Long Learn. **30**, 313–326 (2020)
25. Araiza-Alba, P., Keane, T., Kaufman, J.: Are we ready for virtual reality in K–12 classrooms? Technol. Pedagogy Educ. 1–21 (2022)
26. Slavova, Y., Mu, M.: A comparative study of the learning outcomes and experience of VR in education. In: 2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), pp. 685–686. IEEE (2018)
27. Çakiroğlu, Ü., Gökoğlu, S.: Development of fire safety behavioral skills via virtual reality. Comput. Educ. **133**, 56–68 (2019)
28. Pellas, N., Dengel, A., Christopoulos, A.: A scoping review of immersive virtual reality in STEM education. IEEE Trans. Learn. Technol. **13**, 748–761 (2020)

Roaming Jingliao – The AR Based Learning Assistance for Design Cultural Creation Education

Ching-I Cheng[1](✉), Wen-Chun Hsu[2], and Ming-Han Bai[3]

[1] Southern Taiwan University of Science and Technology, Tainan, Taiwan, R.O.C.
cindycheng@stust.edu.tw
[2] National Pingtung University, Pingtung, Taiwan, R.O.C.
[3] National Yunlin University of Science and Technology, Douliu, Taiwan, R.O.C.

Abstract. The study has taken the issue of "AR in education" into consideration in design cultural creation domain. The specialized areas such as AR development and user satisfaction have been taken into account. The purpose is to develop an AR application for helping students to learn local culture while having Field Learning Activities. Roaming Jingliao is a LBS AR to provide local cultural information and attract students to learn in the field course. The study carried out experiments to assess the impact of exploiting AR in learning local culture. The author brought students to discover Jingliao Old Street in Houbi District by using Roaming Jingliao. The participants were asked to take the satisfactory questionnaire and a short interview. Afterwards, they worked in groups to design and produce e-books based on the cultural knowledge they've obtained, and further register for an e-book contest. Meanwhile, these works were also assessed by three professional judges for cultural and creative scoring. There were 9 e-books produced in the study and 3 of them earned excellent works award in the contest. It is shown that the participants have a positive attitude and high interests of using Roaming Jingliao to learn local cultures.

Keywords: LBS · Game-based learning · Computer-assisted learning

1 Introduction

1.1 Background

"Culture" as the foundation of industrial development, people in various domain keep integrating the design methods, using creative ingenuity, and combining relevant media and tools to design and develop based on culture. Cultural creativity thus emphasizes the transformation and production of cultural perception. In the past decade, departments related to cultural and creative industries have been established in lots of universities in Taiwan to cultivate talents needed by related industries. The understanding of cultural industry has become one of the key courses in design-related fields. Teachers in the field of design are actively guiding students to integrate and apply their professional skills, so

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 97–106, 2022.
https://doi.org/10.1007/978-3-031-15273-3_11

as to become multi-disciplinary talents required by the cultural and creative industries. Therefore, in addition to the cultivation of basic technical skills, it is expected that students will continue to think and explore problems in the process of team interaction, and to learn knowledge of culture through practical exercises.

Generally speaking, culture originates from daily life and is the accumulation of life experiences. A full understanding of culture requires a keen sense of life. Therefore, if the transmission of cultural knowledge only depends on classroom teaching, it will be difficult to achieve effective understanding. However, in the modern age of information explosion, the convenience of obtaining information has led students to become accustomed to receiving information in one direction and gradually lose their sense of life. Due to the lack of sensitivity to life, more and more students are losing their own perspectives, resulting in low creativity. It was ever occurred in the authors' previous teaching experience that students are hard to fully understand the cultural connotation only through lectures in classroom. In order to improve the shortcomings of traditional classroom lectures, educators constantly develop teaching innovations. Experiential learning and community-based learning, for example, are well known learning-by-doing learning modes commonly used to enhancing learning motivation and further improving the effectiveness. The author once took students into the historical and cultural district and learned about the local culture through guided tours for inspiring students' perception. However, students are often affected by particular scenery and lost concentration on the guide's explanation. Group guiding in vast outdoor space also lead to inefficiencies in learning. Mobile digital assistance might be a solution.

Digital game-based learning has been proved that is an effective way to motivate students and improve the learning results [1–4]. Gaming becomes a new form of interactive content, worthy of exploration for learning purposes. Augmented Reality (AR) is an information technology that overlays virtual images on real scenes in real time through computer operations, can easily interacts with users in the form of games. It suits to provide rich interactive experiences as additional information beyond reality is provided through mobile devices to enrich learning content [5, 6]. Hence, the authors conceived of developing an AR based cultural field guide system as a learning assistance can provide learners with individual and timely cultural in-formation during community visits. Through the use of the developed AR guide system, the motivation can be stimulated and the learning effectiveness can be further improved.

1.2 Research Purposes

As mentioned previously, besides the training of skills, students in the field of cultural and creative design need to cultivate the ability to perceive life. Thinking from the perspective of teaching, how to make a proper use of the local cultural environment, supplemented by the ubiquitous characteristics of mobile AR, and further effectively stimulate the learning motivation of students in the field of design, culture and creativity, to explore the cultural stories, so as to improve their cultural literacy is an emerged issue in cultural creation education. Furthermore, students can combine their professional skills for design thinking, and then apply the cultural elements they've understand to develop the ability of content design.

Hence, this study has taken the issue of “AR in education” into consideration. The specialized areas such as AR development and user satisfaction have been taken into account. The purpose of this study is to determine whether the use of AR is helpful for activating the motivation of learning local culture. The research questions are

1. Can the augmented reality situational navigation system stimulate the learners’ willingness to learn local culture, can they deepen their impressions in the cognitive process?
2. Can the learners achieve the purpose of their exploration and further enhance their learning effectiveness?

2 Literature Review

2.1 Augmented Reality

Augmented reality (AR) is a derivative of virtual reality. Through the interaction of mobile devices and contents, the virtual world is extended to the real world. With the development of technology and the maturity of the hardware, AR has been widely used in various fields, such as medical, national defense, education, entertainment, and so on. According to the integration of domestic augmented reality research projects in Taiwan from [7], augmented reality is mostly applied in medical training, education and teaching demonstrations, design development, service design, and environmental space projects. In particular, with Augmented Reality (AR), learners can interact with learning content through mobile devices, which is a new trend in the development of digital learning in recent years. The advantages of AR technology provide information that cannot be provided in the real environment, so as to meet the needs of students of learners and teachers to provide immediate interaction during learning process [5, 6].

From a technical point of view, AR tracking technology is specifically to explore how virtual objects are properly positioned (including position and orientation) in the real world. In a research report published by Billinghurst et al. [8]. in 2015, a variety of AR positioning tracking technologies were discussed, including Magnetic tracking, Vision Based Tracking, Inertial Tracking, GPS Tracking, and Hybrid Tracking. ARToolKit is a software library for building Augmented Reality (AR) applications. It is a very widely used AR tracking library, uses video tracking capabilities that calculate the real camera position and orientation relative to square physical markers or natural feature markers in real time. The ARToolkit component allows quick and easy integration of AR into the application for a wide variety of scenarios. Smart Garden (SG) proposed in [10], which provides information about what to plant where, uses NyARToolkit for processing, in which virtual plants are overlaid on real image to help growers to understand the outcomes of their decisions intuitively.

Moreover, Augmented Reality Software Development Kit (AR SDK) facilities different components into AR applications, including AR recognition, AR tracking, and AR content rendering. A comparative study of various augmented reality software development kits available to create augmented reality apps is proposed in [9]. The researchers organized AR SDKs in Geo-located AR Browsers, Marker based, and Natural Feature

Tracking. Campus event application proposed in [11] is GPS location based AR application developed using marker less tracking feature of Metaio and Android SDK. It was implemented which updates the users with daily campus events by visualizing the event over real world and providing real time map and route to the event. Vuforia supports the creation of both marker-based and marker-less AR and has several key features, including Ground Plane (for adding content to horizontal surfaces), Visual Camera (expands supported visual sources beyond mobile phones and tablets), and VuMarks (custom markers that can be used in Vuforia face recognition and also encode data), that make it one of the best for object recognition and 3D modeling [12].

Hence, through the combination of AR, GPS, and mobile devices, the cultural stories hidden behind the sceneries can be obtained in real time while walking through the streets and alleys. With an AR based learning assistance is developed and eventually exploited in the outdoor lectures, the gamification of learning process is enhanced and the motivation of learning is further activated.

2.2 Game-Based Learning

Games can introduce goals, interaction, feedback, problem solving, competition, narrative, and fun learning environments, elements that can increase learner engagement and sustain motivation [13]. In recent years, many researches proposed that using computer games, or games in general, for educational purpose motivates the learners and further enhances the learning effectiveness and improves the performance. The motivational psychology involved in game- based learning allows students to engage with educational materials in a playful and dynamic way. As indicated in [1], game-based learning has been widely adopted for children's learning and has a proven success in the improvement of learning as well as in children's acceptance. In [14], the researchers proposed a meta-analysis of investigating the learning-theory foundations of game-based learning.

Gaming becomes a new form of interactive content, worthy of exploration for learning purposes. Many studies have investigated the effects of digital game-based learning on learning and motivation in different areas, such as computer science education, business education and advanced training [1–3]. Additionally, [4] reported a positive relationship between the level of intrinsic motivation and learning scores in a digital learning game. Intrinsic motivation refers to the inner desire to engage in a task out of interest or amusement, or even because of the challenge it offers [15, 16]. Furthermore, Erhel and Jamet systematically demonstrated the benefits of digital game-based learning in their publication [17]. The benefits of digital game-based learning are often attributed to its entertainment aspect.

In the study, in order to reduce the boredom caused by traditional guided tours, and make students pay more attention on guiding, the authors designed learning activities that are intrinsically game-like for learning local culture.

2.3 Computer-Assisted Learning

With computer technology development, researchers and workers in various industries, education is no exception, are all using computer technology to improve work efficiency and to create additional value. Computer-assisted learning (CAL) describes the education that uses computers and other technologies and doesn't require human intervention or interaction. With computer technology and instructional design, an interactive, cooperative and real learning situation can be simulated in virtual environment so that participant can interact with situations to stimulate the ability to think and solve problems and to get better learning achievements. For example, in the course of learning equipment operation, students simulate the situation of equipment operation through the computer screen, and follow the instructions step by step to learn the operation; in a Political Science course, students might role-play in the virtual environment as they engage in mock negotiations involving a labor dispute. Barney Dalgarno has summarized the psychological and pedagogical theories that have led to significant changes in accepted teaching and learning strategies in 2001 [18]. It has examined the way that these theories may be applied to Computer Assisted Learning, showing that the range of possible CAL approaches incorporating constructivist theory are broad and varied.

CAL has been claimed to improve knowledge retention and achievement scores, enhance clinical judgement skills and reduce required instruction time; performing as well (if not better) when compared to other more traditional education techniques. More specifically, the researcher in [19] proposed that the advantages of the utilization of CAL in nursing education can be made clear by consideration of adult education theory and curriculum design, as well as the particular learning needs of nurses themselves. Moreover, computer-assisted language learning (CALL) has established itself as an identifiable and fruitful area of inquiry that contributes to the language education community. Research in [20] investigated the perception of EFL/ESL learners on the application of computer in learning English and provided empirical support for its positive effects from the perception of learners. It proposed that most EFL/ESL learners recognized the benefits of using technology in learning English and found computers helpful in learning grammar. The article [21] provides an overview of the evolution of theory and practice in CALL research. It concludes with theoretical and methodological considerations for approaching CALL today and beyond.

3 Methods

3.1 System Architecture

The study designed to develop an AR based application, named Roaming Jingliao, in which users can view virtual object from various orientation to obtain the stories of the locals while having the local tour. According to [22], combining augmented reality with LBS (Location Based Services) technology is considered an innovative application of mobile phones, can provide users with more detailed services in the sports and tourism industries. Hence, the system architecture of the required AR in this study is developed using LBS which overlays a virtual mechanical 3D object based on GPS coordinates. As shown in Fig. 1, it is divided into three parts: User Components, Communication Components, and Service Components. The user components is basically the interface of the application; the communication components includes utilizing GPS satellites signals and mobile networking; and the service components is meant to the service server and the backend operations. The Raw GPS Measurements is obtained through mobile devices and then recalculated to GPS Coordinates. The GPS coordinates is then used to obtain the related local information stored in the Mysql database. In addition, it is suggested that avoid displaying too many POI (Point of Interest) signs on the interface of the LBS system is to provide users with better usability and experience [23]. It is exploited in the study to be the principles while designing the user interface.

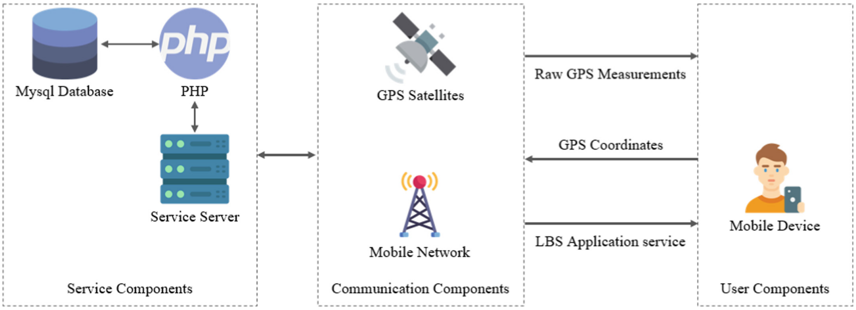


Fig. 1. The mobile-server LBS architecture of Roaming Jingliao.

3.2 Technologies

A variety of familiar and skilled techniques are exploited to develop the AR application, Jingliao, in the study. Unity is mainly used for the development of system core, Adobe XD is for the design of interface, and Blender is used to build fined 3D virtual contents. Figure 2 shows an overview of the technologies exploited for developing Roaming Jingliao. The technologies are categorized as game art software, game engine and SDK, tracking environments, and platform support. In order to achieve rich augmented reality content by tracking the ground and areas, the Vuforia SDK is used to assist in development. Finally, the application will be listed on Google Play and App Store for download and use by research participants.

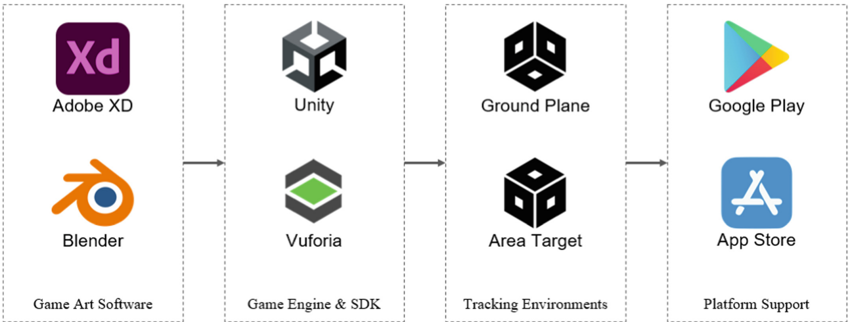


Fig. 2. Overview of technologies exploited for developing Roaming Jingliao.

4 Results and Discussions

The practicality of the proposed methodology is demonstrated through experimental method. The data was collected by questionnaires and interviews that are given after using the designed AR. The authors thus carried out experiments to assess the impact of exploiting AR in learning local culture, bringing the participants to Jingliao Old Street in Houbi District, Tainan, after taking lectures of Taiwanese Countryside and Rice Food Culture. The participants were asked to walk through the field using the AR guide and to take the satisfactory questionnaire and a short interview afterwards. Figure 3 shows a photo collection of travelling with Roaming Jingliao. The participant follows the spot shown on the map in Roaming Jingliao to find out the stories of individual scene. When the AR scene is activated, a virtual character is shown to introduce the story with text and voice. After the course, students worked in groups to design and produce e-books based on the cultural knowledge they've obtained, and further register for the 12th International Chinese Language and Education Cup E-Book Creation Competition. Meanwhile, these works were also assessed by three professional judges for cultural and creative scoring. From the feedback of the judges, although a small number of works lost focus on local culture, most of them combine culture with different elements for various presentation. There were 9 e-books produced in this study and 3 of them earned excellent works.

This study exploits the satisfaction questionnaire used [24]. A total of 33 valid satisfaction questionnaires were collected in this study. The satisfaction discussed in this study is divided into four dimensions, namely "user interface design", "stability", "human-computer interaction", and "system potential for teaching", and the measured score is shown in Table 1. The five-point scale is used to evaluate the satisfaction, and the overall score is around 3.755. It shows the participants have a positive attitude in the cultural study of using Roaming Jingliao. And the user interface and human-computer interactions of the AR system makes self-learning easy. The lowest score goes to the dimension "stability", meaning that the system has to be verified on different mobile devices before released.

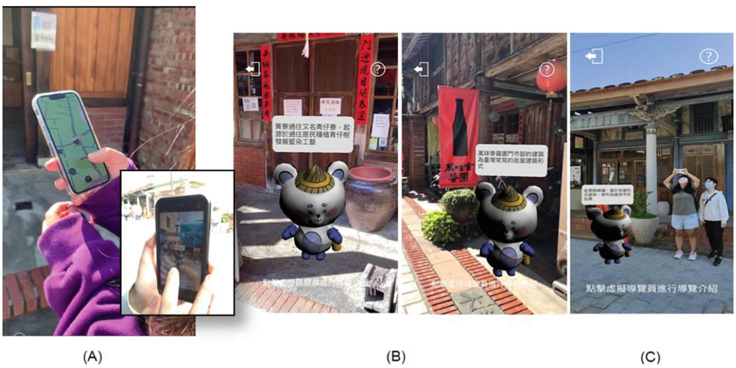


Fig. 3. Travelling with Roaming Jingliao. (A) The participant follows the spot shown on the map in to visit individual scene; (B) scene knowledge introduced by the virtual character; (C) the participant takes photo together with the virtual character.

Table 1. The result of user satisfactory of using Roaming Jingliao to learn local culture.

Dimension	Number of questions	Average score	Standard deviation
User interface design	5	3.76	0.75
Stability	5	3.52	0.87
Human-computer interaction	5	3.79	0.73
System potential for teaching	5	3.95	0.72
Overall	20	3.755	0.77

Moreover, the participants were interviewed after the course to give back the experience of using AR while having field learning. The interview questions basically included "How do you feel about actually visiting the field using AR? Does the use of AR enhance the understanding of local culture?" Most participants indicated that they were initiative on self-learning while using the AR. It is obviously that with the game-based learning, the participants became active to learn because they were interested in the scenario. Some feedback is as follows:

> "Using AR apps made me more willing to explore local stories."
>
> "As the virtual character appeared on the map to guide the visit path, I was unconsciously visiting one after another, with local stories of characteristic attractions."
>
> "The developed AR is like a mobile game, attracting me to actively use so that I was happy to visit the area more."

However, the participants also mentioned that the positioning function of the app is activated after scanning the physical floor, and the operation is not usually smooth. It is because that not all mobile phones can support accurate GPS and the performance is various depending on different types. Students reviewed that they had learned the local culture through the game-based learning.

5 Conclusion

Based on observations in the experimental class, it can be concluded that game-based learning is effective to stimulate the learning motivation of students. If it is supported through the interesting subject matter, methods as well as enthusiasm and fun, make students have a positive desire or inclination to learn. The results shows that the participants are generally satisfied with AR, Roaming Jingliao, in learning local cultural knowledge. Students indicates that they keep active and having higher concentration on learning local cultural knowledge during the class although some crash occurred occasionally while using Roaming Jingliao. AR is thus helpful indeed for activating the motivation of learning local culture.

Moreover, students were asked to work in groups to design and produce e-books based on the cultural knowledge they've obtained, and further register for an e-book contest. There were 9 e-books produced after the course, and were also assessed by professionals. Most of the works show local cultural elements and fully convey the meaning of the title. The works mostly received high evaluation and earned three excellent works award in the contest.

These results can prove that the use of Roaming Jingliao in the field course can effectively stimulate students' interest and achieve cultural learning. Through the process of e-book production, learn how to integrate and use the professional skills that students already have and the cultural knowledge to create cultural works. A well-developed AR application is a solution for activating learning motivation in design cultural creation education.

Acknowledgement. This work was partially supported by the Ministry of Science and Technology of Taiwan R.O.C., under grant MOST- 110–2635-H-218–003-.

References

1. Pivec, M., Dziabenko, O., Schinnerl, I.: Aspects of game-based learning. In: Proceedings of I-KNOW 2003, Austria, pp. 216–225 (2003)
2. Chandel, P., Dutta, D., Tekta, P., Dutta, K., Gupta, V.: Digital game based learning in computer science education. CPUH-Res. J. **1**(2), 33–37 (2015)
3. Garris, R., Ahlers, R., Driskell, J.E.: Games, motivation and learning: a research and practice model. Simul. Gaming **33**(4), 441–467 (2002)
4. Liu, M., Horto, L., Olmanson, J., Toprac, P.: A study of learning and motivation in a new media enriched environment for middle school science. Educ. Technol. Res. Dev. **59**, 249–265 (2011)
5. Cheng, K.H., Tsai, C.C.: The interaction of child-parent shared reading with an augmented reality (AR) picture book and parents' conceptions of AR learning. Br. J. Edu. Technol. **47**(1), 203–222 (2016). https://doi.org/10.1111/bjet.12228
6. Chiang, T.H.C., Yang, S.J.H., Hwang, G.J.: An augmented reality-based mobile learning system to improve students' learning achievements and motivations in natural science inquiry activities. Educ. Technol. Soc. **17**(4), 352–365 (2014)
7. Hsu, C.-B.: Employing usability evaluation to analyze an affective AR-based interface. National University of Tainan, Master thesis, Tainan City (2010)
8. Billinghurst, M., Clark, A., Lee, G.: A survey of augmented reality. Found. Trends Hum.-Comput. Interact. **8**(2–3), 73–272 (2015)
9. Amin, D., Govilkar, S.: Comparative study of augmented reality SDK's. Int. J. Comput. Sci. Appl. **5**(1), 11–26 (2015)
10. Okayama, T.: Future gardening system—smart garden. J. Dev. Sustain. Agric. **9**(1), 47–50 (2014)
11. Chao, J.T., Lei, P., Kevin, R.P.: Campus event app-new exploration for mobile augmented reality. Issues Informing Sci. Inform. Technol. **11**, 001–011 (2014)
12. Vuforia. https://developer.vuforia.com/. Accessed 28 Aug 2021
13. Gamification and game-based learning. https://uwaterloo.ca/centre-for-teaching-excellence/teaching-resources/teaching-tips/educational-technologies/all/gamification-and-game-based-learning. Accessed 28 Mar 2022
14. Wu, W.-H., Hsiao, H.-C., Wu, P.-L., Lin, C.-H., Huang, S.-H.: Investigating the learning-theory foundations of game-based learning: a meta-analysis. J. Comput. Assist. Learn. **28**(3), 265–279 (2018)

15. Deci, E.L., Ryan, R.M.: The, "what" and "why" of goal pursuits: human needs and the self-determination of a behavior. Psychol. Inq. **11**(4), 227–268 (2000)
16. Martens, R.L., Gulikers, J., Bastiaens, T.: The impact of intrinsic motivation on e-learning in authentic computer tasks. J. Comput. Assist. Learn. **20**, 368–376 (2004)
17. Erthel, S., Jamet, E.: Digital game-based learning: Impact of instructions and feedback on motivation and learning effectiveness. Comput. Educ. **67**, 156–167 (2013)
18. Dalgarno, B.: Interpretations of constructivism and consequences for computer assisted learning. Br. J. Educ. Technol. **32**(2), 183–194 (2001)
19. Nerlich, S.: Computer-assisted learning (CAL) for general and specialist nursing education. Aust. Crit. Care **8**(3), 23–27 (1995)
20. Shafaei, A.: Computer assisted learning: a helpful approach in learning English. Front. Lang. Teach. **3**, 108–115 (2012)
21. Han, Y.: Connecting the past to the future of computer-assisted language learning: theory, practice, and research. Issues Trends Learn. Technol. **8**(1), 1–13 (2020)
22. Kanade, P., Prasad, J.P.: Mobile and location based service using augmented reality: a review. Eur. J. Electr. Eng. Comput. Sci. **5**(2), 13–18 (2021)
23. Brata, K.C., Liang, D.: An effective approach to develop location-based augmented reality information support. Int. J. Electr. Comput. Eng. **9**(4), 2088–8708 (2019)
24. Chang, W.-J.: A design of augmented reality learning system to support college students' rural experimental learning. J. Liberal Arts Soc. Sci. **13**(1), 29–64 (2017)

Using Immersive Virtual Reality to Explore the Learning Performance and Cognitive Load of Students in STEAM Electronic Circuits Learning

Yu-Ping Cheng[1], Chin-Feng Lai[1], Shu-Chen Cheng[2], and Yueh-Min Huang[1](✉)

[1] Department of Engineering Science, National Cheng Kung University, Tainan City, Taiwan
cinfon@ieee.org, huang@mail.ncku.edu.tw

[2] Department of Computer Science and Information Engineering, Southern Taiwan University of Science and Technology, Tainan City, Taiwan
kittyc@stust.edu.tw

Abstract. In the recent era applying advanced emerging technologies to educational issues has become a subject for wide discussion, also students have a high scope to obtain much more learning experience and resources through these exclusive technologies. Many such studies have used this immersive virtual reality to explore the feasibility of STEAM education for their students. However, learning activities through immersive virtual reality may have some negative effects as well, indeed which may indirectly reduce student learning performance. Therefore, this study has built an extremely realistic virtual reality system to present the materials of electronic circuits. The students can make use of immersive virtual reality devices and handheld sensing devices to operate and practice the electronic circuit learning tasks in a virtual learning environment. In addition, this study has recruited 20 students to have an investigation on the effect of immersive virtual reality on learning performance and cognitive load in electronic circuit learning. According to this result, the experimental group using the virtual reality system for STEAM learning activities can significantly have an emerging improvement in the learning performance. Additionally, the cognitive load of the experimental group was also lower than that of the control group in the process of STEAM learning activities.

Keywords: Virtual reality · STEM/STEAM education · Learning performance · Cognitive load

1 Introduction

With the vigorous development of information technology, students and users can essentially obtain more learning resources and learning experiences through the available multimedia and emerging technologies, such as virtual reality [1], augmented reality [2], the Internet of Things [3] or business simulation game [4] etc. When compared with the instructional method of traditional lectures on, how students fetch in acquiring

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 107–116, 2022.
https://doi.org/10.1007/978-3-031-15273-3_12

knowledge by combining emerging technology and E-learning has added to become a very vital issue in the educational field. If students passively receive the knowledge, it may have a chance of affecting their learning performance and interest, therefore, when students actively accept the knowledge or practical operation in the process of learning, their effort of learning efficiency can also be improved [5, 6]. As a comprehensive and interdisciplinary instructional method, STEM/STEAM education added positive benefits to students in the process of knowledge acquisition and hands-on practice [7, 8]. Chien [9] stated that, the hands-on activities of STEM/STEAM education can cultivate students' interdisciplinary knowledge, developed problem-solving skill and creativity and enabled students to implement valuable and unique products through hands-on activities [9]. In addition, some studies have also shown that the combination of STEM/STEAM education and emerging technologies can have a positive impact on interdisciplinary courses and can also improve and motivate students' learning engagement [10].

In recent years, some studies have confirmed the effectiveness of virtual reality as an emerging technology in STEM/STEAM education [11]. Virtual reality has enabled people to have knowledge in sensing the reality, presence and engagement in an immersive virtual environment through a first-person perspective and used sensors with headphones to bring people on an immersive sense of presence and experience [12]. In addition, virtual reality can present abstract concepts through three-dimensional (3D) virtual images to essentially help students have a quick understanding concepts [13]. Hsiao, Chen, Lin, Zhuo and Lin [14] have considered that students can gradually improve their understanding skills, and concepts through virtual reality and "learn by doing" in the learning stage and the hands-on development process also can further help students to equally develop their hands-on ability as well [14].

Although, the development and effectiveness of combining virtual reality and STEM/STEAM education in its own educational research has a direct scope for being widely discussed, normally few studies have revealed that, when exactly students have not fully used the virtual reality for practice, there will be an impact of increase in their learning burden and cognitive load [15, 16]. In addition, the authors who has worked on this research has also found that, there are few studies that deeply explored the effect of virtual reality on the learning performance and cognitive load of electronic circuit learning. Therefore, this study has developed a virtual reality system for electronic circuit learning to basically conduct a safe and risk-free electronic circuit practice through immersive virtual reality by discussing and analyzing students' learning performance and cognitive load in virtualized electronic circuit learning.

2 Literature Review

2.1 Virtual Reality

With the advent of the digital age, students can gain even more learning experiences through virtual reality and the positive benefits received from virtual reality in educational research have also been confirmed [17]. Virtual reality is one of the major techniques used by artistic teachers to make students learning performance effectively active and motivational in the classrooms [11]. Virtual reality has eventually used 3D images or environments to mainly emphasize on the sense of existence in the simulated environment, so that users can experience the actual immersive feeling in the virtual environment [18]. On the other hand, virtual reality has included immersive virtual reality and non-immersive virtual reality. The immersive virtual reality has fundamentally interacted and played in the virtual environment by wearing a head-mounted display (HMD) and handheld sensor devices, which indeed has enabled students to essentially perform activities or simulation training in a high-fidelity virtual environment without having any high-risk in the activities [19]. For example, Frederiksen, Sørensen, Konge, Svendsen, Nobel-Jørgensen, Bjerrum and Andersen [15] has been used in immersive virtual reality for the surgical simulation training [15]. Non-immersive virtual reality has used the devices such as keyboards, mice and screens to interact and play in the virtual environment. This method has no determination to enable students to analyze and experience the immersion of virtual environment [20]. For example, Lee and Wong [16] had explored the performance of students' spatial ability through desktop virtual reality [16].

In addition to this, some studies have shown that immersive virtual reality was often used in high-risk situations or in simulation training courses [21]. Wang, Wu, Wang, Chi and Wang [22] showed that virtual reality can also be applied to the implementation of construction engineering education and training through the integration of visualization technologies and education paradigms, thereby improving students' training performance as well [22]. Jensen and Konradsen [23] used HMD to conduct educational training to explore the difference and impact of its method and traditional teaching in cognitive skills, psychomotor skills and affective skills [23].

Although we notice most of the studies have shown that immersive virtual reality can enhance students' learning performance even more effectively, Lee and Wong [16] has specially showed that, using it may increase the learning burden of students without sufficient virtual reality training [16]. In addition, keeping the high level of immersion as a base it has bought about immersive virtual reality, students have a chance of getting distracted in the virtual environment [23], which may also make it easy for students to increase their cognitive load [15]. Therefore, this study has considered matching appropriate learning material and animations to create an interesting and highly realistic virtual learning environment for students to reduce the cognitive load of students in the learning process and effectively improve their learning performance.

2.2 STEM/STEAM Education

STEM education was a novel and interdisciplinary instructional method, which consists of four disciplines, namely science, technology, engineering and mathematics. Bybee [24] considered that, STEM education should basically enhance students to have a knowledge of usage of technology and improve their ground understanding of the operation for anything and any product [24], because STEM education has not explore the content and keep thinking of a single discipline, it has actually paid more attention towards the integration of multiple disciplines to deepen their elementary understanding and skills [25]. Therefore, instructors in many countries were regularly promoting STEM education, which also had emphasized the importance of improving STEM skills and abilities [26]. For example, Hu, Yeh and Chen [27] proposed a framework of knowledge, skills and attitudes to explore the impact of students' STEM competence, creativity and STEM attitudes in making electronic musical pencils [27]. Arís and Orcos [26] explored the STEM skills of secondary education students through educational robotics and the results of this study showed that students can eventually improve and develop their technological competence through robot programming [26]. ZAHIDI, Ong, YUSOF, KANAPATHY, ISMAIL and YOU [28] hold a unique science camp to steadily explore young children's understanding of STEM education. This indeed showed the results of the study that, having the method can effectively improve the students rational understanding and mastery of STEM knowledge, also can stimulate their profound interest in STEM education [28].

On the other hand, Yakman [29] added art to propose a STEAM framework based on STEM education and has described the importance of art in presenting art and aesthetics in the hands-on process [29]. Therefore, STEAM education can ultimately cultivate students' liberal and physical abilities in the discipline of adding art, so that students can not only use STEM knowledge, technology and logical thinking but can also demonstrate creative aesthetic results through engineering practice [29]. For example, Dejarnette [30] implemented a STEAM curriculum in order to explore the self-efficacy and implementation rate of young talented children in hands-on practice and the results essentially showed that young children will have a high degree of acceptance, engagement and cooperation for STEAM curriculum [30]; Shatunova, Anisimova, Sabirova and Kalimullina [31] has been implemented in the project training in creative aspects up to the spaces through the model of STEAM education and explored students' abilities in systematic thinking and art creativity. The study pointed out that the use of creative spaces can even more enable students to cultivate the skills and competencies which are essentially required for Industry 4.0 in the arts [31]; Hsiao and Su [32] has finally combined STEAM courses and virtual reality to explore students of satisfaction, self-efficacy and learning outcomes. The results have suggested that students can still improve their self-efficacy through virtual reality games. However, the quantified authors also have specified that through the ultimate use of virtual reality technology, it was necessarily having an adjustment towards the materials appropriately, so that the students can be even more familiar with the operations of virtual reality [32].

Although the relevant research on virtual reality and STEM/STEAM education has confirmed its effectiveness, there are few more studies to explore the effect of virtual reality and STEAM education on the learning effect of electronic circuit learning. In addition, there is a typical requirement to explore how exactly the students can reduce the cognitive load in the electronic circuits by learning through appropriate virtual reality scenarios, therefore this kind of study has provided two research questions as follows:

RQ1: Does virtual reality gradually increase the learning performance of students in electronic circuits when compared with conventional lectures?
RQ2: Does virtual reality steadily decrease the cognitive load of students in electronic circuits in comparison with conventional lectures?

3 Research Method

3.1 Participants

This study has used immersive virtual reality to basically implement STEAM learning activities to explore the impact of students' learning performance and cognitive load in electronic circuits learning. This study recruited 20 students aged between 16 and 24, where all of whom has agreed to participate in this STEAM learning activity and have proactively signed an informed consent form their parents. In addition, all students were randomly assigned to the experimental group and the control group 10 students were assigned to the experimental group, and 10 students were assigned to the control group.

3.2 Virtual Reality System for Electronic Circuit Learning

This study has developed a virtual reality system for electronic circuit learning, which have basically enabled students to conduct virtual electronic circuit learning through immersive virtual reality. As shown in Fig. 1, the researchers presented the learning material of electronic circuits through entertaining and a highly realistic virtual learning environment. When starting to use virtual reality, the system played an animation to guide students into a virtual learning environment, which has used a computer classroom as a prototype of a virtual situation. Students in real needed to complete the learning tasks in sequence according to the task list of the given system. In this stage, students can use hand-held sensing devices to pick up various 3D virtualized electronic components to perform component pairing operations, such as Raspberry Pi, resistors, Dupont wires, LED, mice and related sensors. If students encounter problems, they can click on the system hint to obtain the name and function instruction of electronic components.

The virtual reality system developed in this study can provide students with a lot of trial and practice so that students did not need to worry about component damage when encountering errors in the pairing process. In addition, the system enabled students to observe the structure of electronic components more easily through the visualization feature, to help the students to further understand the function of each specified component. Therefore, students can not only understand the pairing method of electronic circuits and the knowledge of related components through the virtual reality system, but also even more various complex components and easily understand the structure.

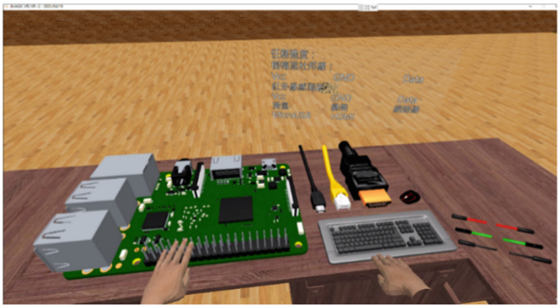


Fig. 1. Virtual reality system for electronic circuit learning.

3.3 Experimental Process

Figure 2 has showed the experimental process. In this study, 20 students were recruited to implement a three-hour STEAM learning activity. The experimental group has used immersive virtual reality to conduct STEAM learning activities and the control group used PowerPoint to conduct STEAM learning activities. Just before the activity, teacher has clearly introduced the materials and tools of the activity to all students present there, additionally the entire students took a pre-test to measure the prior knowledge and concepts they have learned in electronic circuits. Students in the experimental group needed to learn the names and concepts of various electronic components through the virtual reality system and operated the pairing of electronic components in the virtual environment through sensors; students in the control group spontaneously learned the names and concepts of various electronic components through PowerPoint. Finally, the researchers distributed post-test and cognitive load questionnaires to measure the difference between their learning performance and cognitive load using different learning tools.

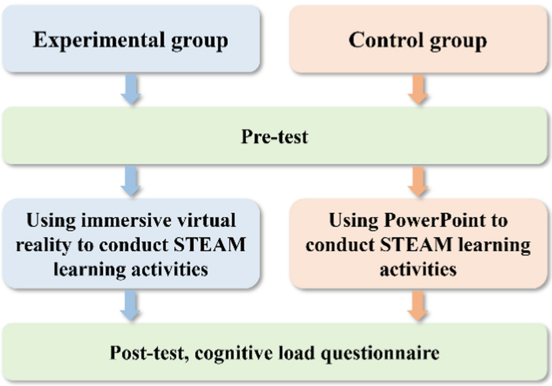


Fig. 2. The experimental process of this study.

3.4 Data Collection and Analysis

The researchers have been designed with a pre-test and post-test based on the electronic circuit learning, including 12 multiple-choice questions, with a complete score of 100 points and collected the results of 20 students before and after the STEAM activity.

In addition to this, the study referred to the cognitive load questionnaire which was proposed by Hwang, Yang and Wang [33] and edited the questionnaire according to the content of the STEAM learning activity, so that it will be definitely suitable for investigating the differences in cognitive load between the two different groups after conducting the experimental activities. The cognitive load questionnaire is basically consisted of 8 items and included two dimensions, 5 items of mental load and 3 items of mental effort. The questionnaire used a 5-point Likert scale, with scales of strongly disagree (1), disagree (2), moderate (3), agree (4) and strongly agree (5).

In this study, a Mann-Whitney U test was used to analyze the pre-test, post-test, and cognitive load questionnaires of 20 students and to explore if there was any significant difference in learning performance and cognitive load of the two groups of students. In addition, this study used Cronbach's alpha to examine the internal consistency of the cognitive load questionnaire, which has a Cronbach's alpha of 0.875, which indicated that the cognitive load questionnaire has good reliability in terms of statistical power.

4 Results

In order to effectively explore the difference between the learning performance of immersive virtual reality and conventional lectures in electronic circuit learning, this study used several Mann-Whitney U test to analyze the learning performance of two groups using different tools. The Mann-Whitney U test results of the pre-test showed that the mean rank of the experimental group was 11.25; the mean rank of the control group was 9.75, and the U value was 42.5 ($p > 0.05$). This result has eventually indicated that, there were no more significant difference found between the two groups in the prior knowledge of electronic circuit learning.

Table 1 showed the Mann-Whitney U test results of the post-test. The mean rank of the experimental group was 15.2; the mean rank of the control group was 5.8 and the U value was 3 ($p < 0.001$), a significant difference was reached between the two groups. This has progressively showed that the learning performance of the experimental group using immersive virtual reality for electronic circuit learning was significantly higher than that of the control group using PowerPoint for electronic circuit learning.

Additionally, Table 2 showed the Mann-Whitney U test results for the cognitive load. The mean rank of the experimental group was 7.6; the mean rank of the control group was 13.4, the U value was 21 ($p < 0.05$), a significant difference was reached between the two groups. Table 3 showed the Mann-Whitney U test results for mental load and mental effort. In terms of mental load, the mean rank of the experimental group was 7.4; the mean rank of the control group was 13.6, the U value was 19 ($p < 0.05$); in terms of mental effort, the mean rank of the experimental group was 8; the mean rank of the control group was 13, the U value was 25. According to these results, the experimental group can significantly decrease the cognitive load of electronic circuit learning through immersive virtual reality, and the experimental group would not produce excessive mental load and mental effort when using the system to practice and operate.

Table 1. The Mann-Whitney *U* test of post-test.

Group	Mean rank	Sun of ranks	*U*	*Z*	*p*
Experimental group	15.2	152	3	−3.598	0.000***
Control group	5.8	58			

*** $p < 0.001$.

Table 2. The Mann-Whitney *U* test of cognitive load.

Group	Mean rank	Sun of ranks	*U*	*Z*	*p*
Experimental group	7.6	76	21	−2.200	0.028*
Control group	13.4	134			

* $p < 0.05$.

Table 3. The Mann-Whitney *U* test of mental load and mental effort.

Dimension	Group	Mean rank	Sun of ranks	*U*	*Z*	*p*
Mental load	Experimental group	7.4	74	19	−2.358	0.018*
	Control group	13.6	136			
Mental effort	Experimental group	8	80	25	−1.926	0.054
	Control group	13	130			

* $p < 0.05$.

5 Conclusion

This study has developed a virtual reality system to actually provide the students with the knowledge and concepts of electronic circuit learning in a virtual environment. Additionally, this study has allowed students to practice and try out with each component pairing in a virtual environment through immersive virtual reality devices and hand-held sensing devices. According to the results compared with the control group, the experimental group using the virtual reality system for STEAM learning activities can significantly improve the learning performance. This means that, the students can pick up different 3D visualization components with hand-held sensing devices to quickly understand the features. Additionally, in terms of cognitive load, the use of virtual reality system in the experimental group was also significantly lower than that in the control group using PowerPoint. This means that the materials presented through a highly realistic virtual learning environment can not only be present complex concepts, but also the system guides students to gradually complete the practice of component pairing. Therefore, even if the experimental group did not have any experience in using virtual reality before the activity, they can quickly complete the task of electronic circuit learning through the virtual reality system developed in this study.

References

1. Boulton, C.A., Kent, C., Williams, H.T.: Virtual learning environment engagement and learning outcomes at a 'bricks-and-mortar' university. Comput. Educ. **126**, 129–142 (2018)
2. Lin, H.-C.K., Lin, Y.-H., Wang, T.-H., Su, L.-K., Huang, Y.-M.: Effects of incorporating augmented reality into a board game for high school students' learning motivation and acceptance in health education. Sustainability **13**, 3333 (2021)
3. Huang, Y.-M., Cheng, Y.-P., Cheng, S.-C., Chen, Y.-Y.: Exploring the correlation between attention and cognitive load through association rule mining by using a brainwave sensing headband. IEEE Access **8**, 38880–38891 (2020)
4. Huang, Y.-M., Silitonga, L.M., Murti, A.T., Wu, T.-T.: Learner engagement in a business simulation game: impact on higher-order thinking skills. J. Educ. Comput. Res. 07356331221106918 (2022)
5. Cheng, Y.-P., Cheng, S.-C., Huang, Y.-M.: An internet articles retrieval agent combined with dynamic associative concept maps to implement online learning in an artificial intelligence course. Int. Rev. Res. Open Distrib. Learn. **23**, 63–81 (2022)
6. Huang, Y.-M., Silitonga, L.M., Wu, T.-T.: Applying a business simulation game in a flipped classroom to enhance engagement, learning achievement, and higher-order thinking skills. Comput. Educ. **183**, 104494 (2022)
7. Ozkan, G., Topsakal, U.U.: Examining students' opinions about STEAM activities. J. Educ. Train. Stud. **5**, 115–123 (2017)
8. Huang, Y.-M., Cheng, A.-Y., Wu, T.-T.: Analysis of learning behavior of human posture recognition in maker education. Front. Psychol. **13** (2022)
9. Chien, Y.-H.: Developing a pre-engineering curriculum for 3D printing skills for high school technology education. Eurasia J. Math. Sci. Technol. Educ. **13**, 2941–2958 (2017)
10. Schelly, C., Anzalone, G., Wijnen, B., Pearce, J.M.: Open-source 3-D printing technologies for education: Bringing additive manufacturing to the classroom. J. Vis. Lang. Comput. **28**, 226–237 (2015)
11. Chang, S.-C., Hsu, T.-C., Chen, Y.-N., Jong, M.S.-Y.: The effects of spherical video-based virtual reality implementation on students' natural science learning effectiveness. Interact. Learn. Environ. **28**, 915–929 (2020)
12. Hite, R., et al.: Investigating potential relationships between adolescents' cognitive development and perceptions of presence in 3-D, haptic-enabled, virtual reality science instruction. J. Sci. Educ. Technol. **28**, 265–284 (2019)
13. Passig, D., Tzuriel, D., Eshel-Kedmi, G.: Improving children's cognitive modifiability by dynamic assessment in 3D immersive virtual reality environments. Comput. Educ. **95**, 296–308 (2016)
14. Hsiao, H.S., Chen, J.C., Lin, C.Y., Zhuo, P.W., Lin, K.Y.: Using 3D printing technology with experiential learning strategies to improve preengineering students' comprehension of abstract scientific concepts and hands-on ability. J. Comput. Assist. Learn. **35**, 178–187 (2019)
15. Frederiksen, J.G., et al.: Cognitive load and performance in immersive virtual reality versus conventional virtual reality simulation training of laparoscopic surgery: a randomized trial. Surg. Endosc. **34**(3), 1244–1252 (2019). https://doi.org/10.1007/s00464-019-06887-8

16. Lee, E.A.-L., Wong, K.W.: Learning with desktop virtual reality: Low spatial ability learners are more positively affected. Comput. Educ. **79**, 49–58 (2014)
17. Shadiev, R., Wang, X., Huang, Y.-M.: Cross-cultural learning in virtual reality environment: facilitating cross-cultural understanding, trait emotional intelligence, and sense of presence. Educ. Tech. Res. Dev. **69**(5), 2917–2936 (2021). https://doi.org/10.1007/s11423-021-10044-1
18. Steuer, J.: Defining virtual reality: dimensions determining telepresence. J. Commun. **42**, 73–93 (1992)
19. Sherman, W.R., Craig, A.B.: Understanding Virtual Reality: Interface, Application, and Design. Morgan Kaufmann, Burlington (2018)
20. Gazit, E., Yair, Y., Chen, D.: The gain and pain in taking the pilot seat: learning dynamics in a non immersive virtual solar system. Virtual Reality **10**, 271–282 (2006)
21. Huber, T., Wunderling, T., Paschold, M., Lang, H., Kneist, W., Hansen, C.: Highly immersive virtual reality laparoscopy simulation: development and future aspects. Int. J. Comput. Assist. Radiol. Surg. **13**(2), 281–290 (2017). https://doi.org/10.1007/s11548-017-1686-2
22. Wang, P., Wu, P., Wang, J., Chi, H.-L., Wang, X.: A critical review of the use of virtual reality in construction engineering education and training. Int. J. Environ. Res. Public Health **15**, 1204 (2018)
23. Jensen, L., Konradsen, F.: A review of the use of virtual reality head-mounted displays in education and training. Educ. Inf. Technol. **23**(4), 1515–1529 (2017). https://doi.org/10.1007/s10639-017-9676-0
24. Bybee, R.W.: What is STEM Education?, vol. 329, p. 996. American Association for the Advancement of Science (2010)
25. English, L.D.: STEM education K-12: perspectives on integration. Int. J. STEM Educ. **3**, 1–8 (2016)
26. Arís, N., Orcos, L.: Educational robotics in the stage of secondary education: empirical study on motivation and STEM skills. Educ. Sci. **9**, 73 (2019)
27. Hu, C.-C., Yeh, H.-C., Chen, N.-S.: Enhancing STEM competence by making electronic musical pencil for non-engineering students. Comput. Educ. **150**, 103840 (2020)
28. Zahidi, A.M., Ong, S., Yusof, R., Kanapathy, S., Ismail, M.J., You, H.W.: Effect of science camp for enhancing STEM skills of gifted young scientists. J. Educ. Gifted Young Scientists **9**, 15–26 (2021)
29. Yakman, G.: What is the point of STE@ M?–A brief overview. Steam Framework Teach. Across Disciplines. STEAM Educ. **7** (2010)
30. Dejarnette, N.K.: Implementing STEAM in the early childhood classroom. Eur. J. STEM Educ. **3**, 18 (2018)
31. Shatunova, O., Anisimova, T., Sabirova, F., Kalimullina, O.: STEAM as an innovative educational technology. J. Soc. Stud. Educ. Res. **10**, 131–144 (2019)
32. Hsiao, P.-W., Su, C.-H.: A study on the impact of STEAM education for sustainable development courses and its effects on student motivation and learning. Sustainability **13**, 3772 (2021)
33. Hwang, G.-J., Yang, L.-H., Wang, S.-Y.: A concept map-embedded educational computer game for improving students' learning performance in natural science courses. Comput. Educ. **69**, 121–130 (2013)

Visual Reality as a Reinforcement for Entry-Level Therapist to Do the Speech Language Pathology Inquire

Yingling Chen[1], Chinlun Lai[2], and Yu Shu[3](✉)

[1] Center for General Education, Asia Eastern University of Science and Technology, New Taipei City, Taiwan
cil0226@mail.aeust.edu.tw

[2] Department of Communication Engineering, Asia Eastern University of Science and Technology, New Taipei City, Taiwan
fo001@mail.aeust.edu.tw

[3] College of Languages, National Taichung University of Science and Technology, Taichung, Taiwan
verashu@gm.nutc.edu.tw

Abstract. According to the 2019 statistics, more than 580,000 people have sought medical treatment for cerebrovascular disease, and "stroke" has always ranked fourth among the top ten causes of death. The shortage of the language therapists becomes an issue to stroke patients. Yet there are relatively few studies suggesting ways on how language teachers cooperate with entry-level therapist to do the speech language pathology inquiry by implementing virtual reality technology. The purpose of this qualitative research is to identify whether the integration of VR helped increasing the inquiring ability for less experienced language therapist. The procedure of the inquiry is recorded in order to provide and identify accurate practical training. The prototype is revealed. Based on this technology, professionals are able to develop the level of competence for medical treatment and determine any improved performance on the patients. Virtual reality simulation is allowing the intern language therapist to learn skills that prepare them for the real world. Two female and one male intern language therapists were participated in the research. The results indicated that technology support creates more opportunities to build confidence and competence for entry-level professionals. However, some difficulties and challenges in the application of VR in the medical field were also exposed.

Keywords: Cerebrovascular disease · Stroke · Virtual reality · Speech language pathology · Therapist · Inquire

1 Introduction

Visual Reality technology has surrounded the environments and played an important role in the daily lifestyles. Virtual Reality technology has become a part of the civilization in

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 117–124, 2022.
https://doi.org/10.1007/978-3-031-15273-3_13

enhancing better education and quality life [1]. Incorporating existing technologies and techniques such as Visual Reality as treatment and instructional support is an inevitable movement worldwide. According to the 2019 statistics, more than 580,000 people have sought medical treatment for cerebrovascular disease and stroke. The way of effectively reducing long-term disability is to strengthen the patient's activeness after a stroke. A language therapist plays a critical role in helping the patient to rehabilitate after the stroke attack.

VR has been widely used in medical education, clinical skills training, clinical applications, anatomy and physiology teaching, customized VR learning material development, drug development, wound management, rehabilitation, and other practical applications. VR technology support can actually help students to learn, teachers to teach, medical staff to train and communicate. VR significantly improves learning and working effectiveness and medical quality. This system provides somatosensory feedback which assists or train entry-level therapist to do the speech language pathology inquiry and to communicate with patients. VR technology generates a three-dimensional visual virtual world in which enables users to simulate, immerse, and interact with 3D imagery and sound [2].

Speech Therapy is based on the needs of individual patient. Stroke, brain injury, degenerative diseases, head and neck surgery, cleft lip, hearing loss, developmental delay patients need rehabilitation. Patients normally receive the training or treatment from the therapists' designed activities. They also do oral exercise to improve their communication skills, solve the difficulties and improve the quality of life. The treatments normally include individual therapy or small group therapy. Speech therapists design and implement treatment plans according to different needs, achieve the set goals through patients' background and symptoms. Instruments, teaching aids, health education and counseling are often provided to patients, family members, and caregivers. Medical situations can be simulated by implementing VR. The provided practical training followed by feedback and debriefing, the system allows entry-level therapist to do the speech language pathology inquiry and learn from their mistakes.

The compact of VR systems and the fact that faculty are not required to be present make the access of the practical training more flexible and broad-based [3]. The effect of the speech therapy is not immediate but requires the cooperation from patients and therapists, and the support of family members and caregivers. Sometimes, the cooperation with other professionals such as physicians, physical therapists, occupational therapists, nurses, and social workers are suggested in order to achieve optimum treatment outcome.

According to the Common Health Magazine, there are 6 key points for caregivers to consider when assisting a patient with motor speech disorder:

1. Have Conversation and communication with patients in a quiet environment.
2. Avoid lengthy, complex and compulsive conversational patterns.
3. Remind patients to express in simple sentences, even with images, gestures, expressions, and writing.
4. Be patient and give ample time for conversations, or guess what the patient means or simple prompts.
5. Avoid correcting and asking patients, try to encourage and guide them positively.

6. Severe patients do not need to insist on oral communication, but can try phonetic symbols, pictures, communication books, computer typing, etc. to assist patients in communication.

Motor speech disorder is mainly due to the damage of the central or peripheral nervous system by having stroke, brain injury, disease, or brain tumor, resulting in dysregulation of speech muscle control. Patients need the treatment or cure for the problems of vocalization, resonance, articulation, and rhythm control in order to develop speech intelligibility [4]. In addition, VR has also gradually integrated in the field of medical care, medical nursing education and training, surgical simulation, and rehabilitation. Meanwhile VR effectively improve the training usefulness of medical staff and the quality of care [5]. Language instructor cooperates with language therapist and patients under speech language pathology treatment can be a new intervention especially for training entry-level medical staff to achieve optimum treatment outcome. Stroke patients normally face difficulties in moving, thinking, and perceiving in the daily living, such as the ability to write, walk, and drive. Virtual reality with interactive treatment provides a new type of rehabilitation for stroke patients. This therapy involves the use of computer programs to simulate real-life objects and events. Virtual reality and interactive activities may offer additional advantages over traditional treatment modalities and stimulate more motivation, such as giving patients the opportunity to perform training in activities of daily living.

In the virtual environment, all the features of activity such as duration, severity and type of feedback can be adopted based on the type of treatment and individuals' ability [6]. As a result, individuals can see their motor results and correct them by themselves or by the medical staff if necessary after using this VR system. Therefore, the purpose of this study was to pinpoint whether the integration of VR helped entry-level therapist to help the patients and do the speech language pathology inquiry. Applying VR technique develop a new training platform to help language entry-level language therapy acquire inquire skills without time and environment limit. Therefore, target-based treatment with VR support is considered and implanted by the researcher and language therapist in order to minimize the gap between the practical training and reality. VR into the language treatment where applications offer a great deal of promise, especially in education and training [7]. The tremendous impact of a wide range of VR technology on language treatment is unmeasurable, but patients' improvement is valuable.

2 The Research Methodology

When medical intervention is driven by VR technology, it is necessary to pay attention to its additional impact on patients. At the same time, it is necessary to understand that the intervention of VR support is based on the preventive health education and experiential health education. Virtual reality is an artificial environment presented by software and images, allowing users to believe and accept that they are in a real environment. In other words, VR is the use of goggles and two screens for imaging, using the perspective of both eyes to create a three-dimensional effect, and the sound effects created with headphones, so that users can isolate themselves from the outside world when using the technology goggles, as if they are in another world and so-called immersion.

Virtual reality provides 3D objects to users with an immersive virtual space. The virtual objects, sound, and images interact with the users in real-time and allows users to be fully integrated into a controlled, risk-free environment [9]. The VR environment is a simulation tool, which provides a safe learning environment, and the advantage of VR is that it eliminates external interference, allow users to devote themselves to learning, and the implementation of the teaching plan can be adjusted according to the level of different personalized learning progress. The design and implementation of the VR system prototype and some operation procedures are shown in Fig. 1.

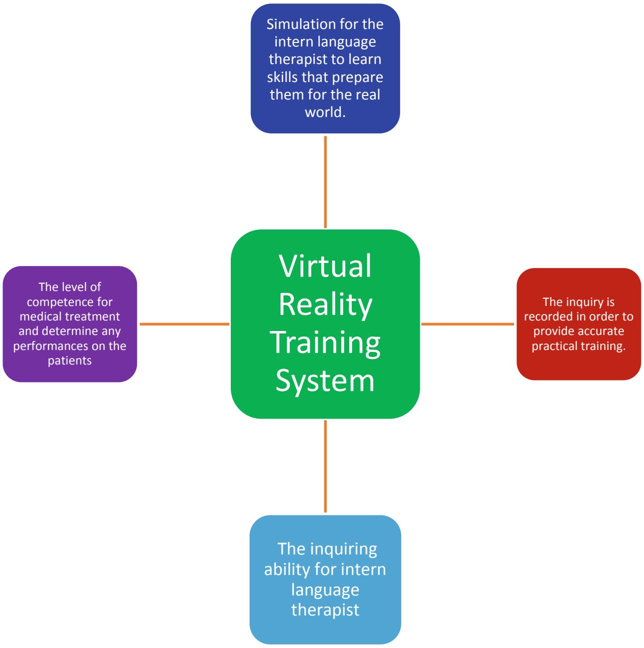


Fig. 1. The structure of the proposed VR system

This prototype instructs, identifies, increases, and improves the clinical experience of intern language therapist. It is divided into four stages, the first and second stage were designed to collect patient's personal information. It is designed to evaluate patients' basic oral ability. The third part is to assign the patient to do the picture matching. It is aimed to discover patient's understanding ability. The final stage is to evaluate patient's listening comprehension. From the VR Simulation, it instructs the intern language therapist to learn skills that prepare them for the real world. The inquiry is identified and recorded in order to provide an accurate practical training. The system is designed to increase the inquiring ability for intern language therapist. This VR system improves the level of competence for medical treatment and determine performances on the patients. An on-the-spot survey was carried out and then the VR simulation was constructed with inquire process and visual aid support. VR simulation training was designed to meet the needs of interns.

2.1 Design of the Display Platform

This VR inquire training system was constructed to achieve the goal of high immersive experience while keeping the hardware and software cost low and efficient. Unity was applied to present a 2D and 3D activity engine that can develop cross-platform simulation [10]. In addition to developing video games, VR kit was implemented to make the effect, which allows the software in Unity to link with HTC's VR glasses to make 3D objects virtual reality. Also, MAYA was applied to construct models, such as tasks, visual aids, and covers to rich and reach the training system. The training sequence can be formulated by the therapist; they are able to practice repeatedly in their free time for achieving better training results. The illustrations of the VR system prototype and some operation illustrations are shown in Fig. 2.

(a) An on-the-spot survey (b) Flash card support (c) Scenario and inquiring training

Fig. 2. VR speech language pathology inquire training for entry-level therapist

2.2 Research Data Collection

The purpose of this qualitative study was to investigate the effectiveness of VR application on entry-level therapist to do the speech language pathology inquiry. Qualitative interview is one of the most widely used data collection methods in social science research. It mainly focuses on the interviewee's personal feelings and experience statement. Understand and explain respondents' personal perceptions of social facts. Hence, the use of semi-structure interview technique was applied to be the main method of research data. The data was obtained through adapted and modified open-ended questions. 1 male and 2 female participants who received less than 6 months training were selected. 3 entry-level therapists used VR system to practice the inquire procedure 3 times a week for 2 months. They were asked to reflect and identify whether the integration of VR helped increasing their language therapy inquiring ability. Individual and group interviews were conducted for 1 months in order to identify the usefulness of the training system. Transferability and dependability are the keys to credibility. Credibility is the counterpart of internal validity [11]. Validity refers to whether the measurement tool used by the researcher which can really measure the problem that the researcher wants to investigate [12]. Therefore, the researcher must be cautious on how participants interact and react to each interview questions, it influences the analysis of the data [13]. Furthermore, the researcher consulted one experienced language therapist to ensure all the open-ended questions covered the research scope.

3 Experimental Results and Discussions

3.1 Qualitative Data

Research Question 1. How does VR training system help entry level language therapist increase the inquiring ability?

Virtual reality has become a new trend in the rapid development of science and technology. At first, the commercial application of VR focused on game design and the film industry, and later it was also well introduced in medical education. With the VR support, intern language therapists were able to be skilled with the speech language pathology inquire for the real world.

"The integration of VR and language therapy is an innovative implementation in my professional career. Virtual reality is an artificial environment presented by software and images, allowing me to believe and accept that I am in a real environment. This system is a simulation support, it provides a safe training atmosphere, and the advantage of VR is that it can eliminate external interference, allowing less experienced language therapists to devote themselves to practice, and the implementation of the training procedure can be adjusted according to the progress of the users, which can be regarded as a personalized learning tool." (April, Female Therapist 1).

Regarding VR facilitates entry-level therapist to do the speech language pathology Inquire. Language therapist expressed that training should be connected to their professional background. Tasks should be prioritized according to practical relevance.

"VR offers me an efficient task training mode. It allows me to learn how to follow the procedure, to locate, perform treatment, complete missions and techniques and collect information. I can complete my own training in a virtual environment, from watching demonstrations to final self-operation assessments on the system." (April, Female Therapist 2).

"VR in the clinical field allows users interact with the situation from a first-person perspective. Immersion in the environment helps build professionalism, and during the COVID-19 pandemic, reducing human contact is also a clinical trainee solution." (April, Female Therapist 2).

"If the stroke patient has aphasia, he or she will need the assistance from a speech therapist, I need to help him reestablish the communication skill and provide emotional support. I will be frustrated if I suddenly can't fully express my thoughts and feelings due to stroke attack. Therefore, be very familiar with the inquire protocol is critical. Most of the time, stroke patient will not receive the treatment alone. They are always companied by the caregivers. Sometimes, the caregiver interrupts the treatment and answer the questions for the stroke patient. I will need to repeat or demo the task again. Therefore, be proficient of the procedure is helpful." (April, Male Therapist 3).

Research Question 2. How does the VR training system function to you?

With the support of VR technology, medical personnel can be placed in virtual reality, they no longer need to consider the limitations of consumables, they can practice repeatedly according to their learning needs to improve their inquire skills!

"In the traditional clinical situation, speech therapists need to practice from patients to improve their experience! Patients and their families have to endure the unskilled skills of the interns. The construction of VR clinical technology simulation with VR virtual reality as the main technical application trains the interns and reduce the pain from patients!" (April, Male Therapist 3).

"Quantitative objective data such as the skill training time at each stage, and after the event, it can be reviewed and improved through multi-angle playback is helpful to my personal development." (April, Male Therapist 3).

"Whether it is a stroke patient who needs rehabilitation or cognitive training, Patients can cooperate with the language therapist to carry out a rehabilitation method that suitable for their own level. The difficulty level can be set, and data such as the frequency of use and performance of the patients can be recorded, which is great and helpful to the progress and effectiveness of rehabilitation." (April, Female Therapist 1).

Disadvantages of VR, users may experience discomfort similar to motion sickness. In addition, the current high cost of VR hardware, VR headset and system development challenge to popularize application and large-scale of implementation. Tech. Technology maintenance is also one of the keys to function VR training system well.

"The advantage of VR system is that it can create an infinite world, infinite vision, but the disadvantage is that it is virtual, that is, the lack of realism, and the visual effect can only approximate the real, but cannot replace the real. I can improve the inquire protocol. The interaction with the patient and the response from the patients may not be the same." (April, Female Therapist 2).

"Patients with motor speech disorders need to develop individualize lan-gauge training, combined with drug therapy and surgery if necessary. For patients with mild and moderate motor speech disorder, speech therapy inquire VR training can effectively improve their speaking situation; but for patients with severe motor speech disorder, it is necessary to further follow the individual's ability and cooperate with non-verbal communication strategies to promote their functional communication skills. Unfortunately, VR training system could only provide basic support" (April, Female Therapist 2).

"The input method of VR and the communication interface of the training system are relatively unfamiliar new technologies, so it causes practical problems. To be honest with you, if you are not here, I will not be able to use this training system to practice the inquire procedure. It's really a serious barrier to adoption. VR is a convenient and educated technology, and the hospital officials must understand that it needs be a long-term investment and will require considerable support" (April, Male Therapist 3).

4 Conclusions

Based on this VR training system technology support, "practice makes perfect." Professionals of various medical backgrounds can develop the level of competence for medical treatment and determine any improved performance on the patients. However, due to the number of minor entry-level therapists in a hospital, the limitation of this study was the small sample size. Carry out this project in few different hospitals can be the future research goal in order to collect a larger sample size. VR faces many challenges and needs more supporting data, so that medical technology can bring innovation and progress to human health. There are still many difficulties and challenges in the application of VR in the medical field. On the hardware, the volume and weight of VR glasses may reduce the user's sense of reality. Therapeutic training for VR is also an issue, speech therapists, abdominal therapists and physicians do not have the skill of implementing VR technology, track and give VR treatment can also be challenged. The technology is lacking in convenience and practicability, and the cost of system construction is quite high, so therapists cannot use this technology without assistance in the actual diagnosis and treatment process. Meanwhile, it is expected that the price of VR hardware will be more reasonable to the public, and if the mobile version of VR software development can be more proficient, the emerging training or teaching will be more popular. Allowing users to take the advantages of VR technology will bring a big change to not only the medical field but wildly extensive use.

References

1. Chen, Y.L.: Students' attitude toward learning and practicing English in a VR environment. In: Huang, T.-C., Wu, T.-T., Barroso, J., Sandnes, F.E., Martins, P., Huang, Y.-M. (eds.) ICITL 2020. LNCS, vol. 12555, pp. 128–136. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-63885-6_15
2. Motomatsu, H.: Virtual reality in the medical field. UC Merced Undergraduate Res. J. **7**(1) (2014). https://doi.org/10.5070/M471025003, https://escholarship.org/uc/item/0bs5p31h
3. Pottle, J.: Virtual reality and the transformation of medical education. Future Healthc. J. (2019). https://doi.org/10.7861/fhj.20190036, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6798020/
4. Brady, M.C., et al.: Speech and language therapy for aphasia following stroke. Cochrane Database Syst. Rev. **6**, CD000425 (2016)
5. You, S.H., Jang, S.H., Kim, Y.H., Kwon, Y.H., Barrow, I., Hallett, M.: Cortical reorganization induced by virtual reality therapy in a child with hemi paretic cerebral palsy. Dev. Med. Child. Neurol. **47**, 628–635 (2005)
6. Rizzo, A., Kim, G.J.: SWOT analysis of the field of virtual reality rehabilitation and therapy. Presence **14**, 119–146 (2005)
7. Yong. J.Q. The rehabilitation treatment of stroke (2020). http://web.csh.org.tw/web/cshmagazine/?p=710
8. Milgram, P., Kishino, F.: A taxonomy of mixed reality visual displays. In: IEICE Transactions on Information and Systems, pp. 1321–1329 (1994). Accessed 10 May 2022
9. Li, L., et al.: Am. J. Transl. Res. **9**(9), 3867–3880 (2017)
10. Chen, Y.: Augmented reality technique assists target language learning. In: Rønningsbakk, L., Wu, T.-T., Sandnes, F.E., Huang, Y.-M. (eds.) ICITL 2019. LNCS, vol. 11937, pp. 558–567. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-35343-8_59
11. Creswell, J.W., Clark, V.L.P.: Designing and Conducting Mixed Methods Research. Sage Publications, Thousand Oaks (2011)
12. Hee, O.C.: Validity and reliability of the customer-oriented behaviour scale in the health tourism hospitals in Malaysia. Int. J. Caring Sci. **7**(3), 771–775 (2014)
13. Fischer, E., Guzel, G.T.: The case for qualitative research (2022). https://doi.org/10.1002/jcpy.1300

Development of Web-Based Learning with Augmented Reality (AR) to Promote Analytical Thinking on Computational Thinking for High School

Chayaphorn Thabvithorn[1] and Charuni Samat[2](✉)

[1] Educational in Science and Technology, Faculty of Education, Khon Kaen University, Khon Kaen, Thailand
[2] Computer Education, Faculty of Education, Khon Kaen University, Khon Kaen, Thailand
scharu@kku.ac.th

Abstract. The objectives of this research were 1) to development of web-based learning with augmented reality (AR) to promote analytical thinking on computational thinking for high school. 2) to study the analytical thinking of the students who learned through development of web-based learning with augmented reality (AR) to promote analytical thinking on computational thinking for high school. These aims were used for students in grade 4 The target for this study were 35 students in grade 4/2 who studying in the subject of Technology (Computational Science) in the first semester in 2021 at Khon Kaen University Demonstration School, Secondary Department. (Education) The tools which used for data collection consisted of 1) an analytical thinking measure, 2) an achievement test and 3) a satisfaction questionnaire. The results of research found that; 1.The result of students who study the development of web-based learning with augmented reality (AR) to promote analytical thinking on computational thinking for high school, Secondary Department. (Education) There are 6 important elements in creating and development, namely 1) problem situations, 2) learning resources, 3) exchanging knowledge, 4) analytical thinking center, 5) supporting base and 6) advice center. 2. The result of students who study the development of web-based learning with augmented reality (AR) to promote analytical thinking on computational thinking for high school, Secondary Department (Education). The mean score was 29.43, representing 98.1%, which was higher than the specified threshold of 70% of the full score, divided into different aspects of the analysis as follows: The analysis had an average score of 5.71 or 95%, the relationship analysis had an average score of 7.86 and an average of 98.3%, and the principle analysis had an average score of 15.57, representing 86.5%.

Keywords: Analytical thinking · Augmented reality · Web-based learning

1 Introduction

At present, the world has new changing in the era of globalization which is driven by the rapid progress due to the advances in information technology and communication affects

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 125–133, 2022.
https://doi.org/10.1007/978-3-031-15273-3_14

the awakening of the revolution in terms of society, culture, economy, politics, science, technology and including reform and change in teaching and learning management as well as preparing in various fields that are supporting factors that will lead to learning the advancement of technology [1]. Since the outbreak of the coronavirus 19 has greatly affected teaching and learning. Online teaching is therefore being used instead of traditional teaching and learning and tend to use online tutoring more and longer. Information technology is therefore an important variable that plays a role in teaching and learning to make teaching and learning more effective.

An important method that can develop learners to have characteristics that respond to change in society. As mentioned above is the application of augmented reality technology which is a technology that combine the real world into the virtual world through a webcam device, mobile phone camera or computer with using of various software that will make the image seen on the screen to be objects such as people, animals, things in a 3D which has a 360-degree view. At present, the world has new changing in the era of globalization which is driven by the rapid progress due to the advances in information technology and communication affects the awakening of the revolution in terms of society, culture, economy, politics, science, technology and including reform and change in teaching and learning management as well as preparing in various fields that are supporting factors that will lead to learning the advancement of technology [1, 2]. Since the outbreak of the coronavirus 19 has greatly affected teaching and learning. Online teaching is therefore being used instead of traditional teaching and learning and tend to use online tutoring more and longer. Information technology is therefore an important variable that plays a role in teaching and learning to make teaching and learning more effective [2].

The researchers are interested in conducting research on "Development of web-based learning with augmented reality (AR) to promote analytical thinking on computational thinking for high school" to help learners see clearly in the form of a three-dimensional model such reasons above which can understand the body of knowledge more easily. The results of this study can be used as a guideline to promote and continue to support effective learning management. Bringing lessons on the network with augmented reality technology to support analytical thinking on computational concepts for students in grade 4 as a teaching material will increase interest in learning, resulting in reinforcement to encourage analytical thinking [3, 4].

2 Research Objectives

1. To develop of web-based learning with augmented reality (AR) to promote analytical thinking on computational thinking for high school.
2. To study the analytical thinking of learners who learned through development of web-based learning with augmented reality (AR) to promote analytical thinking on computational thinking for high school.

3 Research Scope

This research is development research according to Richey and Klein (2007), this study is a type of development research that concentrates on the design and development process. Its goal is to develop of web-based learning with augmented reality (AR) to promote analytical thinking on computational thinking for high school. This includes document research, a study of the educational context, and learning management in this design and development process. Combining design ideas to increase quality.

4 Research Method

Development of web-based learning with augmented reality (AR) to promote analytical thinking on computational thinking for high school. in this research study. Based on the development by applying the concept of Richey & Klein (2007) [4]. which consists of 3 process;

1. Design Process
2. Development Process
3. Evaluation Process

4.1 Target Group

The target group used in this study were grade 4/2 students studying in the course for 31181 Technology (Computational Science) in the first semester of the academic year 2021 at Khon Kaen University Demonstration School, Secondary (Education) for 35 students.

4.2 Researching Tools

1. Development of web-based learning with augmented reality (AR) to promote analytical thinking on computational thinking for high school.
2. Analytical Thinking measurement, built on the framework of Suwit Munkham (2005).

4.3 Collecting Data

1. Perform document analysis by studying and analyzing the guiding ideas and theories behind the creation of the learning environment model, which consists of the following pillars: To be used as the foundation for synthesizing the theoretical framework for the construction of learning environment on the network include psychological base, pedagogies base, problem-solving thinking, media, technologies base, and contextual base.

2. This research study was based on the principle that pertinent research and theories can be synthesized from the theoretical framework from the basic theory is as follows. Theoretical framework creates a conceptual framework based on study and analysis of theoretical principles, research, and variables [5]. Analytical Thinking Foundations (Suwit Munkham, 2005) The Foundations of Learning Psychology (Cognitive Constructivism, Social Constructivism, Information Processing), The Foundations of Media Theory (Media Symbol System), The Foundations of Technology (Web-based, Interactive), and The Foundations of Pedagogical Sciences. Contextual basis, cognitive apprenticeship, and constructivist learning environment.
3. Study the context of teaching and learning in the course of Wor31181 Technology (Computational Science), which consists of content analysis. The subjects used in the research were on the topic of problem solving and the study of learner contexts, results of the study, contexts related to teaching and learning in the course of Wor31181 Technology (Computational Science).
4. Synthesis of the design framework from the results of theoretical conceptual framework studies and context studies It can be used as a basis to synthesize a conceptual framework for web-based learning design, which will be the component of a web-based learning model [6]. Then use it to develop knowledge on the network and assess the effectiveness of web-based learning by bringing the web learning model to present to a consultant for review.
5. Bring the web-based learning on the network that have been evaluated by experts to be tested in real context.

4.4 Data Analysis and Statistics Used

1. Checking the quality of the format by experts in content, media, and measurement and evaluation. Data analysis was performed using interpretive summaries.
2. The student's analytical thinking as determined by the analytical thinking assessment of the student. Statistics like percentage, mean, and standard deviation were used to examine the data.

5 The Result of Research

Creating a theoretical conceptual framework, a conceptual framework based on the study and analysis, Research and related theories are able to synthesize the conceptual framework as follows (Fig. 1).

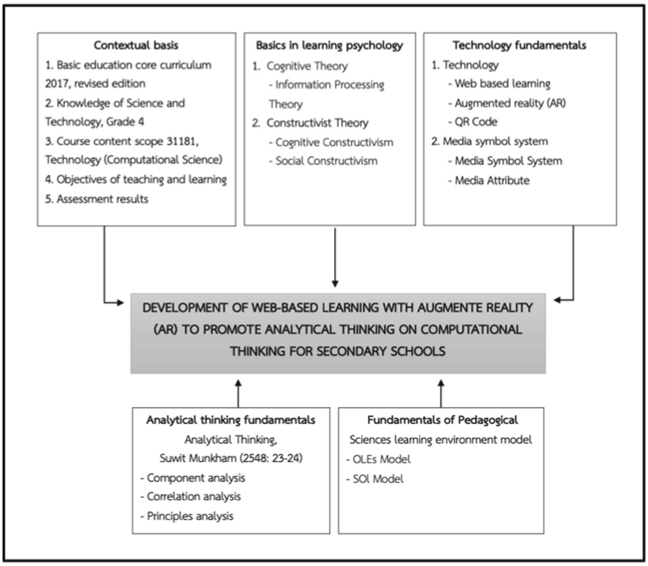


Fig. 1. Theoretical framework of the development of web-based learning with augmented reality (AR) to promote analytical thinking on computational thinking for high school.

5.1 Synthesize a Design Conceptual Framework.

The researcher has applied the theoretical framework as a guideline for the synthesis as a design conceptual framework based on theoretical principles which shows the details of the design conceptual framework in Fig. 2.

The researcher has brought a conceptual framework for developing lessons on the network with augmented reality technology that promotes analytical thinking on computational concepts (Fig. 2), each of them has details as follows.

(1) Problem based is designed to stimulate cognitive structures for learners to create knowledge in designing problem situations in this research. The principles of intellectual constructivism were introduced (Piaget, 1955) and taken as a basis with the principles of Situated Learning to design environment, it is used to design problem situations that are designed in authentic contexts learn to face in real life because it will help learners to link their knowledge to problem solving [7].

(2) Learning resources involved in creating knowledge which the researcher has carried out in the development process based on the technology and the symbolic system of the media. It is the unique features of technology and media symbol system in the process of developing learning resources which can display text, audio, still images, animations, videos and virtual reality technologies leading to learn that promotes learners' learning [7, 8].

(3) Collaboration is based on Lev Vygotsky's theory of social constructivism, which emphasizes social interaction in learning. It is another element that supports learners to share experiences with others to expand their perspectives, collaborative problem-solving encourages learners, teachers, and experts to discuss, express your opinions

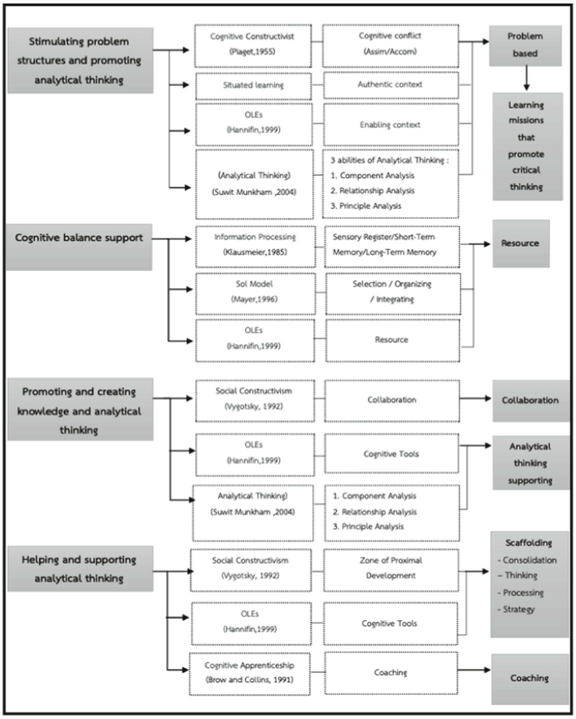


Fig. 2. Designing framework of development of web-based learning with augmented reality (AR) to promote analytical thinking on computational thinking for high school.

with others for designing collaborative solutions while creating knowledge. In addition, collaborating to solve problems is also an important part of change and prevent misunderstandings that will occur while learning as well as expanding the concept by using Facebook and Line as ways between learners and teachers for using in contacting questions or suggesting solutions to solve problems.

(4) Analytical Thinking Promotion Room is to promoting knowledge and analytical thinking through intellectual balance. Based on OLEs principles, the researcher has designed and developed to help supporting the learning process and the students analytical thinking as an intermediary to support, enhance or expand their thinking. Collaborative problem-solving is based on Lev Vygotsky's theory of social constructivism which emphasizes social interaction in learning. It is another element that supports learners to share experiences with others. In addition, collaborative problem-solving is also an important part of modifying and preventing misunderstandings that occur while learning and expanding ideas as well as the development of a room to promote analytical thinking to help encourage students' analytical thinking that consists of component analysis, correlation analysis principle analysis [9].

(5) Scaffolding is a supportive part of helping thinking that supports an individual's thought process. It guides the way of thinking between learning the thinking methods used to solve the problems under which to study and the possible strategies that should be considered helping [9, 10]. A process that recommends how to use it and resources and tools, strategic assistance that will assist learners in supporting their thinking analysis in which students consider how they can be applied to problem-solving situations and conceptual assistance that allows them to conceptualize the subject matter of the unit.

(6) This principle has become a constructivist approach to learning that has transformed the role of an instructor who transfers knowledge or imparts knowledge to a "coach", providing advice and guidance for learners as an exercise for learners by educating students in terms of providing intelligence which the researcher has designed and developed on the basis of technology and media symbol system [11].

6 Summary and Discussion

The result of developing of web-based learning with augmented reality (AR) to promote analytical thinking on computational thinking for high school.

Researcher designed and developed a networked lessons with augmented reality technology that promoted analytical thinking in Computational Concept for secondary school, grade 10. This research aim was based on development by applying the concept of Richey & Klein (2007), including Design Process which focused on designing and developing environment through augmented reality technology and conducted a study of theoretical principles, study and review related research to apply the acquired knowledge to create a theoretical framework. Development Process, the aforementioned design led to the developing a networked lessons with augmented reality technology that promoted analytical thinking by using a framework of design concept synthesis to develop to create lessons on the network with augmented reality technology. There were 6 components namely 1) Problem situations and learning tasks promote analytical thinking, 2) Learning resources was a source of information content that learners need to solve problems learning resource design, 3) Collaboration was based on the design principle that "The brain will develop very well when interacting with other brains", 4) The Analytical Thinking Room consists of 3 components as follows: (1) promoting component analysis, (2) promoting correlation analysis, (3) promoting analysis of principles. 5) Scaffolding will help to support leaners to problem solving or in order to they cannot success by themselves, including (1) Concept help base, (2) Thinking help base (3) Process help base (4) Strategic help base 6) Advice Center was the part where students can consult their doubts and solve problems from experts. Evaluation Process used an assessment model by applying from the assessment of the efficiency and development of the learning environment of Sumalee Chaicharoen (2004), which consists of 1) Productivity Assessment 2) Context Assessment 3) Satisfaction Assessment 4) Assessment of the students' analytical ability found that the content was accurate, clear, interesting, suitable, coverage the subject matter in the field of study which used to study and solve problems that correspond to the problem situation and learning mission. There were text, images, sounds, and colors are presented to help learners easily understanding and encouraging students to think analytical thinking and engaging in problem-solving. [10, 11]; The screen designing was attractive and appropriate that can be easily linked to other sources of knowledge or access to information. 2) Assessing the context used in real conditions from the analysis of using context, it was found that grouping of 4–5 learners per group was appropriate and help learners to learn quickly. 3) Assessment of learner satisfaction found that most of the students thought that learning was interesting then causing enthusiasm to learn on their own. 4) Assessment of the students' analytical thinking abilities found that most of the students had the ability to think analytically in all 3 components according to the conceptual framework of analytical thinking, (1) Component Analysis (2) Relationship Analysis (3) Principle Analysis.

The result of development of web-based learning with augmented reality (AR) to promote analytical thinking on computational thinking for high school.

The study of a networked lessons with augmented reality technology that promoted analytical thinking in Computational Concept obtained from the analytical thinking by using the framework of analytical thinking according to the concept of Suwit Munkham (2005: 23–24), the characteristics of analytical thinking were classified into 3 aspects, 1) component analysis, 2) correlation analysis, and 3) principle analysis. The results of this research were showed the analytical thinking test of the learners. The target group consisted of 35 students from a full score of 30. There were 35 students who received a score of 21 or higher, with a mean of 29.43 and a standard deviation of 0.74, or 98.1%, exceeding the threshold of 70% of the total score. It can be broken down into various analytical thinking facets as follows: The average score for component analysis was 5.71, or 95%, the average score for relationship analysis was 7.86, or 98.3%, and the average score for principle analysis was 15.57, or 86.5%.

This was due to the fact that learners have practiced in every step of the learning process by themselves and also have the opportunity to practice analytical thinking from the analysis of components, correlation analysis and analysis of principles to find answers and to exchange experiences and ideas enabling learners to be aware of new information, expanding the intellectual structure for learning. From the findings of the research in this study show that networked learning with augmented reality technology promotes analytical thinking on computational concepts which is a combination of principles, theories, basic technological features and media symbolism by design based on constructivist theory that focuses on knowledge creation helping to promote the knowledge creation of learners and problem situations promotes analytical thinking [10] including all elements of study development of web-based learning with augmented reality (AR) to promote analytical thinking on computational thinking for high school, that has brought the advantages of open learning environment (OLEs) to the development of learning environment enabling students to study and acquire knowledge as needed unlimited search for information to answer the mission of the problem situation and to support learning management in the 21st century, [10, 11] emphasizing on learning management by using technology to transfer knowledge to learners in order to develop quality learning management and achieve maximum efficiency for all learners which is consistent.

7 Suggestion

1. Should study development of web-based learning with augmented reality (AR) to promote analytical thinking on computational thinking for high school among learners in other ways by considering that model to be consistent and appropriate to promote analytical thinking of learners
2. The learning environment should be arranged in accordance with the ability to analytical thinking and solve problems in each area.

Acknowledgments. This work was supported by the Research and Creative Educational Innovation Affairs, Faculty of Education, and the Department of Master of Education Program in Science and Technology Education, Faculty of Education, Khon Kaen University.

References

1. Samat, C., Chaijaroen, S.: Design and development of constructivist augmented reality (AR) book enhancing analytical thinking in computer classroom. In: Rønningsbakk, L., Wu, T.-T., Sandnes, F.E., Huang, Y.-M. (eds.) ICITL 2019. LNCS, vol. 11937, pp. 175–183. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-35343-8_19
2. Samat, C., Chaijaroen, S., Wattanachai, S.: The designing of constructivist web-based learning environment to enhance problem solving process and transfer of learning for computer education student. In: Rønningsbakk, L., Wu, T.-T., Sandnes, F.E., Huang, Y.-M. (eds.) ICITL 2019. LNCS, vol. 11937, pp. 117–126. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-35343-8_13
3. Junruang, C., Kanjug, I., Samat, C.: The development of a computational thinking learning package that integrates a learning experience design for grade K. In: Huang, Y.-M., Lai, C.-F., Rocha, T. (eds.) ICITL 2021. LNCS, vol. 13117, pp. 144–151. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-91540-7_16
4. Arifin, Y., et al.: User experience metric for augmented reality application: a review. Procedia Comput. Sci. **135**, 648–656 (2018)
5. Lewandowski, G., et al.: Commonsense understanding of concurrency: computing students and concert tickets. Commun. ACM **53**(7), 60–70 (2010)
6. Yimwilai, S.: The effects of project-based learning on critical reading and 21st century skills in an EFL classroom. J. Liberal Arts Maejo Univ. **8**(2), 214–232 (2020)
7. Threekunprapa, A., Yasri, P.: Unplugged coding using flow blocks for promoting computational thinking and programming among secondary school students. Int. J. Instr. **13**(3), 207–222 (2020)
8. Nouri, J., Zhang, L., Mannila, L., Norén, E.: Development of computational thinking, digital competence and 21st century skills when learning programming in K-9. Educ. Inq. **11**(1), 1–17 (2020)
9. Suryana, F., Jalinus, N., Rahmad, R., Efendi, R.: Cooperative project based learning models in programming languages: a proposed. Int. J. Adv. Sci. Technol. **29**(6), 1876–1886 (2020)
10. Harimurti, R., Asto, B.I.: The concept of computational thinking to-ward information and communication technology learning. Mater. Sci. Eng. **535**, 1–7 (2018)
11. Maharani, S., Kholid, M.N., Pradana, L.N., Nusantara, T.: Problem solving in the context of computational thinking. J. Math. Educ. **8**(2), 109–116 (2019)

The Development of Augmented Reality Book to Promote Analytical Thinking on the Basic of Life Units for Secondary School

Chamawee Samranchai[1] and Charuni Samat[2](✉)

[1] Educational in Science and Technology, Faculty of Education, Khon Kaen University, Khon Kaen, Thailand
[2] Computer Education, Faculty of Education, Khon Kaen University, Khon Kaen, Thailand
scharu@kku.ac.th

Abstract. This study aims to 1) Develop an augmented reality (AR) book to help students develop basic analytical thinking abilities on the basic life units. 2) Examine how well students use analytical thinking when studying AR books. 3) Compare the learning outcomes of students before and after using the AR book. 4) Examine the students' satisfaction with the AR book. 40 students from Thailand's secondary school as the research participants. Analytical thinking tests, pre-tests and post-tests, and satisfaction assessments all are part of data collection method. The results showed that AR book "the basic of life units" was developed using unity 3D and designed using Adobe InDesign for 4 chapters. (1) the ability to identify elements of something or a particular subject (2) the capacity to recognize linked reasons, and (3) the capacity to judge the worth of items. The result found that the students' Analytical thinking score were higher than the specified criterion as 70% of 37 people, representing 92.50%. (4) The test performance of the students' achievement scores because of their study with the AR book exceeded the stipulated requirement as 70% of 36 people, or 90.00%, achieved such. At the level of.01 on the t-test scale, the post-test scores were significantly higher than those obtained during the initial testing. Most students gave the AR book a high rating for its ability to help them develop their analytical thinking skills ($\overline{x}$ 4.56, S.D. = 0.90).

Keywords: Development of book · Augmented Reality Technology · Analytical thinking · The basic of life units

1 Introduction

Distance learning has become relatively simple thanks to rapid technological advancements. This type of distance learning is known by a variety of names, including online learning. open education Web-based learning is a type of blended learning that involves the use of computers as a medium. It is the capacity to link computers to a network that allows teachers and students to stay in touch. and may teach at anytime, anywhere, and in any beat using a variety of methods Online learning is a tool that allows for a

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 134–143, 2022.
https://doi.org/10.1007/978-3-031-15273-3_15

more student-centered learning experience. Because of technological advancements in connectivity and communication, as well as more flexibility. The term "online learning" refers to a learning experience that takes place in a multi device context. such as cell phones, computers, and Internet access to live in an atmosphere where students can engage with professors and other students through these surroundings. Students can learn without regard to their physical location.

Students can attend live lectures in this learning environment. Teachers and students can connect in real time and can interact with each other right away. Synchronous learning is the term for this. Social interactions arise because of this method of learning. From the teaching data of teachers who teach scientific courses in the second semester of the academic year 2021 at Surawittayakarn school; the secondary school at Surin province, Thailand. The teacher found that the secondary school who study about fundamentals of living organisms. They do not understand, and Students do not understand and cannot imagine images the composition and shape of cells, cell types, cell structure, and transport of substances into and out of cells. The students currently study using 2D images in textbooks. The diagrams aren't clear. As a result, kids become bored with learning, and teachers lack augmented reality technology-based teaching tools. It is aligned with the National Education Act of 1999, stressing learners from the philosophy of learning that relies on learners to build knowledge from confrontation with problem circumstances. As a result, a constructivist approach to learning should be used, which encourages learners to create self-learning, encourages learners to learn from knowledge-building methods through processes, and focuses on learners building knowledge through actions that follow their own thought process. Present, many countries have introduced augmented reality technology to assist in teaching and learning. In a similar much research, they are observed that AR-based application help to show a more positive attitude and enhancing analytical thinking skills of students [1–5].

For the reasons stated above as a result, we are considering create an augmented reality book in the topic of "the basic of life units" for enhancing learning and encourage analytical thinking of the secondary. The contents of the book include how to operate a microscope, cell structure and function of plant and animal cells, transport of substances into and out of cells. In the form of a 3D model, assist learners in seeing clearly. may more readily comprehend the collection of information The use of augmented reality technology in the books to encourage analytical thinking.

2 Research Objectives

1. To develop an augmented reality book to promote analytical thinking on the topic of the basic of life units.
2. To study the analytical thinking skills of students in learning augmented reality book.
3. To compare the students' learning achievement before and after using augmented reality book.
4. To study the satisfaction of students after learned with augmented reality book.

3 Research Scope

This study is a type of development research that focuses on the design and development process, according to Richey and Klein [6]. Its goal is to design and develop an online learning environment. To that end, research is conducted on pertinent documents, the teaching and learning management context is examined, design conceptual frameworks are synthesized, a learning environment model is designed and developed, and quality is improved. Below are specifics about performing research.

4 Research Method

The development of an AR book will help secondary school students develop their analytical and computational thinking skills. in this investigation. Based on the application of Richey & Klein's notion from 2007 [7, 8], This involves 3 processes: 1) Design Process 2) Development Process 3) Evaluation Process.

4.1 Population and Sample

The population of this research was the secondary school studying in Surawittayakarn school, Surin province, Thailand. A total sample of 580 students from 16 rooms. The samples were selected using purposive sampling technique. The samples were 40 students from room No. 5 who took the exam scored less than the criteria for analytical thinking skill.

4.2 Research Procedure

This study was to develop interactive multimedia augmented reality book to promote analytical thinking skill of students in learning on the basic of life units. The steps of research and development in this study followed:

1) The development of a four-chapter interactive augmented reality book using Adobe In Design and Unity 3D about the fundamentals of life. after design verification and early AR book testing. The augmented reality book prototype was then tested by professionals to gather feedback and ideas before they received the team's approval. There were two specialists participating, including professionals in media technology and biochemistry. The updated AR book will be tested in secondary schools, and its efficacy will be assessed.
2) Study the analytical thinking skills of students in learning augmented reality book "The basic of life units" by designed and developed environmental learning based on the analytical framework according to Chaisomboon and Samat [9]. consist of 1) the situation problem and learning tasks 2) learning resources 3) promote analytical thinking center 4) base of support (5) coaching and (6) knowledge exchange. The problem situations and learning tasks that are created must follow to a three-step analytical thinking framework, which includes: 1) the ability to identify elements of something or a particular subject 2) the ability to identify correlated reasons, and 3)

the ability to assess the value of things. Next step, the students' analytical thinking skills were measured using an analytical thinking exam. The test results are used to calculate the basic statistical variables, such as mean and standard deviation. The students must achieve 70% score on the analytical thinking criteria.

3) Compare the learning of the students before and after using the AR book. Create the assessment of learning progress. After that, experts examined the quiz that had been enhanced. The updated test will be administered with secondary school assistance. The test's confidence level will be assessed using the equation KR-20 according to Kuder Richardson is equal to 0.8550 and the exam results.
4) Evaluate the satisfaction of students after learned with augmented reality book "The basic of life units". The questionnaires evaluated using rating scale and five-point Linkert scale.

4.3 Data Collection Technique and Instruments.

Data collection research used tests and questionnaires. The students' analytical thinking skills were measured using an essay test. The students' answer was then measured using an analytical thinking skill rubric [10]. Before used, the research instruments had been validated using expert validation and empirical validation. The students' learning achievement were compared the score before and after study with AR book "the basic of life units". The satisfaction questionnaire aims to evaluate students' satisfactions toward the AR book interactive multimedia in learning the basic of life unit.

4.4 Data Analysis

Analyze the effectiveness of AR book according to the 80/80 criteria. Analytical thinking measured by solving 4 situations using basic statistical values, i.e., percentage, mean ($\overline{x}$) and standard deviation (S.D.). Learning achievement of learners who study with augmented reality technology textbooks measure was measured by having students take a pre-test and post-test. The results were used to analyze the quantitative data such as percentage, mean score ($\overline{x}$), standard deviation (S.D.) Evaluate the satisfaction of students after learned with augmented reality book "the basic of life units". The questionnaires evaluated using rating scale and five-point Linkert scale.

5 The Result of Research

Design and development of AR book.

Constructing a theoretical conceptual framework that is based on the investigation and evaluation of theoretical concepts, data, variables, and connections between theoretical concepts. The following is a synthesis of the conceptual framework based on research and related theories (Fig. 1).

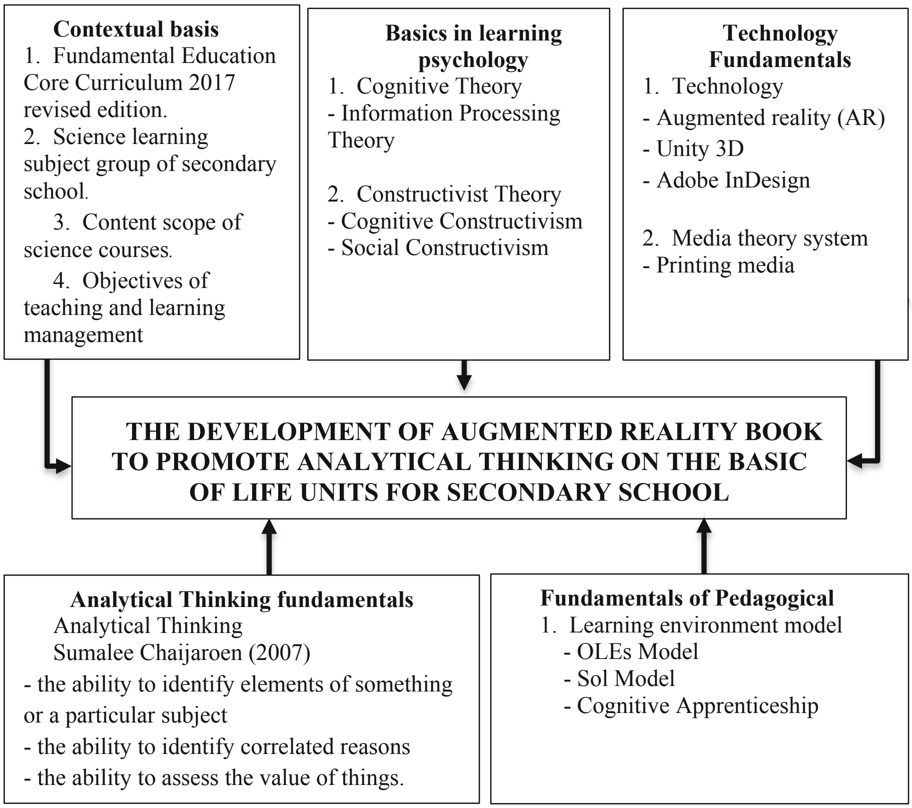


Fig. 1. Theoretical framework of learning development on AR book on the basic of life units.

Synthesize a design conceptual framework.

The conceptual framework to produce the AR book is being synthesized in this step to encourage critical thinking on the fundamental life units. The theoretical framework served as a guide for the researcher as she synthesized a theoretical design conceptual framework. which shows the details of the design conceptual framework in Fig. 2.

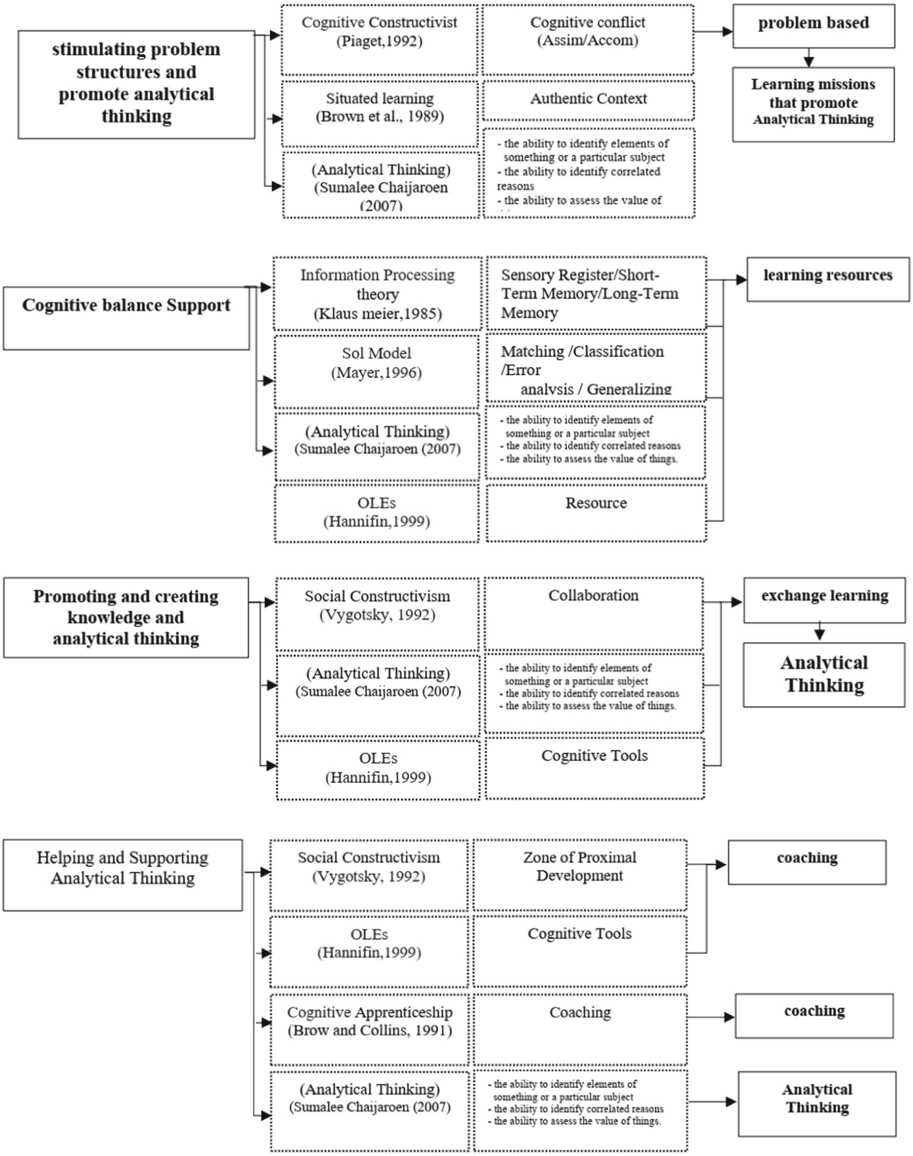


Fig. 2. Designing framework of development of AR book on the basic of life units.

There is a book named AR that has four components.

Once it has been modified to reflect the advice of experts, teachers will use it with their intended audience. Figure 3 in the example AR book "the basic of life units".

The analytical thinking results obtained from the analytical thinking measurement of the learners. AR book to promote analytical thinking on the basic of life units.

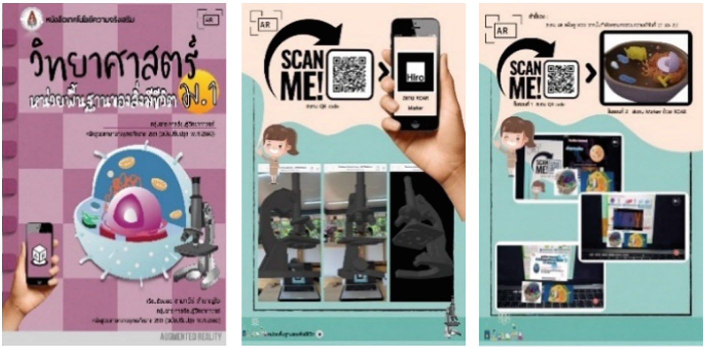


Fig. 3. Example of AR book on the basic of life units.

Design a learning environment for use in promoting students' analytical thinking skills. of 4 problem-based Fig. 4.

Fig. 4. Example of learning environment

The results of analytical thinking obtained from the analytical thinking measure of the learners (Table 1).

Table 1. The results of analytical thinking obtained from the analytical thinking measure of the learners.

	The ability to identify elements of something or a particular subject	The ability to identify correlated reasons	The ability to assess the value of things	Total
				Show total
$\bar{x}$	5.48	6.88	14.28	26.63
S. D	0.60	1.02	1.54	2.64
Total students (person)				40
Number of students with a passing score of 70% (person)				37
Percentage of students with a passing score of 70% (21 points)				92.50
Student grade point average ($\bar{x}$)				26.63
Standard Deviation (S.D)				2.64

* means a passing score of 7o% or more (21 points)

The results of the study on the achievement of the learners who studied with AR book AR book to promote analytical thinking on the basic of life units for secondary school (Table 2).

Table 2. Comparison of Pre-test and post-test achievement t-test

Achievement	n	$\bar{x}$	S.D	t-test	sig
Pre-test	40	19.80	3.81	46.16**	<.001
Post-test	40	27.10	2.93		

** Statistically significant at the level .001

The results of the study of the satisfaction of the learners who studied with AR book AR book to promote analytical thinking on the basic of life units for secondary school (Table 3).

Table 3. The results of the study of the satisfaction of the learners who studied with AR book AR book to promote analytical thinking on the basic of life units for secondary school.

Assessment item	$\bar{x}$	S.D	Quality
content	4.73	0.44	Very satisfied
Instructor side	4.54	0.54	Very satisfied
Print media (AR book)	4.44	0.53	Very satisfied
Measurement and evaluation	4.76	0.42	Very satisfied
Assessment of overall learning management	4.56	0.90	Very satisfied

6 Discussion and Conclusion

The results of this study demonstrate that the AR book "the basis of life units" can foster learners' analytical thinking abilities and give them information and understanding of the lesson. Students can comprehend the many parts of a microscope. and microscopy can be used to initially investigate the intracellular makeup of plants and animals. Additionally, students can identify the functions of numerous organelles and differentiate between the appearance of organelles. inside the prison It was discovered that the learners had higher learning achievements after using the AR book. According to a related study by Yeh & Tseng [2], augmented reality-based programs dramatically improved students' academic performance and attitudes toward scientific classes. Moreover, AR book "the basic of life units" to be used as a media in teaching and learning to help learners have higher analytical thinking skills. According to research by Tamam et al. [4], employing augmented reality (AR) technology in a biology class can help students pay more attention to developing their analytical thinking skills. Moreover, consistent with the research of Syawaludin et al. [1] indicate that the development of augmented reality-based interactive multimedia to improve the analytical thinking skills of elementary school teacher education students.

Classification, identification, and reasonable linkages are all part of the learning environment. The creation of a learning environment that enables students to research endlessly and study as needed to solve problems and support learning management in the twenty-first century, with a focus on learning management using technology to transfer knowledge to learners to create high-quality learning management and achieve the highest level of efficiency for all students.

In conclusion, incorporating AR technology into teaching and learning will benefit students by facilitating interactive learning, which involves receiving feedback in the form of ideas, arguments, and explanations. This will also help students develop their analytical thinking skills and problem-solving abilities when using AR books to learn about the fundamentals of life.

7 Suggestion

1. Should study augmented reality technology books in other formats by considering that model to be consistent and appropriate to promote the analytical thinking of the learners.
2. Results of a study on development of AR book can be used to guide the development of other relevant learning environments.

Acknowledgments. This work was supported by the Research and Creative Educational Innovation Affairs, Faculty of Education, and the Department of Master of Education Program in Science and Technology Education, Faculty of Education, Khon Kaen University.

References

1. Syawaludin, A., Rintayati, A.: Development of augmented reality based interactive multimedia to improve critical thinking skills in science learning. Int. J. Instr. **12**(4), 331–344 (2019)
2. Yeh, H.-C., Tseng, S.-S.: Enhancing multimodal literacy using augmented reality. Lang. Learn. Technol. **24**(1), 27–37 (2020)
3. Ahied, M., Muharrami, L.K., Fikriyah, A., Rosidi, I.: Improving students' scientific literacy through distance learning with augmented reality-based multimedia amid the Covid-19 pandemic. J. Pendidikan IPA Indonesia **9**(4), 499–511 (2020)
4. Tamam, B., Corebima, A.D., Zubaidah, S., Suarsini, E.: The contribution of motivation components towards students' critical thinking skills in biology learning using augmented reality. Humanit. Soc. Sci. Rev. **8**(3), 1433–1442 (2020)
5. Cetin, H., Türkan, A.: The effect of augmented reality based applications on achievement and attitude towards science course in distance education process. Educ. Inf. Technol. **27**, 1397–1415 (2022). https://doi.org/10.1007/s10639-021-10625-w
6. Richey, R.C., Klein, J.: Design and Developmental Research. Lawrence Erlbaum Associates, New Jersey (2007)
7. Arifin, Y., et al.: User experience metric for augmented reality application: a review. Procedia Comput. Sci. **135**, 648–656 (2018)
8. Lewandowski, G., et al.: Commonsense understanding of concurrency: computing students and concert tickets. Commun. ACM **53**(7), 60–70 (2010)
9. Chaisomboon, P., Samat, C.: Design framework of constructivist web-based learning environments to enhance problem solving on c programing language for secondary school. Turk. Online J. Educ. Technol. (October Spec. Issue INTE), 700–704 (2017). https://www.scopus.com/authid/detail.uri?authorId=54965753900
10. Chaijaroen, S., Samat, C.: The relationship between preconception and mental effort of the learners learning with constructivist web-based learning environments. Turk. Online J. Educ. Technol. (December Spec. Issue INTE), 564–569 (2017). (https://www.scopus.com/authid/detail.uri?authorId=54965753900)

Design and Framework of Learning Systems

The Application of Mind Map and Cooperative Learning Teaching Method on the Machining Technology Course

Dyi-Cheng Chen(✉), Jui-Chuan Hou, Shang-Wei Lu, and Hsi-Hung Peng

Department of Industrial Education and Technology, National Changhua University of Education, Changhua 500, Taiwan
dcchen@cc.ncue.edu.tw, {d1031006,m0931007}@gm.ncue.edu.tw

Abstract. On-site practical machine operation skills were taught in the Machining Technology Course to implement the skills domain courses under the "108 curriculum" promoted by the Ministry of Education and help students in different professional backgrounds achieve the same cognitive level. The mind map and cooperative learning teaching method is adopted to guide students in solving machining technical problems through image thinking and group discussion. As a result, students can have a deeper and wider learning effect and machining cognition to strengthen their own technical ability, ultimately fulfilling the goal of becoming technical engineers. The Cronbach's alpha was used in this study as the reliability evaluation method, and grade B machining course test questions and a scoring table were used for scoring. In addition, a systematic strategy was used as the teaching stage procedure. A T-test was used to statistically analyze samples to explore the differences among students before and after learning. Furthermore, this study aimed to prove that the core teaching method of mind map and cooperative learning can effectively improve professional ability while allowing teachers and students to create the core value of win-win teaching in an environment where teaching benefits both students and teachers.

Keywords: Machining technology course · Mind map · Cooperative learning · Cronbach's alpha

1 Introduction

1.1 Motivation

One of the motivations of this study revolves around helping students with different professional backgrounds to achieve the same cognitive level after course arrangement and learning after the implementation of the "108 curriculum" [1].

The "Machining Technology Course" adopted the teaching method of on-site practical machine operation skills. Therefore, this study was also driven to guide students in solving machining technical problems through image thinking tools and group discussions with the mind map and cooperative learning teaching method and provide them with more knowledge about machining.

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 147–156, 2022.
https://doi.org/10.1007/978-3-031-15273-3_16

1.2 Purpose

This research project was mainly based on the Machining Technology Course of the Undergraduate Precision Manufacturing Technology Courses. By enabling students to understand and familiarize themselves with the operation technology, machining process, and operating procedures of traditional machining tools, they become equipped to independently and cooperatively plan the optimal process in the mechanical engineering practice.

This study aimed to explore the effects of mind maps and cooperative learning on students' learning in the Machining Technology Course. The method was adjusted accordingly in the teaching process, and the cooperative learning mode was adopted to enable students to cooperate in finishing the machined products. Furthermore, this method helps establish students' processing skills and the cooperative relationship among their learning peers while promoting teachers' teaching and research development.

2 Literature Review

2.1 Mind Map

Tony Buzan [2] proposed that the content of a person's thinking mode is directly associated with individual thinking. David Egan [3] pointed out that pictorial organization uses visual appearance to present knowledge and information structurally to make the absorbed new knowledge clearer in reading. Joshi, Chandrashekhar V. [4] suggested that communicating students' ideas quickly and concisely in the form of charts not only enables teachers to understand and assess students' understanding, but it can also be used for learning and assessment. Akanbi, Abdulrasaq Oladimeji [5] showed that using the mind map teaching strategy can improve students' learning performance.

Sun [6] mentioned that a mind map is a tool that assists thinking and learning based on diffuse thinking, which is closer to the human thinking mode than the traditional text. In addition, Aurelian Eminet [7] proposed that using a mind map can provide effective teaching methods to reduce differences among multicultural backgrounds or the degree of differences among students from different backgrounds. Rosemary Wette [8] also proposed that the application of a mind map in education can achieve good teaching effects, allowing students to make significant progress in the breadth and depth of formal learning and improve their motivation and self-efficacy. Further, David N. Hyerle and Larry Alper [9] suggested that the visual model of the mind map could improve learners' cognitive and critical abilities and that using the mind map could improve the professional development performance of teachers, build their leadership skills, and improve student scores on tests.

2.2 Cooperative Learning

Since the inception of the Cooperative Learning Center in 1960, the theoretical model of cooperative learning was gradually established, along with the advancement of the cultivation of cooperative learning among teachers. The proverb, "When three are walking together, I am sure to find teachers among them" from the Confucian Analects is the best demonstration of cooperative learning. In cooperative learning, a small group of more than two people can achieve clear teaching objectives through cooperation, mutual assistance and discussion, sharing learning results, and actively completing group tasks (Huang, Cheng-Chieh, Lin, Pei-Hsuan) [10].

Although there are many cooperative learning teaching methods, they all share the same characteristics: heterogeneous grouping, positive interdependence, face-to-face encouraging interaction, individual performance, interpersonal skills, and group process [11].

3 Research Methods

3.1 Research Design

This study aimed to apply the teaching method of mind map and cooperative learning in the Machining Technology Course. Therefore, this study took the freshmen attending the Machining Technology Course as the research subjects. Further, the pre-test and post-test were conducted before and after the course to explore the differences among students after the teaching practice research. The research structure and implementation process of this course are shown in Figs. 1 and 2.

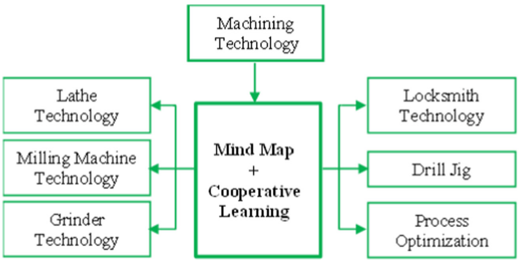


Fig. 1. Research structure

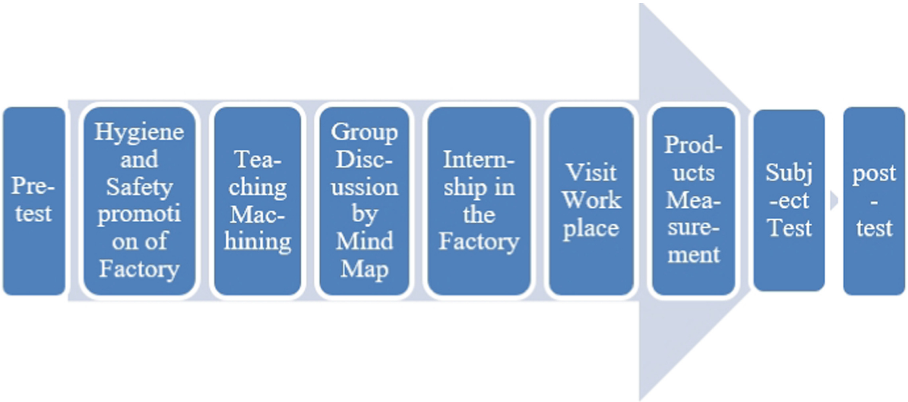


Fig. 2. Course implementation process

The machining technology is widely applied from high-tech information electronics to traditional industry and from industrial components to people's livelihood articles that need the technology. This course focuses on the examination questions for machining and the machine operation of common hand tools and various processing methods of metal forming in machining technology.

The four principles of cooperative learning and mind map learning in the teaching process (i.e., Key Word, Radiant Thinking, Color, and Picture or Image) are the core of practical problems [12]. The students were encouraged to have group discussions to cultivate their active learning, critical thinking, and problem-solving abilities.

This research project was based on a mind map and cooperative learning as the teaching method, with the Machining Technology Course as the main research content. The main assessment methods include group discussions, processing procedures, discussion results reporting, class participation, and measuring the machined products.

3.2 Research Steps

In this study, teachers' questions and grade B machining test questions were generated using a mind map and cooperative learning. The purpose was to help students find the best way to solve the problem and determine the best processing method through group discussion.

Undergraduate students from Classes A and B who took the Machining Technology Course were selected for this study. The cooperative learning group teaching model was employed in the class to draw and make mind maps in groups in order to find the optimal processing method in the machining technology. Machining technicians and machining verification and evaluation personnel in the industry were invited to join the on-site teaching assistance in the teaching experiment research to solve students' problems and give them guidance in a new thinking direction. Figure 3 shows the machined products.

Fig. 3. Class B machined products and detailed drawings

This study referred to the student learning outcome assessment proposed by Wang [13]. It also used the Reaction, Learning, Behavior, and Results of four evaluation steps of Kirkpatrick [14] as the structure to understand the professional knowledge, technology, attitude, and behavior accumulated by students after the teaching process. The students were assessed before and after the test through professional ability, learning achievement, and inspection methods to evaluate their learning effectiveness.

This teaching practice research plan mainly took data collection, processing, and analysis of the pre-test and post-test as the statistical data. The Cronbach's alpha was used as the reliability evaluation method [15] to analyze the reliability of all students' questions. Then, the differences between the pre-test and post-test were compared to explore and analyze learning differences among students.

In addition to using pre-test and post-test to analyze students' learning differences, the Examination Paper for Technical Examination of Machining in Class B and the grading table [16] published by the Skill Evaluation Center of Workforce Development Agency Ministry of Labor were also used in this study to observe students' skill performance in the process of work-piece machining and precision measurement of machined products. The assembly and functional tests were also completed for grading. Furthermore, this study carried out a statistical analysis of the grading result through the statistical method of average value and standard deviation to discuss the students' learning differences before and after the course.

The teaching procedure used in this study mainly adopted System Strategy proposed by Kang and Tzu-Li [17], which is a three-stage process including preparation, development, and improvement. It takes designed objectives and expected results as the prerequisite and considers all factors in the process. Continuously giving feedback and corrections allows the System Strategy to obtain data and experience to provide the best solution to the problem [18].

3.3 Course Material Design and Implementation

In the first class, teachers made clear the course objectives and adopted the teaching method of group cooperative learning. Students' cognition of machining technology and their expectation and demand for the course were understood through a pre-test. With a mind map and team cooperative learning, subsequent course materials were developed and effectively implemented. The main implementation methods of the course are as follows:

Group discussions are conducted according to the units in the activity study sheet, and the teacher will provide guidance in time and remind students of the correct discussion.

Draw mind maps for the course content of manufacturing procedures and learn to search for relevant knowledge.

Discuss learning topics in groups, propose topics to be discussed, and search related materials to realize the concept of cooperative learning.

3.4 Data Collection and Analysis

Researchers' teaching records, study sheets, pre-test, learning results, post-test, and other data were analyzed and summarized to obtain the study results.

The experimental configuration is shown in Table 1. The code names in the table are described as follows: E indicates that the experimental group receives the experimental processing of the mind map and group cooperation teaching method. El represents the pre-test implemented before experimental processing. E3 represents the post-test implemented after experimental processing.

4 Results and Discussions

The pre-test and post-test's average values and standard deviations are 4.40 and 1.49, and 4.61 and 1.67, respectively, as shown in Table 2. The results show that the core teaching method of mind map and cooperative learning has significantly improved students' learning results in the Machining Technology Course. Table 3 shows the average value difference test of the pre-test and post-test. On the other hand, Tables 4 and 5 present the statistical results.

Table 1. Experimental configuration table

	Pre-test	Experimental processing	Post-test
Experimental group	E1	E	E3

Table 2. The average value and standard deviation of the pre-test and post-test

Average value			Standard deviation	
Number of people	Pre-test	Post-test	Pre-test	Post-test
48	4.40	4.61	1.49	1.67

Table 3. The test of the difference in the paired samples' average value by each item's pre-test and post-test

Item	Pre-test/post-test	No. of sample	Average value	Variance	Statistic (T)	Significance (P)
Learning motivation 1	Pre-test	48	3.8333	0.695	2.843	0.0066**
	Post-test	48	3.4583	1.0621		
Learning motivation 2	Pre-test	48	4.0208	0.5315	– 1.2313	0.2243
	Post-test	48	4.1458	0.5102		
Learning motivation 3	Pre-test	48	4.3125	0.4322	0	1
	Post-test	48	4.3125	0.4747		
Learning motivation 4	Pre-test	48	4.0833	0.5035	– 0.8136	0.42
	Post-test	48	4.1667	0.5248		
Learning motivation 5	Pre-test	48	4.0417	0.5514	– 0.3503	0.7277
	Post-test	48	4.0833	0.5461		
Learning motivation 6	Pre-test	48	4.1042	0.7762	0.4647	0.6443
	Post-test	48	4.0417	0.5514		
Learning motivation 7	Pre-test	48	3.9792	0.6591	– 0.1838	0.8549
	Post-test	48	4	0.6383		
Learning performance1	Pre-test	48	4.2083	0.7216	0.2921	0.7715
	Post-test	48	4.1667	0.6525		
Learning performance 2	Pre-test	48	4.0833	0.6738	– 2.4238	0.0193*
	Post-test	48	4.4167	0.3333		
Learning performance 3	Pre-test	48	4	0.5106	0	1
	Post-test	48	4	0.6383		
Learning performance 4	Pre-test	48	4.1458	0.5102	– 0.1838	0.8549
	Post-test	48	4.1667	0.4397		
Learning performance 5	Pre-test	48	4	0.5106	0.2921	0.7715
	Post-test	48	3.9583	0.7642		
Learning performance 6	Pre-test	48	3.875	0.4947	0	1
	Post-test	48	3.875	0.6649		
Learning performance 7	Pre-test	48	3.8333	0.5674	– 0.4647	0.6443
	Post-test	48	3.8958	0.6485		
Learning performance 8	Pre-test	48	3.6667	0.5674	– 1.458	0.1515
	Post-test	48	3.8542	0.6379		

(*continued*)

Table 3. (*continued*)

Item	Pre-test/post-test	No. of sample	Average value	Variance	Statistic (T)	Significance (P)
Learning performance 9	Pre-test	48	3.9375	0.5279	– 0.5182	0.6067
	Post-test	48	4	0.6383		
Learning interest 1	Pre-test	48	6.5208	6.9357	– 1.7855	0.0806
	Post-test	48	7.2917	4.1684		
Learning interest 2	Pre-test	48	6.0208	6.7868	– 4.5108	0***
	Post-test	48	7.8542	2.5102		
Learning interest 3	Pre-test	48	6.4167	6.7163	– 3.2123	0.0024**
	Post-test	48	7.75	2.617		

In the T-test of paired samples, the performance of "learning motivation", "learning performance", and "learning interest" are examined respectively before and after the test. Among them, "learning motivation" only takes learning motivation Item 1, "learning performance" only takes learning performance Item 2, and "learning interest" takes learning interest Items 2 and 3. $P < 0.05$ shows a significant difference. Table 4 shows sample narrative statistics, while Table 5 presents a two-sample variance (standard deviation) difference test.

Table 4. Sample narrative statistics

Grouping variable	Count	Average value	Median	Minimum	Maximum	Std. dev.
Pre-test	1026	4.4006	4	1	10	1.4955
Post-test	969	4.6161	4	1	10	1.6766

I: None of the sample narrative statistics contain missing values.

Table 5. Two-sample variance (Standard deviation) difference test

Null Hypothesis: The variance of the two groups of data is equal to H_0: $\sigma_1{}^2/\sigma_2{}^2 = 1$					
F-statistics	d.f. of numerator	d.f. of denominator	p-value	95% C.I. for ratio	
0.7956	1025	968	0.0003***	0.7025	0.9008

I: Significance code: '***': < 0.001, '**': < 0.01, '*': < 0.05, '#': < 0.1

The independent sample T-test is used to compare the average value difference between the pre-test and post-test. $P = 0.0003$ means achieving a significant level, indicating a significant difference in the variance between the two groups of samples ($P < 0.001$).

Table 6. Students' views on and satisfaction with the course content and textbooks in this study

Item	Average value	SD	Order
The course content and/or activities are appropriate to the course's educational objectives	4.33	0.74	1
The course topics are organized coherently throughout the semester	4.31	0.76	2
The course meets my learning needs	4.22	0.70	3
The content of this course matches my ability and level	4.12	0.82	4
The content of this course can arouse my motivation to learn	4.06	0.83	5
This course features a moderate difficulty level and amount of materials, including textbooks, handouts, and reference books	4.00	0.94	6
The content of this course can be adjusted and updated to meet the needs of the times	3.94	0.90	7

Table 6 shows the students' views on and satisfaction with the course content and teaching materials. The average scores of each question in the Machining Technology Course range from 3.94 to 4.3, equivalent to between "strongly agree with" and "generally agree with".

5 Conclusions

With mind map and cooperative learning as the core teaching method, students can use the concept of cooperative learning and their practical experience of the machining process to gain a substantial understanding of relevant knowledge.

In the course implementation, teachers also evaluated students' learning achievements and recorded their problem-solving skills and achievement performance when exploring problems. It was found that the participants actively collected more information and related topics about the curriculum or development and sought answers to questions through online videos, expert consultation, and field visits, implementing the spirit of mind map and cooperative learning as the core of the teaching.

Furthermore, this study selected the freshmen taking the Machining Technology course as the research subjects. Due to the uneven knowledge background of the students, the results of the pre-test, post-test, and relevant teaching evaluation in the same groups were only used for statistical analysis, and the experimental and control groups could not be compared as a result. In addition, due to the limited number of school machines, students were assigned to specific machines to complete their work. The test results show that students had a declining trend of learning motivation. Therefore, in terms of future teaching, students should first be grouped according to the subject groups of their vocational senior high schools [19] for course planning. Moreover, with the resources of the industry or the addition of relevant equipment, the overall results should be better.

Acknowledgments. The author is grateful to the Ministry of Education, Taiwan, for its support and funding for this research. The project number is PEE1090361.

References

1. Ministry of Education: Curriculum guidelines of 12-year basic education. Ministry of Education Taipei (2014)
2. Tony Buzan, B.B.: The Mind Map Book: How to Use Radiant Thinking to Maximize Your Brain's Untapped Potential Paperback, p. 320. Plume Books, New York (1996)
3. Egan, D.: Revolution of learning: e-learning. Asia-Learn. Wkly **66**(3), 121–134 (2000)
4. Joshi, C.V.: Use of simple mind maps in the adventures of learning. DAWN: J. Contemp. Res. Manag. **4**(1), 1–11 (2017)
5. Akanbi, A.O., Olayinka, Y.W., Omosewo, E.O., Mohammed, R.E.: Mohammed, ridwan enuwa, effect of mind mapping instructional strategy on students' retention in physics in senior secondary schools. Anatolian J. Educ. **6**(1), 145–156 (2021)
6. Sun, I.H.: Mind Mapping Theory and Application (revised edition). Whole Brain Learning Series, p. 352. Business Weekly Publications, Inc., Taiwan (2020). (In Chinese)
7. Eminet, A.: using mind maps to distinguish cultural norms between french and united states entrepreneurship students. J. Small Bus. Manag. **56**(S1), 177–196 (2018)
8. Wette, R.: Using mind maps to reveal and develop genre knowledge in a graduate writing course. J. Second Lang. Writ. **38**, 58–71 (2017)
9. Hyerle, D.N.: Student Successes With Thinking Maps: School Based Research, Results, and Models for Achievement Using Visual Tools, 2nd edn., p. 221, Thousand Oaks, USA (2011)
10. Huang, C.C., Lin, P.H.: Cooperative Learning, 1st edn., 2nd printing edn., Education Series. Wu-Nan Book Inc., Taiwan (2008). (In Chinese)
11. Chang, Y.-N.: Research on teaching practice of university courses by using group cooperative learning teaching method. J. Teach. Pract. Res. High. Educ. **4–1**, 35–76 (2020). (In Chinese)
12. Wang, C.-H.: Analysis of digital mind mapping and cooperative learning approach on the learning effectiveness of international trade practice. Commer. Manag. Q. **21**(2), 201–223 (2020). (In Chinese)
13. Wang, C.-L.: Experience sharing of learning effect evaluation promotion at ming chuan university. J. Eval. **28**, 23–29 (2010). (In Chinese)
14. Kirkpatrick, D.L.: Techniques for evaluating training programs. Train. Dev. J. **33**(6), 78 (1979)
15. Olvera Astivia, O.L., Kroc, E., Zumbo, B.D.: The role of item distributions on reliability estimation: the case of cronbach's coefficient alpha. Educ. Psychol. Meas. **80**(5), 825–846 (2020)
16. Reference for Technical Examination of Machining Certified Technician in Class B, The Ministry of Labor, Editor. 106, Skill Evaluation Center of Workforce Development Agency, pp. 8–20, Taiwan. (In Chinese)
17. Kang, T.L.: The development strategy of vocational training materials. Employ. Training, **12**(2), (1994). (In Chinese)
18. Liao, C.W., Lu, C.Y., Shyr, W.J.: A study of employing experimental teaching to enhance students' concept of energy education. J. Ind. Educ. Technol. **31**, 1–19 (2007). (In Chinese)
19. Senior High School Education Act, Ministry of Education, Editor. Ministry of Justice, Taiwan (2021). (In Chinese)

METMRS: A Modular Multi-Robot System for English Class

Pui Fang Sin[1], Zeng-Wei Hong[1](✉), Ming-Hsiu Michelle Tsai[2], Wai Khuen Cheng[3], Hung-Chi Wang[1], and Jim-Min Lin[1]

[1] Department of Information Engineering and Computer Science, Feng Chia University, Taichung, Taiwan
zwhong@fcu.edu.tw
[2] Department of Foreign Languages and Literature, Feng Chia University, Taichung, Taiwan
[3] Department of Computer Science, Faculty of Information and Communication Technology, Universiti Tunku Abdul Rahman, Kampar, Malaysia

Abstract. English is always an important second or foreign language in Asia countries such as Taiwan. However, elementary or secondary schools in Taiwan encounter the shortage of teachers especially in rural areas. With the maturity of IT technology, IT equipment like educational robots offers opportunity to reduce teachers' effort and even replace teachers. The evidence of applying robot-assisted language learning (RALL) in L2 class has been exhibited positive effectiveness. Nevertheless, RALL in class often supports single or single type of robot. Therefore, our present research was aimed to propose a modular English teaching multi-robot system (METMRS) that incorporates multiple heterogeneous robots in English class. Moreover, in order to ease teachers' effort on design of course content, METMRS provides an editing system and seven instruction modules. The teacher simply manipulates the proposed editor to create module, fill in instructional content, and configure the sequence of modules. After launching the modules, a NAO robot acts like a teachers and Zenbo Junior robots act like assistants are able to perform instructions in place of teachers in class. Therefore, the objective of this paper concentrates the elaboration of design of the proposed METMRS.

Keywords: Robot-Assisted Language Learning (RALL) · Modular English Teaching Multi-Robot System (METMRS) · Heterogeneous robots

1 Introduction

Even though most people in Taiwan recognized the importance of English education, elementary and secondary schools in rural areas still suffer from shortage of teachers, due to inconvenient transportation. Fortunately, IT technology has provided opportunity for robot-assisted language learning (RALL) [1]. In RALL, robots perform verbal speech and non-verbal behaviors like gestures and movements. Consequently, robots are able to play roles of learners' companions, tutors, and even teachers. In addition, educational robots might be deployed in or out of classrooms. Recent literatures have exhibited

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 157–166, 2022.
https://doi.org/10.1007/978-3-031-15273-3_17

the effectiveness of RALL in language education [2, 3]. Moreover, the study found that learners were motivated by robots in contrast to human teachers such that engaged longer in learning [4]. Therefore, deployment of RALL in classrooms perhaps is a good strategy to resolve the shortage of EFL teachers in rural areas.

However, deploying RALL in classrooms still has challenges. First, in order to increase flexibility of educational materials presented by robots, teachers need a tool to edit instructional content in robots. This is hard to most of teachers who are not IT professionals and untrained to configure the settings of robots. Second, in terms of most RALL studies, educational robots were assigned to play single role and take corresponding responsibility. This limits variety of robots in classrooms. In fact, there is more than just an educator in a physical classroom. For example, one teacher and several tutors or assistants can present in a classroom in the meantime. The teacher dominates the main instruction but coordinates assistants to help learners' affairs while taking teamwork activities in class. Nevertheless, installing more kinds of robots in a classroom makes RALL more complex in either system design or instruction design.

In order to overcome the two issues above, the present research was aimed to propose a design of Modular English Teaching Multi-Robot System (short for METMRS). There are two objectives of METMRS: first, it offers teachers a facility to edit instructional materials and configure the robot's appearance and presentation. Second, the system such far supports deployment of two kinds of physical robots, NAO developed by Aldebaran and Zenbo Junior developed by ASUS. One NAO and several Zenbo Junior robots can be deployed in a classroom and play roles of a teacher and assistants respectively. Finally, class activities with presentations of multiple robots are organized as course modules. METMRS also offers tool for English teachers to configure the course modules to form a complete course activity.

2 Related Works

2.1 Robot-Assisted Language Learning (RALL)

Robot-assisted language learning (RALL) refers to the use of robots for scaffolding language learning. Current studies of RALL have explored the effectiveness. Park et al. proposed a RALL that adopted ROBOSEM to be an English teaching assistant [5]. In this study, students used various input devices like remote controller to interact with ROBOSEM such that cognitive ability could be enhanced via human-robot interaction. The experiment results in this study show that ROBOSEM improved students' English proficiency. Lee et al. developed another educational robot as assistant for foreign language learning and evaluated the effectiveness [6]. A total of 24 primary school students aged from 9 to 13 participated in the English language course. The course helped students immersed in learning by meaningful human-robot interactions. A pretest-posttest evaluation was designed to assess the cognitive effect of the RALL method in students' oral skills. The result exhibited no significant difference in auditory skills but significant improvement in oral skills. Hung et al. adopt education robot as teaching assistant for enhancing and sustaining student's learning motivation [7]. This study was based on the theory of RALL and ARCS learning motivation model to evaluate the learning motivation, learning performance and continuance intention of the proposed RALL system. Their experiment results showed significant differences between two groups of participants in terms of sustainability of learning motivation, learning performance and continuance intention. Lin et al. proposed a method that adopted integration of an educational robot and IoT-based 3D book to enhance children's English vocabulary learning [8]. The result showed that two males fourth graders participated in the experiment significantly improved their oral productive skill. Chen et al. developed a RALL system to offer five learning activities to engage students in learning [9]. The results showed students' perception are positive towards the system and students enjoyed learning with the system.

The studies above concentrated on the development of RALL for personal language learning. However, deployment of RALL in class was emerging. You et al. proposed a humanoid robot that played a role of teacher's partner in three English classes [10]. Five models of collaboration between teacher and robot were proposed as well. The results of this study showed students had positive attitude and interest in class. Hong et al. proposed a RALL system to be deployed in an English class for elementary students [11]. A total of 52 elementary school students in two groups enrolled in quantitative and qualitative experiment and the results exhibited that experiment group learning with robot had more improvement on motivation, attention, confidence, acceptance of the teaching materials, satisfaction in learning process, and language ability. Chin et al. proposed a humanoid robot as a teaching assistant in a classroom to evaluate the teaching efficacy of humanoid robot [12]. The experiment results showed the humanoid robot increased student's learning interest as well as potential for elementary education. Chin et al. further adopted an education robot in elementary education to evaluate the student's motivation [13]. As shown in the results of studies above, deployment of educational robots in classroom revealed a good effectiveness to students. However, these studies adopted single or single type of educational robot and the robot played only role in class. Nevertheless, as stated in introduction, not only teacher but tutor or assistant might simultaneously present and perform different instructional tasks accordingly in class. Therefore, the need of deploying multiple and heterogeneous robots in class is increasing.

2.2 Multi-Robot System (MRS)

The field of decentralized robotics originated in the late 1980s, mainly to study the difficulties and problems encountered in multiple mobile robotic systems. Prior to this, research has mainly focused on the problem solving of single robots or decentralized systems that do not involve robotic components. Early decentralized robotics technologies include Dynamically Reconfigurable Robotic System (DDRS) based on cell structure proposed in [14], which can reconfigure its settings and software according to a given task, and is composed of many intelligent components with basic mechanical functions, so its flexibility and adaptability are much higher than traditional single robots. Research [15] proposed a new concept ACTRESS (ACTor-based Robots and Equipment Synthetic System) for advanced robotic systems. This system is an autonomous and decentralized robotic system consisted of multiple robotic elements. Each element has functions that understand mission objectives, recognize the surrounding environment, and communicate with components of other elements to make decisions. Kondaxakis et al. proposed research on communication protocols in multi-robot systems [16]. They adopted NAO robot to point to an object and uses KUKA YOUBOT's convenient moving feature to cooperate with Kinect to access the label of the object pointed by NAO. When the system wants to find the object next time, KUKA YOUBOT will directly locate the object's location. It can be found from the above research that no matter whether the multi-robot system is applied in any field, it is necessary to solve the problem of communication between robots and or between robots and servers. Because heterogeneous robots can be used for the integrity of the system, different types of robots have different advantages to achieving complementarity.

3 Development of METMRS

Figure 1 shows two categories of robots in the proposed METMRS. One is NAO robot designed by SoftBank Robotics, and the other is Zenbo Junior designed by ASUS. METMRS allows only NAO but several Zenbo Junior robots in class. Both categories are humanoid robots. The appearance of NAO is very similar to a real person has four limbs but equips no touch screen. NAO has several joints such that the body movements are able to be various to act like a person. Thus, NAO robot is assigned to carry out a teacher's job in class. In contrast, Zenbo Junior equips only head with a touch screen and a body with sensors and speakers. Various facial or emotional expressions can be played by the touch screen. Therefore, Zenbo Juniors could be assigned to be tutors or assistants directly face to students in classroom by nonverbal interactions. Zenbo Junior is able to show instructional multimedia materials on screen and students are able to interact with the robot via the touch screen as well. A scenario of communication between NAO and Zenbo Junior might be that teacher (i.e. NAO) requests students to watch an instructional video displayed by Zenbo Junior or ask a student to answer a question by pressing a choice on Zenbo Junior's screen.

(A) (B)

Fig. 1. (A) NAO robot (B) ASUS Zenbo Junior robot

3.1 METMRS Architecture

We adopted Django Web Framework to develop METMRS, including the client-end website, server and database. QiMessaging JavaScript is a tool used to obtain the instruction modules in NAOqi, and then we adopted this tool to assign tasks to the NAO robot, such as rollcall. In terms of tasks for NAO robot, the design of METMRS referred to the thinking of transforming the teaching or learning activities in English classrooms into instruction modules. NAO or Zenbo Junior has to perform actions according to each module. The instruction modules are independent, good readability and the coupling is reduced. This design helps better debugging and maintenance. It is matched with the MTV architecture of Django Web Framework. Zenbo Junior's function extracts the current function module status from View to perform tasks by using Zenbo Junior API. The architecture of METMRS is shown in Fig. 2. Quiz items are included in Google forms to request students to sit for a quiz. Views collects data sent back to the database and render webpages. NAOqi connects to the server to get the current module and then NAOqi accesses the modules of the NAO robot to drive the NAO robot to perform a presentation. Table 1 lists the summary of these modules.

3.2 Design of Instruction Modules

Table 1. Instruction modules in METMRS

Module	Description
Roll call	Record student attendance
Vocabulary teaching	NAO leads students to read aloud and learn vocabulary
Lesson teaching	NAO reads paragraphs of a lesson aloud and explains keypoint
Quiz	NAO randomly chooses students to answer questions
Classroom activity	Robots play music to help students relax
Group discussion	Robots help grouping students and encourage group discussion
Rest time	Teachers insert a break in-between modules

METMRS supported seven instruction modules for teachers to edit an instruction by configuring the order of instruction modules. Once an instruction module is added, the system will access the database corresponding to the instruction modules and teachers can choose the content of teaching materials. NAO and Zenbo Junior can lead the modules in an English classroom according to the defined teaching process and teaching material content.

- **Roll-call module**
  METMRS supports a QR code function on Zenbo Junior, allowing students to scan their own students' ID to carry out rollcall. Zenbo Junior plays the role of teaching assistant in class. Figure 3 shows the user interface of rollcall module. After pressing the 'Scan ID' button of the interface displayed by Zenbo Junior, the robot will speak "Please show me your ID QRCode!" Then, students have to hand in their student QR code. NAO robot will speak out loud those didn't sign for attendance. After that, NAO will say "Please remember to sign in for those who have not signed in!". Figure 4 shows the flow of this module.

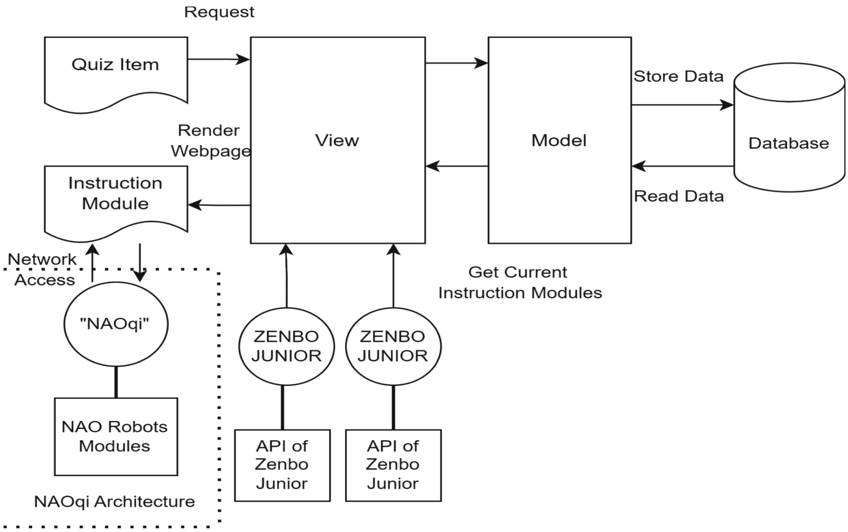


Fig. 2. METMRS architecture

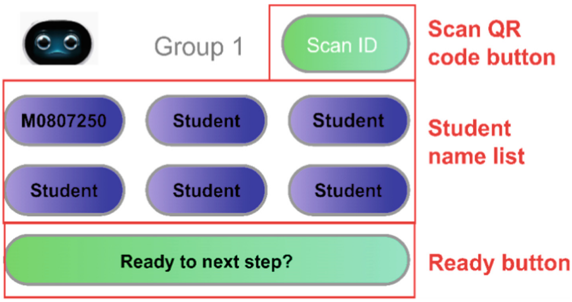


Fig. 3. Roll-call's screen of Zenbo Junior

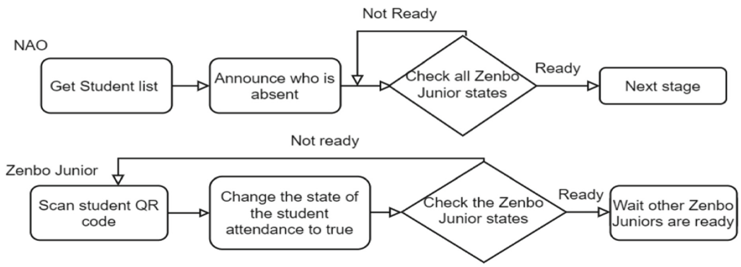


Fig. 4. Flow of rollcall module

- **Vocabulary teaching module**

  We designed this module to assist the students' vocabulary acquisition. At the start of this module, NAO attract student attention by announced "Now we start vocabulary read-aloud, please follow me to read!" Then, NAO reads every word aloud twice and explain the meaning of the vocabulary in Chinese. Each student has to repeat what he heard from NAO's read-aloud. Press ready button to move on next stage.

- **Lesson teaching module**

  This module is to delegate NAO read aloud main paragraphs of a lesson and make supplementary explanation to students. NAO connects to the server to retrieve paragraphs of the target lesson. NAO will read-aloud a paragraph, students have to read it again by themselves. Once all students are finished reading current paragraph by pressing the ready button, NAO reads the next paragraph until cycle ends. The 'Explanation' button on Zenbo Junior screen is giving student to learn the supplementary multimedia content. All of these multimedia files were previously provided before class.

- **Quiz module**

  Since teachers might need tests or quizzes to assess students' learning achievement, this module supports an editor formed as a Web form to teachers to import question items to METMRS's question bank. During a quiz, NAO randomly chooses some students in the classroom to answer the selected questions. After answering a question, NAO announces the answer to students. The flow of this module is depicted by Fig. 5.

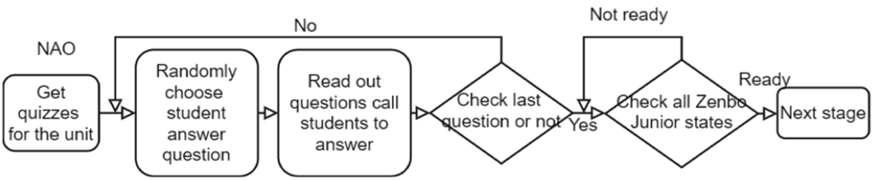


Fig. 5. Flow of quiz module

- **Classroom activity module**

  It is very important to help students' concentration on learning. Current studies have mentioned that RALL can effectively reduce students' learning anxiety. Therefore, offered a module to perform classroom activities to increase joyfulness in class. For example, NAO is able to play music during short break in-between classes to make students relax.

- **Group discussion module**

  This module is designed for students to share their comment and opinion from the lesson. Students divided to several group, each group is consisted five to six students. NAO reads the topic and allows students to prepare their comments for couple of minutes. During discussion time, Zenbo Junior act like a coach to encourage and help students engage to the group discussion. For example, Zenbo Junior can play a video related to the topic to help students share their comment. In the discussion period, NAO asks every group to share their comments. Then, press ready button to next stage.

- **Rest time module and Class note**

  This module is designed to prevent students from being overburdened in the learning process. Teachers can arrange a break in-between regular activities. Class note module is a simple facility that allows a teacher to make important announcements which must be known by students. The notes are linked to the course, meaning that NAO reads the notes to students in the commencement and the end of a class.

- **Course management tool**

  The management tool is developed for teachers to create, delete, and manage modules that were described above. This tool was implemented in form of Web application. The following displays homepage of this tool (see Fig. 6). When teacher signed in the system, teacher has to name the course firstly. For example, as shown in Fig. 6, the course was named "Unit 10". After that, teacher can optionally create a new note to this course. Besides the two functions above, this tool enables a teacher to create, add, remove, and edit modules. As shown in Fig. 6, a list now is consisted of seven existing modules. Once the teacher is going to add more modules in the list, there is a drop-down list box that contains options of modules and the teacher is able to select any of them to be added in the list. The order of modules in the list can be changed, sequence of modules is confirmed, these modules will be admitted and run by METMRS.

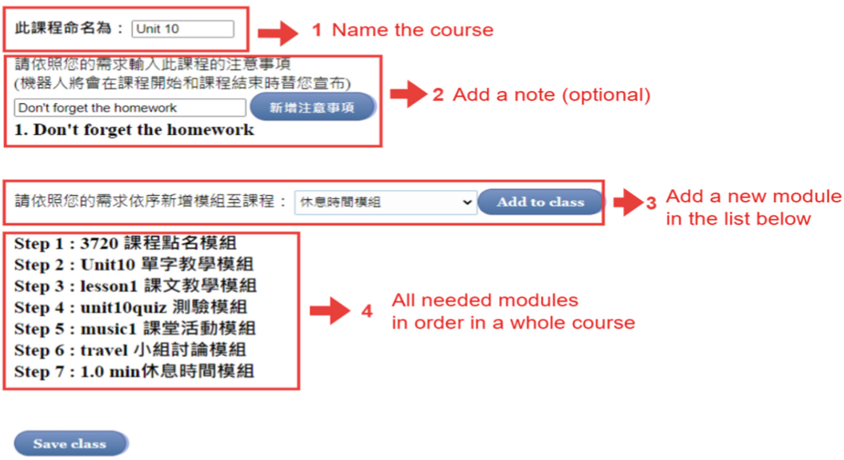


Fig. 6. Homepage of course management tool

4 Conclusion and Future Works

Our present research, METMRS, carried out the concept of multiple heterogeneous educational robots and modularization of English classroom process. In METMRS, NAO robot and Zenbo Junior act like a Teacher and assistants concurrently in English class. We suggest to adopt METMRS to ease human teacher's effort in classroom such that the teacher can have more time to coach students in learning. METMRS even can be applied in place of teachers. We believe METMRS can reduce the problem of teachers' shortage in particular to schools in rural areas. Therefore, METMRS supports modularization of course activities. A management tool was developed in METMRS for teachers to edit seven categories of instruction modules and organize modules into a course process. Robots execute and perform presentations according to the instruction modules. Teachers do not need to get involved in the process, they only need to observe the students' learning status in the classroom.

However, there are still limitations in METMRS. First, METMRS such far supports only NAO and Zenbo Junior. Second, METMRS disables to create a custom instruction module other than the seven proposed categories. Third, investigation of effectiveness of METMRS is ongoing. So far, we don't have evidence to exhibit the multiple education robots presented in the meantime in class is better. In the future, we hope to apply METMRS not only in English curriculum but for more subjects.

References

1. Kanda, T., Hirano, T., Eaton, D., Ishiguro, H.: Interactive robots as social partners and peer tutors for children: a field trial. Hum.-Comput. Interact. **19**(1), 61–84 (2004)
2. Han, J.H., Jo, M.H., Jones, V., Jo, J.H.: Comparative study on the educational use of home robots for children. J. Inf. Process. Syst. **4**(4), 159–168 (2008)
3. Kennedy, J., Baxter, P., Belpaeme, T.: Comparing robot embodiments in a guided discovery learning interaction with children. Int. J. Soc. Robot. **7**(2), 293–308 (2014). https://doi.org/10.1007/s12369-014-0277-4
4. Shen, W.W., Tsai, M.H.M., Wei, G.C., Lin, C.Y., Lin, J.M.: ETAR: an English teaching assistant robot and its effects on college freshmen's in-class learning motivation. In: Rønningsbakk, L., Wu, T.T., Sandnes, F., Huang, Y.M. (eds.) ICITL 2019. LNCS, vol. 11937, pp. 77–86. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-35343-8_9
5. Park, S.J., Han, J.H., Kang, B.H., Shin, K.C.: Teaching assistant robot, ROBOSEM, in English class and practical issues for its diffusion. In: Proceedings of IEEE Workshop on Advanced Robotics and its Social Impacts, California, USA, pp. 8–11 (2011)
6. Lee, S., et al.: On the effectiveness of robot-assisted language learning. ReCALL **23**(1), 25–58 (2011)
7. Hung, I.C., Chao, K.J., Lee, L., Chen, N.S.: Designing a robot teaching assistant for enhancing and sustaining learning motivation. Interact. Learn. Environ. **21**(2), 156–171 (2013)
8. Lin, V., Yeh, H.C., Huang, H.H., Chen, N.S.: Enhancing EFL vocabulary learning with multimodal cues supported by an educational robot and an IoT-based 3D book. System **104**(6), 102691 (2021)
9. Chen, N.S., Quadir, B., Teng, D.C.: Integrating book, digital content and robot for enhancing elementary school students' learning of English. Australas J. Educ. Tec. **27**(3), 546–561 (2011)
10. You, Z.J., Shen, C.Y., Chang, C.W., Liu, B.J., Chen, G.D.: A robot as a teaching assistant in an English class. In: Proceedings of the 6th IEEE International Conference on Advanced Learning Technologies, ICALT 2006, Kerkrade, The Netherlands, pp. 87–91 (2006)
11. Hong, Z.W., Huang, Y.M., Hsu, M., Shen, W.W.: Authoring robot-assisted instructional materials for improving learning performance and motivation in EFL classrooms. J. Educ. Techno. Soc. **19**(1), 337–349 (2016)
12. Chin, K.Y., Wu, C.H., Hong, Z.W.: A humanoid robot as a teaching assistant for primary education. In: Proceedings of the 5th International Conference on Genetic and Evolutionary Computing, Kitakyushu, Japan, pp. 21–24 (2011)

13. Chin, K.Y., Hong, Z.W., Chen, Y.L.: Impact of using an educational robot-based learning system on students' motivation in elementary education. IEEE Trans. Learn. Technol. **7**(4), 333–345 (2014)
14. Fukuda, T., Nakagawa, S.: Dynamically reconfigurable robotic system. In: Proceedings of the 1988 IEEE International Conference on Robotics and Automation (ICRA), vol. 3, pp. 1581–1586 (1988)
15. Matsumoto, A., Asama, H., Ishida, Y., Ozaki, K., Endo, I.: Communication in the autonomous and decentralized robot system ACTRESS. In: IEEE International Workshop on Intelligent Robots and Systems (IROS), vol. 2, pp. 835–840 (1990)
16. Kondaxakis, P., Gulzar, K., Kinauer, S., Kokkinos, I., Kyrki, V.: Robot-robot gesturing for anchoring representations. IEEE Trans. Robot. **35**(1), 216–230 (2019)

A Pilot Study on Maker Spirit-PBL Innovation and Entrepreneurship Course Design and Effect Evaluation

Chuang-Yeh Huang[1], Chih-Chao Chung[2](✉), and Shi-Jer Lou[3]

[1] Department of Tropical Agriculture and International Cooperation, National Pingtung University of Science and Technology, Pingtung, Taiwan

[2] General Research Service Center, National Pingtung University of Science and Technology, Pingtung, Taiwan

ccchung@g4e.npust.edu.tw

[3] Graduate Institute of Technological and Vocational Education, National Pingtung University of Science and Technology, Pingtung, Taiwan

Abstract. This study aimed to develop a maker spirit problem–based learning (PBL) innovation and entrepreneurship course and explore its impact on students' learning effectiveness. A mixed research method was adopted for this study, in which qualitative and quantitative data were collected for inductive analysis. The research subjects comprised 49 students who took the "Innovation and Entrepreneurship Course" at a university of science and technology. Further, an 18-week experimental teaching activity was implemented, in which the "Maker Spirit-PBL Innovation and Entrepreneurship Course" was innovatively developed. Results revealed that most students showed significant positive learning effectiveness in three levels, namely "PBL" and "maker practice", after the experimental teaching. There're two major implementation points of the "Maker Spirit-PBL Innovation and Entrepreneurship Course" were proposed to provide references for future implementations and applications in the teaching field.

Keywords: Maker spirit · PBL · Innovation · Entrepreneurship · Education reform

1 Introduction

Maker education emphasizing "hands-on learning" has become popular around the world. It mainly recommends that teachers make learning more interesting and practical and integrate knowledge through hands-on practical tasks by adopting the maker spirit [1]. This way, students can cultivate their key competencies for the 21st century in innovating, critiquing, problem-solving, cooperating, and communicating [2]. Therefore, it is significant to integrate maker spirit into the school curriculum, create an innovative and hands-on atmosphere on campus, and cultivate high-quality talents with practical and innovative abilities.

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 167–173, 2022.
https://doi.org/10.1007/978-3-031-15273-3_18

Furthermore, maker education also fosters creative and critical thinking in traditional professional courses, encourages teachers and students to engage in creative interactions, and allows students to apply their professional knowledge in fields related to innovation and entrepreneurship [1]. Many scholars pointed out that the problem-based learning (PBL) curriculum design can enhance students' practical learning ability for innovation and creativity, cross-field integration, and hands-on practice while strengthening the link between classroom teaching and industrial practice [3, 4]. In response to the diverse needs of the rapidly changing world, universities of science and technology must cultivate students with the maker ability and maker spirit of communication, creative thinking, problem-solving, and cross-disciplinary learning.

Hence, this study aimed to conduct research on teaching practice and integrate maker spirit into the student-centered PBL topic as the basis for the "Innovation and Entrepreneurship Course" content design.

2 Teaching Method Design Concept and Theoretical Basis

2.1 Problem-Based Learning

PBL is a teaching method that enables learners to acquire knowledge and skills by researching and investigating complex problems or challenges [5]. Since the teaching method of PBL is inclined to real-time education, its main teaching features are practical hands-on operation, guiding students with problems to stimulate students' motivation for active learning, and solving problems with teamwork strategies [6].

2.2 Maker Education

Maker spirit encourages sharing and cooperation rather than competition, as any idea can be created by starting from fun with uninterrupted motivation [7]. Noteworthily, it is recognized by many scholars as a hands-on learning process that can positively improve students' knowledge absorption and creation ability [8]. Therefore, schools are encouraged to plan maker-themed courses and integrate maker education into cross-disciplinary subjects. Schools at all levels should make good use of maker space, plan a special course on the maker in the school-based curriculum, establish school characteristics and encourage students to develop their maker expertise [9].

In summary, this study proposed the following key points for implementing maker education as an important reference for the maker spirit–PBL innovation and entrepreneurship course design in this study: (1) students take the initiative, (2) students' creative ideas can be realized, (3) students understand their own works, (4) students can solve problems, and (5) students can demonstrate their self-confidence.

3 Research Design

The research was designed and planned according to the research purposes and literature review as follows: The "Maker Spirit–PBL Innovation and Entrepreneurship Course" was developed for this study. A mixed research design was adopted. After the teaching activity, a questionnaire survey was carried out to understand the students' learning status. Furthermore, the students' text data and their feedback on the learning experience were collected during the students' learning process. In addition, the students' data at the learning venue were cross-collected and verified, and their feelings toward the learning process were summarized and analyzed to verify the feasibility and effectiveness of the course. 49 students of the "Innovation and Entrepreneurship Course" were taken as the research subjects and were divided into 10 groups, each with 4 to 5 students.

The effectiveness questionnaire designed in this study included the three levels of "PBL Learning Effectiveness" (five items), and "Maker Practice Effectiveness" (five items). The factor loadings of each dimension were between .86 and .91, respectively; the total Cronbach's α was .89, indicating that the scale has good reliability.

The course design is including the planning of an 18-week course and the design of diversified industry teaching activities, such as writing business plans and financial planning, focusing on leading students to stimulate their own potential from implementation to practicing their own ideas. A brief description of the course implementation is as follows: 1st week–School Opening Week: The teaching objectives, course requirements, implementation methods, and assessment items of the "Maker Spirit–PBL Innovation and Entrepreneurship Course" were explained to the students. 2nd–15th weeks–Unit Teaching: The innovation and entrepreneurship course contained 14 units in total. 4th, 7th, 11th, and 16th weeks–Diversified Course Teaching: External industry teachers were employed to jointly teach and participate in the course to provide students with a more diverse and pragmatic learning experience. 9th and 10th weeks–Mid-term Seminar Report: The mid-term seminar report was implemented according to students' progress in each group. 7th–16th weeks–Project Production Course: The learning outcomes of each unit were integrated for students to apply their learnings to the project production competition. 17th–18th weeks–Final Seminar Report: Students in each group published and exchanged their project results.

4 Research Findings and Analysis

The following section discusses the impacts of "Maker Spirit-PBL Innovation and Entrepreneurship Course" on students' learning effectiveness from the two aspects, namely students' learning effectiveness, and comprehensive discussion:

4.1 Analysis of the Learning Effectiveness of Maker Spirit-PBL Innovation and Entrepreneurship Course

This study aimed to explore students' learning effectiveness in the "Maker Spirit-PBL Innovation and Entrepreneurship Course" at the university of science and technology. Hence, a questionnaire survey and statistical analysis were carried out for "PBL learning effectiveness", and "maker practice learning effectiveness", which are described as follows: The statistical results of basic data after analyzing the 49 questionnaires for the course are as follows. The majority of students in this course comprised 23 senior students, accounting for 46.9%. 16 junior students accounted for 32.7%; 6 sophomores accounted for 12.2%; 4 freshmen accounted for 8.2%.

1. In terms of "PBL learning effectiveness", (see Table 1), the average score of each item was between 4.38 and 4.56, the t-value was between 10.61 and 15.25, and all of them were significantly different. Item 3, "This course improves my ability to communicate with peers", scored the highest with an average of 4.56 (S.D. = .64) and a t-value of 15.25. The second-highest-scoring item was Item 1, "This course makes me understand the importance of teamwork", with an average of 4.46 (S.D. = .72) and a t-value of 12.68. Further, Item 5, "This course teaches me to embrace and appreciate diverse opinions", scored an average of 4.44 (S.D. = .79) and a t-value of 11.38.
2. In the aspect of "maker practice learning effectiveness" (see Table 1), the average score of each item was between 4.45 and 4.54, the t-value was between 11.28 and 16.01, and all of them were significantly different. Item 4, "This course can improve my problem-solving ability", scored the highest, with an average of 4.54 (S.D. = .60) and a t-value of 16.01. The second-highest-scoring item was Item 3, "This course offers me the opportunity to present my creative ideas", with an average of 4.51 (S.D. = .64) and a t-value of 14.68. Further, Item 2, "I can actively participate in the project production in this course", scored an average of 4.49 (S.D. = .82) and a t-value of 14.28.

Table 1. Summary of statistical analysis of learning effectiveness

	Aspect / Item	Average	S.D.	t
PBL	This course makes me understand the importance of teamwork	4.46	.72	12.68***
	This course provides the experience of team members discussing together	4.38	.81	10.61***
	This course improves my ability to communicate with peers	4.56	.64	15.25***
	This course provides an opportunity for me to share my experience with peers	4.38	.78	11.06***
	This course teaches me to embrace and appreciate diverse opinions	4.44	.79	11.38***
Maker practice	This course provides me with hands-on experience in making products	4.48	.64	13.43***
	I can actively participate in the project production in this course	4.49	.82	14.28***
	This course offers me the opportunity to present my creative ideas	4.51	.64	14.68***
	This course can improve my problem-solving ability	4.54	.60	16.01***
	This course gives me confidence in myself	4.45	.65	11.28***

4.2 Comprehensive Discussion

As shown in Fig. 1, the following is the description of the course implementation, focusing on "professional knowledge and ability development" and "innovative application implementation".

1. Professional Knowledge and Ability Development–PBL Significantly Strengthened Students' Learning Effectiveness of Professional Knowledge and Ability in Innovation and Entrepreneurship. The qualitative and quantitative analysis results showed that most students believe that their satisfaction in innovation and entrepreneurship learning and PBL is positive after the "Maker Spirit–PBL Innovation and Entrepreneurship Course", consistent with the research findings of Sumarni, Wardani, Sudarmin & Gupitasari [10]. Further, the student-centered PBL strategy was adopted for the "Innovation and Entrepreneurship Course" to plan physical teaching to provide students with teaching by diversified teachers, corporate visits, case discussions, and other practical learning stimulation [11]. Therefore, the intervention of online-assisted learning (virtual classroom) of the LINE group was needed to provide students with a learning channel without time and space constraints, including pre-class preview, group discussion, course feedback, and online consultation for the exchange of learning experience, which can improve students' learning interest and proactiveness [12].
2. Innovative Application Implementation—Maker & PBL Significantly Improved Students' Application Ability of Innovation and Entrepreneurship Implementation. The qualitative and quantitative analysis results showed that most students believe that their satisfaction with the maker practice experience and PBL is positive after the course, consistent with the research results of Terjesen and Elam [13]. A variety of learning activities were planned for this study's "Maker Spirit-PBL Innovation and Entrepreneurship Course", and government-related innovation and entrepreneurship competitions were integrated into the special topics so that students can look at problems with empathy, share ideas, and analyze problems and solutions through

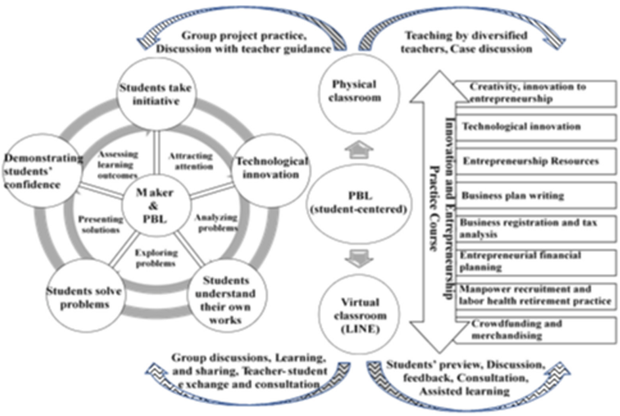


Fig. 1. Teaching design of maker spirit-PBL innovation and entrepreneurship course

online and offline team discussions [14]. Furthermore, students were encouraged to try innovative methods to solve problems and complete thematic tasks [15]. In this way, students' teamwork, beneficial communication, problem ideation, inquiry, and problem-solving skills can be enhanced.

5 Conclusion and Suggestions

In the era of fast and constantly changing technologies, cultivating talents with innovation and entrepreneurship knowledge and problem-solving ability has become a worldwide trend. In particular, improving the effectiveness of innovation and entrepreneurship education is an important topic that educational institutions in various countries eagerly discuss. Therefore, this study suggested that innovation and entrepreneurship course planning should not be confined to classroom teaching and on paper. Instead, more diverse and specific teaching stimuli should be planned for students, such as real case discussions, industry-teacher collaborative teaching, corporate visits, and maker project productions, to stimulate students' creativity. Students should also be encouraged to make products from their creative ideas and realize innovative attempts, problem-solving, teamwork, and entrepreneurial thinking from the practice of innovation, maker, and entrepreneurship. Thus, in enabling students to fully learn and participate in activities, it is suggested that teachers rely on and make good use of the convenience and versatility brought by technology in teaching.

References

1. Chung, C.C., Tsai, C.L., Cheng, Y.M., Lou, S.J.: Action research on integrating maker spirit and maker space for the special topic courses of engineering students in vocational high schools. Int. J. Eng. Educ. **36**(4), 1136–1150 (2020)
2. Lou, S.J., Chou, Y.C., Shih, R.C., Chung, C.C.: A study of creativity in CaC2 steamship-derived STEM project-based learning. Eurasia J. Math. Sci. Technol. Educ. **13**(6), 2387–2404 (2017)
3. O'Brien, R., McGarr, O., Lynch, R.: Exploring students' justifications for studying a master's degree in business through problem-based learning. Innov. Educ. Teach. Int. **58**(4), 398–407 (2021)
4. Tang, Y.T.: Application and implementation of problem-based learning teaching in an international marketing course. J. Teach. Pract. Pedagogical Innov. **2**(2), 75–114 (2019)
5. Reddy, S., McKenna, S.: The Guinea pigs of a problem-based learning curriculum. Innov. Educ. Teach. Int. **53**(1), 16–24 (2016)
6. Lou, S.J., Liang, C.P., Chung, C.C.: Effectiveness of combining STEM activities and PBL: a case study of the design of fuel-efficient vehicles. Int. J. Eng. Educ. **33**(6), 1763–1775 (2017)
7. Yeh, C.Y., Cheng, Y.M., Lou, S.J.: An internet of things maker curriculum for primary school students: Develop and evaluate. Int. J. Inf. Educ. Technol. **10**(12), 889–896 (2020)
8. Babu, S.K., et al.: Igniting the maker spirit: design and pilot deployment of the kappa tangible electronics prototyping kit. In: 2019 IEEE Tenth International Conference on Technology for Education (T4E), pp. 23–26. IEEE (2019)
9. Li, Z., Pei, S., Wang, Y.: Design and implementation of maker system based on wechat public platform present. Int. Core J. Eng. **7**(3), 350–359 (2021)

10. Sumarni, W., Wardani, S., Sudarmin, S., Gupitasari, D.N.: Project based learning to improve psychomotoric skills: a classroom action research. J. Pendidikan IPA Indonesia **5**(2), 157–163 (2016)
11. Fernández-Jiménez, C., Fernández-Cabezas, M., Sánchez, M.T.P., Batanero, M.C.D.: Autonomous work and skill learning strategies applying problem-based learning: experience of innovation in subjects related to disability. Innovations Educ. Teach. Int. **56**, 617–627 (2018)
12. Uludag, A., Apt, A.C.K.: The rise of blended learning in K–12: teacher perspectives on khan academy and student outcomes in mathematics in middle schools. Int. J. Educ. Res. **3**(12), 73–86 (2015). http://www.ijern.com/journal/2015/December-2015/07.pdf
13. Terjesen, S., Elam, A.: Transnational entrepreneurs' venture internationalization strategies: a practice theory approach. Entrep. Theory Pract. **33**(5), 1093–1120 (2009)
14. Chung, C.C., Cheng, Y.M., Shih, R.C., Lou, S.J.: Research on the learning effect of the positive emotions of "Ship Fuel-Saving Project'' APP for engineering students. Sustainability **11**(4), 1136–1159 (2019). https://doi.org/10.3390/su11041136
15. Hjorth, D., Johannisson, B.: Learning as an entrepreneurial process. Rev. de lEntrepreneuriat **8**(2), 57–78 (2009)

The Development of Constructivist Web-based Learning Environments Model to Enhance Critical Reading and Reading Literacy

Phennipha Thongkhotr and Sumalee Chaijaroen(✉)

Department of Education Technology, Faculty of Education, Khon Kaen University, Khon Kaen, Thailand
pennipa.t@kkumail.com, sumalee@kku.ac.th

Abstract. Critical reading and Reading literacy It is important and necessary to read in today's technology far and wide. If the reader has a critical reading and reading literacy will make the reader read more efficiently. This research applied the principles of critical reading and reading literacy to create a networked learning environment to promote critical reading and reading literacy. Therefore, this research aims to synthesize the theoretical framework of a networked learning environment that promotes critical thinking and reading literacy. Model Research [9]: The design and development process was used in the study in Phase I. The statistical method was document analysis and survey. The steps are as follows: 1) Synthesize a theoretical framework that consists of 5 components: context base, psychology base, technology base, critical reading base, and reading knowledge base. And learning environment a model of basic teaching, knowledge; 2) a synthesis of the constructivist theory framework; critical reading and reading literacy.

Keywords: Constructivist theories · Critical reading · Reading literacy

1 Introduction

Thai society is a rapidly changing society with new problems. Happens all the time Therefore, the development of quality people is the most important thing. In order to prepare people to be ready to accept the changes and step into the new era firmly and keep up with the world The basic mechanism of human development that is important is education. by education must develop quality people Actual and rational thinking [7], as can be seen from the 12th National Economic and Social Development Plan. 2017–2021, referring to the vision of Thailand's development as "It is to develop people as a whole to be complete people of all ages who are able to manage changes that are living environments well. Especially the development of human capital through upgrading the quality of education, learning, and skill development. And upgrading the quality of public health services in all areas as well as to promote the role of social institutions in fostering good people, discipline, good values and social responsibility [4].

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 174–179, 2022.
https://doi.org/10.1007/978-3-031-15273-3_19

Today's world is technology and information. Human beings can communicate all over the world. Knowledge and information can be obtained through various media, such as books, newspapers, magazines and electronic media. These treatments require basic reading skills and reading skills, which are very necessary in today's era [9].

Critical Reading and Reading Literacy are very necessary today, because it is a tool for intellectual development. Promote students' Reading Literacy ability, analyze and think about appropriate social benefits. In addition [5], the researchers asked Thai language teachers in junior high school and other Thai language teachers. The results show that most students' reading is still a challenge, and teachers should consider the guidelines and learning process. The purpose of this course is to develop students' reading and reading ability. Therefore, the concept of learning management must be changed to find appropriate methods. Improve reading and reading intelligence based on the design of learning environment The concept of a large amount of information and information in the creation of knowledge must be highly consistent with the philosophy of materialism. What are the constructive answers to these questions? It is important to find the truth of knowledge. [1] put forward the basis of the philosophy of knowledge creation. Knowledge is conscious communication through experience or environment.

According to the Ministry of Education [6], Reading Literacy is a skill that is essential for learning. And life development to success fluent reading and understanding the meaning will bring knowledge and encourage analytical thinking, critical thinking, separation and application of useful information for life. as well as being able to communicate knowledge and ideas to others to know and understand This is an important skill in the 21st century. or lack of ability to read will result in learning unable to progress and will suffer hardships in life Therefore, it is the duty of the departments involved in educational management to develop reading ability. Promote analytical thinking and communication to people from a young age to be able to learn at a more complex level as they grow up and lead to being a lifelong learner Therefore, during the period of 9 years of providing compulsory education and 12 years of providing basic education for children and youth It is therefore an important time to lay the foundation for students who are capable of solid learning. Which literacy or literacy read fluently write fluently and able to communicate It is the first and most important foundation of the development of learners' abilities The development of reading ability In addition to the teacher must have knowledge, understanding, skills and processes to develop students' reading ability. Both regular students and students who need special attention must also understand the difference between students. Both intellectual differences and differences in family background are important factors to consider in the development of learners' reading ability [1].

For the above reasons, Therefore, researchers realize the importance of developing web-base learning environment and improve reading literacy through constructivist methods. The conceptual framework of learners' abilities according to Programmed for International Student Assessment (PISA) [5], guidelines based on theoretical framework including studying various research. To develop a student-centered teaching and learning process, to develop a web-based learning environment model that promotes reading literacy, which is an important and one of the goals of Thai language learning management at all levels. Especially at the secondary level which the findings will lead to the development of learners along with learning in today's world.

2 Methodology

The purpose of this study was to synthesize a theoretical framework of constructivism to promote critical reading and reading literacy. Research methodology is a method of analyzing research design documents for the study of constructivist theories. Critical reading and reading literacy.

3 Theoretical Framework

We aim at the framework design. This theoretical framework is synthesized from the study and analysis of the principles, theories and literature related to design. Cognitive theory constructivist theory A constructivist learning environment model to promote critical reading and reading literacy. Theoretical framework shows five key theoretical bases. Theoretical framework illustrates five key theoretical foundations: 1) Psychology base 2) Teaching base 3) Media and technology base 4) Critical Reading and Reading Literacy base 5) Context of junior high school students.

4 Method and Result

4.1 Data Collection

In this study, Researchers have created tools to study and collect data. Document research tools are detailed as follows: 1) Documents, audits and analysis to create a theoretical framework, use the theoretical framework to record, analyze, and analyze theoretical documents and conduct research related to critical reading and writing, 2) student surveys on learning contexts, 3) teacher surveys on learning management contexts.

Detailed data analysis 1) The theoretical framework uses analytical methods by description and analytical conclusions. Interpretation of the principles, related theories, research papers and from the analysis of documents from the data 2) the teaching context of the learner. Use data analysis methods as "Fig. 1".

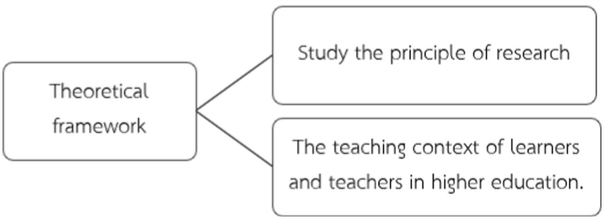


Fig. 1. Show how to collect data, how to conduct research.

4.2 Research Results

This research is synthesized from literature (literary) reviews, research papers from theoretical studies. About constructivism that promotes critical reading and reading literacy The theory framework provides a theoretical foundation relevant to constructivism to promote critical reading and reading literacy. The theoretical framework outlines five major theoretical foundations: 1) Psychology, 2) Teaching, 3) Media and Technology, 4) Critical Reading and Reading Intelligence, and 5) Student Context. Junior high school as in Fig 2.

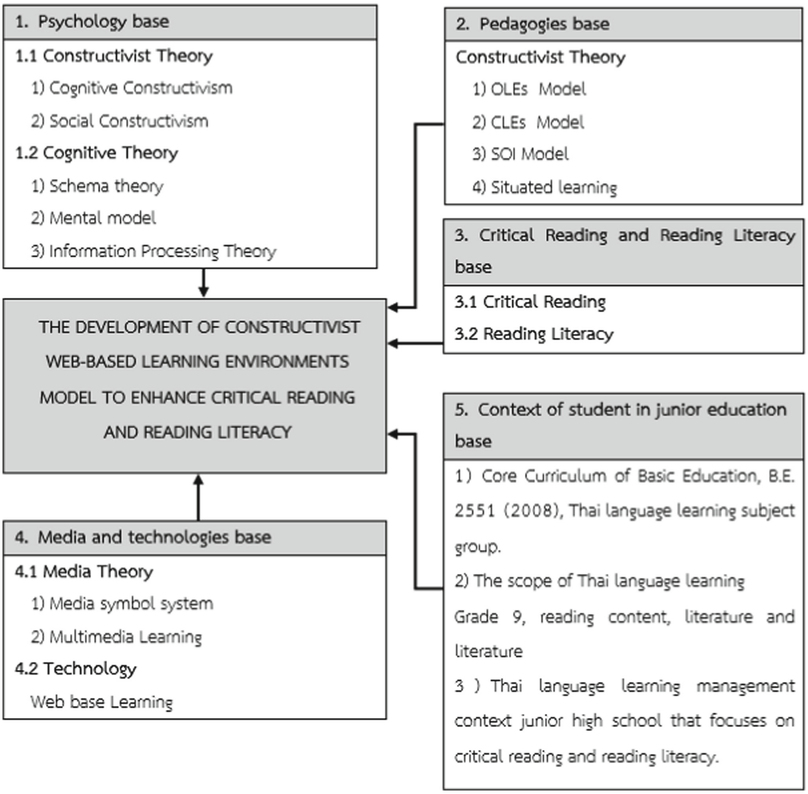


Fig. 2. A theoretical framework of constructivism that promotes critical reading and reading literacy.

Psychological Base: The Development of Constructivist web-base learning environment model to enhance that promotes critical reading and reading literacy. It is studied using two principles: Piaget 's cognitive constructivist theories and Vygotsky's social constructivist theories have been applied [10].

Pedagogies Base: Principles of learning environment design. The Hannafin OLEs [3] focus on the development of critical reading and reading literacy, This allows students to create many alternatives to different elements and principles. Design principles of learning environment The focus of the learning environment of the Comtism is to develop critical reading and reading literacy combined with the contextual education of learners and teachers to design the learning environment for maximum efficiency [8].

Media and Technologies Base: The basis of media and technology is media symbol system principles that describe the impact of a web-based learning environment. Each type of media has a symbolic system. The symbol system is the basis of design. Features of each media design [9].

Critical Reading and Reading Literacy Base: The foundation of critical reading and reading literacy correspond to literacy and critical literacy. [5] It is the ability of a person to consider the message or messages received and synthesize, analyze and evaluate it appropriately [8].

Context of Student in Junior Education Base: Designing a course that corresponds to Criteria. Standard framework for lower secondary education curriculum and with the scope of learning Thai language Grade 9 in reading and literary literature It is a framework that Demonstrates the country's lower secondary education system [6].

5 Conclusion

The purpose of this study is to synthesize the theoretical framework of critical reading and reading comprehension. Comprehensive theoretical framework of research and analysis principles, theory and related literature design, theoretical knowledge and understanding. Web based learning environment model, symbol system Research tools and data collection developed by researchers. In the literature and survey of learning management, data analysis adopts the theoretical framework. Teaching and context analysis of teaching and learning Research based on theoretical studies on constructivism to promoting critical thinking and reading literacy in reading in the junior middle school level. The theoretical framework includes psychological basis, teaching media basis and technical basis. On the basis of critical reading, reading comprehension and junior middle school students' context This study will be developed and applied to the junior middle school level.

References

1. Auranatraksa, H.: A model of learning environments enhancing learner's critical thinking and responsibility. Faculty of Education, Khon Kaen University (2013)
2. Sathanarugsawait, B., Samat, C.: Synthesis of theoretical framework of constructivist creative thinking massive open online courses (moocs) for higher education. In: Wu, T.-T., Huang, Y.-M., Shadieva, R., Lin, L., Starčič, A.I. (eds.) ICITL 2018. LNCS, vol. 11003, pp. 146–150. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-99737-7_14
3. Hannanfin, M., Land, S., Oliver, K.: Open learning environments: foundations, methods, and models. In: Reigeluth, C.M. (ed.) Instructional Design Theories and Models: A New Paradigm of Instructional Theory, vol. II. Lawrence Erlbaum Associates, Newjersy (1999)

4. Kanjug, I.: Development of learning environments model enhancing expertise mental model. Faculty of Education, Khon Kaen University (2009)
5. OECD: PISA 2018 Assessment and analytical Framework, PISA. OECD Publishing, Paris (2019)
6. Office of the National Education Commission: National Education Plan (2002–2016): the conclusion. Sweet graphics, Bangkok (2011)
7. Samat, C.: The development of constructivist web-based learning environment model to enhance creative thinking for higher education students. Faculty of Education, Khon Kaen University (2009)
8. Chaijaroen, S. et.al.: A study of thinking potential of students studying instructional innovation enhancing thinking potentiality. A Research Report (2007)
9. Wattanachai, S.: Design and development of constructivist web-based learning environment model to foster problem solving and transfer of learning. Faculty of Education, Khon Kaen University (2008)
10. Vygotsky, L.S.: Mind in Society: The Development of Higher Psychological Processes. Harvard University Press, Cambridge (1980)

The Development of Constructivist Web-Based Learning Environment Model to Enhance Solving Mathematic Problems of Statistics for High School Grade 11

Sathapon Chaisri(✉), Sumalee Chaijaroen, and Sarawut Jackpeng

Department of Education Technology, Faculty of Education, Khon Kaen University, Khon Kaen, Thailand

sathapon_c@kkumail.com

Abstract. Objective of research was to develop learning of constructivist environment model to enhance solving mathematic problems and to examine the learners' solving mathematic problems. There were three phases model research is model development, model validation and model use. The target group consisted of 18 high school grade 11 school registered in the mathematics course on statistics in the academic year 2021, 10 teachers of mathematics on statistics in the academic year 2021. Model research was designed for each domain following the subject matters media and teaching design by the expert and outsourcing technical support including; 1 researcher, 1 designer, 1 developer, and 3 experts. Qualitative and quantitative data were gathered. Protocol analysis used summarization elucidation and assay description was applied to analyze the qualitative data and analyzed by descriptive statistics consisted of means, standard deviation, and percentages. The result pointed out that development learning of constructivist environment model to enhance solving mathematic problems comprised of 8 components; 1) problem bases, 2) resources, 3) related cases, 4) tool learning center, 5) communication learning center, 6) solving mathematic problems center, 7) scaffolding, and 8) facilitating. The troubleshooting of student learning with constructivist learning environment to enhance solving mathematic problems from evaluation of solving mathematic problems achieved a mean score of 47.28 (S.D. = 3.06). There were 94.56% of all students passed the criteria of 80%, and there were 94.44% of all students passed the specified scores of 80%. Problem solving of student learning with learning of constructivist environment to enhance solving mathematic problems resulted from the asking in the protocol analysis consisted of 5 processes; 1) understanding the problem, 2) problem representations and searching for solutions, 3) planning, 4) carrying out the plan and 5) following up.

Keywords: Model research · Learning environment · Constructivist theory · Solving mathematic problems · Web-based learning

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 180–186, 2022.
https://doi.org/10.1007/978-3-031-15273-3_20

1 Introduction

Technology is rapidly changing and impacting lives in many aspects, especially, in education. The furtherance of technology is affected globalization. Learning and problem solving skills are imperative for a human being in learning [1, 2]. However, most instructional pedagogy focused on communicating and memorizing information. There is lacking problem solving skills quest development for the learners [3]. Hence, the teaching design must be improved to arrange problem solving and acquiring knowledge instead of latently getting the knowledge. Instructional design theory [4] is the learning strategy counting on innovation that is applied to be consistent with the child centered. Continuation and lifelong learning can emulate and participate creatively affecting the modern learners in the world more than teaching students to remember [5]. Cognitive constructivism and social constructivism are the important theories, utilized as a foundation of the constructivist theories. Cognitive theories are an approach to learning focused on; schema theory, information processing, metacognition theory, cognitive load theory, and mental model theory [6]. This whole theory delivered learners to acquire knowledge and solving mathematic problems [7] and support knowledge construction [8]. Mathematics problem solving utilized their knowledge, mathematics experience, and other science to analyze, synthesize, and decide. The mathematicians need to explore the student's abilities related to the theories. It has got to educate problem solving techniques among students more than finding the answer to the problem. In addition, it should energize the learners to discover the patterns of problem solving, or manually done. There should be a focus on the students' thinking skills [9]. Researchers realized the importance of studying the process of development of learning of constructivist environment model to enhance solving mathematic problems. This study aimed at studying process of the problem solving of student learning with learning of constructivist environment to enhance solving mathematic problems by evaluating solving mathematic problems scores of students and from asking students' problem solving and by protocol analysis.

2 Research Methodology

Research was model research [10] comprised 3 phases: 1) Model development 2) Model validation and 3) Model use. Model development was studying the process developing of constructivist web-based learning environment model to enhance solving mathematic problems. There were 6 processes; 1) Literature review, 2) Exploring the learning context, 4) Synthesize theoretical framework, 5) Synthesize designing framework, and 6) Model development. Model validation is the studying quality of the model evaluated by experts 3 person domains; subject matter, media, and teaching design. Model use launched to test the effective utilization of solving mathematic problems measure.

2.1 Research Objectives

Research aimed at studying process of development learning of constructivist environment model to enhance solving mathematic problems and pre-experimental design using a one-shot case study depending on the evaluation of solving mathematic problems scores of student and information from interviewing student's problem solving and by protocol analysis.

2.2 Target Group

There are consisted of 18 high school grade 11 school registered in the mathematics course on statistics in the academic year 2021. There were the subject matters, media, and instructional design collaborated in this study; 10 teachers of mathematics on statistics in the academic year 2021, 1 researcher, 1 designer, 1 developer, and 3 experts for each domain.

2.3 Research Tools

The instruments comprised of 9 instruments as follows;

- Record form which applicable for record assay of documents and related research,
- Survey form which applicable for learning context,
- Survey form which applicable for attribute to students, teachers, researcher, designers, and developers,
- Record form which applicable for synthesizing theoretical framework,
- Record form which applicable for synthesizing designing framework,
- The experts' assessment forms applicable for each domain are as follows; subject matters, media, teaching design,
- Learning of constructivist web-based environment model to enhance solving mathematic problems,
- Measurement form which is applicable for solving mathematic problems,
- Interview form which is applicable for an in-depth interview.

2.4 Data Collection and Analysis

Quantitative data was analyzed by protocol analysis. Conclusion and explication and analytical description were employed analysis qualitative data. Descriptive statistics were used to assay quantitative data.

3 Research Results

3.1 Model Development

The result yielded that development learning of constructivist environment model to enhance solving mathematic problems consisted of 8 elements: 1) problem bases, 2) resources, 3) related cases, 4) tool learning center, 5) communication learning center, 6) solving mathematic problems center, 7) scaffolding and 8) facilitating, as shown in Figs. 1, 2, 3, and 4.

Fig. 1. Problem bases and resource.

Fig. 2. Related cases and tool learning center.

Fig. 3. Communication learning center and solving mathematic problems center.

Fig. 4. Scaffolding and facilitating.

Table 1. Quality of the constructivist learning environment model.

No.	Assessment item	Expert		
		No. 1	No. 2	No. 3
1	Subject matter			
	1) Suitable of subject matter	+1	+1	+1
2	Media			
	1) Suitable navigation icon	+1	+1	+1
	2) Suitable constituent art	+1	+1	+1
	3) Suitable animations	+1	+1	+1
	4) Stability	+1	+1	+1
3	Teaching design			
	1) Problem bases	+1	+1	+1
	2) Resource	+1	+1	+1
	3) Related cases	+1	+1	+1
	4) Tool learning center	+1	+1	+1
	5) Communication learning center	+1	+1	+1
	6) Solving mathematic problems center	+1	+1	+1
	7) Scaffolding	+1	+1	+1
	8) Facilitating	+1	+1	+1

3.2 Model Validation

The quality of learning of constructivist environment model to enhance solving mathematic problems evaluated by experts 3 person in 3 domains as follows; subject matter, media, and teaching design. Results were shown in Table 1.

Table 1, Learning subject matter feature, experts 3 persons agreed that subject matter is suitable for learners. Media aspect, experts agreed that the navigation icon, constituent art, and animations are stable and capable. The last aspect, instructional design, experts agreed that all components are suitable and functional.

3.3 Model Use

The problem solving of student learning with learning of constructivist environment to enhance solving mathematic problems from interviewing student problem solving and protocol analysis consisted of 5 processes; 1) Understanding the problem, 2) Problem representations and searching for solutions, 3) Planning, 4) Carrying out the plan and 5) Following up. Evaluation of solving mathematic problems scores, the results were shown in Table 2.

According to Table 2, Problem solving of student learning with constructivist learning environment to enhance solving mathematic problems from evaluation of solving mathematic problems mean scores of students was 47.28 (S.D. = 3.06).

Table 2. Evaluation solving mathematic problems scores.

Number of students	Means ($\overline{X}$)	Standard deviation (S.D.)	Percentage (%)	Number of students passed specified	
				Number of students	Percentage (%)
18	47.28	3.06	94.56	17	94.44

There was 94.56% passed the criteria of 80%. There were 94.44% of all students passed the specified scores at 80%.

4 Conclusion and Discussion

Development learning of constructivist environment model to enhance solving mathematic problems consisted of 8 components; 1) Problem bases, 2) Resources, 3) Related cases, 4) Tool learning center, 5) Communication learning center, 6) Solving mathematic problems center, 7) Scaffolding, and 8) Facilitating. The validation of the quality of the model evaluated by the expert 3 person agreed that the subject matter is suitable for learners 3 domains; the learning subject matter aspect. The media aspect, the navigation icon, constituent art, and animations were appropriate and stable to use in this study. Teaching design, experts concurred that all constituent were suitable and functional. Problem solving student learning with constructivist learning environment to enhance solving mathematic problems from evaluation solving mathematic problems mean scores was 47.28 (S.D. = 3.06). There was 94.56% passed the criterion of 80%. There were 94.44% of all students passed the specified scores of 80%. Problem solving of student learning with constructivist learning environment to enhance solving mathematic problems resulted from interviewing in the protocol analysis consisted of 5 processes; 1) understanding the problem, 2) problem representations and searching for solutions, 3) planning, 4) carrying out the plan and 5) following up. This study was stable with prior research related to developing the learning of constructivist environment model using the theory of problem solving [11]. The theoretical validity of constructivist web-based learning environment model designed was reviewed by experts 3 person. The discovery could be supported the solving mathematic problems [10]. The designing of a constructivist web-based learning environment consisted 5 processes that may assist the learner to acquire the knowledge and enhance the higher-order thinking skills. Problem solving occurred among learners of 7 processes from well-structured problem solving [1].

Acknowledgements. This study supported by educational technology, Faculty education, Research group for innovation and cognitive technology, Khon Kaen University, research and technology transferring affairs section, Khon Kaen University, and graduate school, Khon Kaen University which hereby giving the gratitude to all through this.

References

1. Jonassen, D.H.: Instructional design models for well-structured and ill-structured problem solving learning outcomes. Educ. Tech. Res. Dev. **45**(1), 65–97 (1997). https://doi.org/10.1007/BF02299613
2. Dede, C.: Comparing frameworks for 21st century skills. 21st Century Skills Rethinking How Students Learn **20**, 51–76 (2010)
3. Mai, N., Tse-Kian, N.: Engaging students in multimedia-mediated Constructivist learning Students' perception. Educ. Technol. Soc. **12**(2), 254–266 (2009)
4. Fosnot, C.T.: Constructivism: a psychological theory of learning. In: Fosnot, C.T. (ed.) Constructivism: Theory, Perspectives, and Practice, pp. 8–33. Teachers College Press, New York (1996)
5. Akyol, S., Fer, S.: Effects of Social Constructivist Learning Environment Design on 5th Grade Learners' Learning. Procedia - Soc. Behav. Sci. **9**, 948–953 (2010)
6. Wongchiranuwat, S., Samat, C.: Synthesis of theoretical framework for augmented reality learning environment to enhance creative thinking on topic use of graphic design for grade 9 students. In: 24th International Conference on Computers in Education: Think Global Act Local - Main Conference Proceedings, pp. 639–641 (2016)
7. Cobb, P.: Where is the mind? Constructivist and sociocultural perspectives on mathematical development. Educ. Res. **23**(7), 13–20 (1994)
8. Wang, Y., et al.: Perspectives on cognitive computing and applications. Int. J. Softw. Sci. Comput. Intell. **2**(4), 32–44 (2010)
9. Yuan, S.: The teacher's role in problem-solving: a study of elementary mathematics programs from teachers' perspectives. A research paper submitted in conformity with the requirements for the degree of master of teaching department of curriculum, Teach. Learn. Ontario Inst. Stud. Educ. Univ. Toronto (2016)
10. Richey, R.C., Klein, J.D.: Design and Development research Methods, Strategies and issues. Lawrence Erlbaum Associates, Mahwah (2007)
11. Samat, C., Chaijaroen, S.: Design and development of learning environment to enhance creative thinking and innovation skills for teacher training in the 21st century. In: Proceedings of the 23rd International Conference on Computers in Education, ICCE 2015, pp. 667–672 (2015)

Theoretical and Designing Framework of Constructivist Learning Environment Model that Promotes Ill-Structured Problem Solving and Competence in Psychomotor Skills for Industry Students

Onnapang Savaengkan(✉) and Sumalee Chaijaroen

Department of Educational Technology, Khon Kaen University, Khon Kaen 40002, Thailand
kaorao@kkumail.com, sumalee@kku.ac.th

Abstract. Workers graduating from vocational institutions are of great importance for the development of the domestic industry and to promote the domestic industry to drive efficiently. Vocational institutions must produce knowledgeable workers. Analytical ability and able to solve problems with complex structures and competence in practical skills. Therefore, this research aims to synthesize the theoretical framework and design of a constructivist theory-based learning environment to promote poorly structured problem solving and cognitive skills. This research is used model research (Richey and Klein 2007) that focuses on the design processes and the development of learning models consisting of 3 steps. The steps include 1) Document analysis and learning context 2) Analysis of principles of learning theory and learning design theory 3) Synthesis and creation of theoretical framework and design framework. The research results showed that There are five elements of theory that support research to achieve its objectives: (1) learning theory (2) teaching style (3) contextual basis (4) poorly structured problem solving and skill proficiency. (5) Media Theory The design framework has five main goals: (1) stimulating cognitive structuring (2) promoting cognitive balance (3) promoting problem solving with poor structure (4) to promote the ability of mental skills; (5) the promotion and helps to create intellectual balance The framework design consisted of seven elements: (1) Problem situation, (2) Learning Resources, (3) Promoting ill-structured problem solving Center, (4) Promoting competence in psychomotor skills Center, (5) Collaboration Center, (6) Scaffolding Center, (7) Development center learning.

Keywords: Constructivist theories · Ill-structured problem · Psychomotor skills

1 Introduction

Developing personnel to be ready for the transformation of a learning and innovation society. Must have an educational model that focuses on analysis Discrimination And rational and modern integration (Jithitikulchai 2020). This kind of thinking helps thinkers

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 187–194, 2022.
https://doi.org/10.1007/978-3-031-15273-3_21

to clearly understand and identify the cause of the problem. Especially the middle and high-level manpower in industrial development It is necessary to have knowledge that can be accumulated as a specialized skill in each branch. To be consistent with the development of the country's specific industry and therefore it is important for students in the 21st century, along with organizing vocational education that requires the production of middle-class manpower into the labor market. Including courses according to the competence of the Vocational Education Commission (VEC). Which is a teaching program that is mainly focused on students and encourages and encourages students to do activities in real locations Have thinking and problem solving skills to integrate with work in various professions.

Workers who graduate from vocational institutions. It is extremely important to the development of the domestic industry. And to promote the domestic industry to drive efficiently Vocational institutions must produce workers with knowledge, analytical ability, and can promote ill-structured problem solving and competence in psychomotor skills. The research therefore recognizes the importance of creating a learning environment for industrial department students in vocational institutions. To have the ability to analyze solutions that are structured, ill-structured problem solving and competence in psychomotor skills. Therefore, this research aims to study and develop the theoretical framework of the learning environment. Enlightenment to promote solutions to ill-structured problem solving and competence in psychomotor skills.

2 Research Purpose

The objective of this research is on to study the design and development of a model of the learning environment based on constructivist concepts to promotes ill-structured problem solving and competence in psychomotor skills. And develop the theoretical framework and designing framework of constructivist learning environment model to promotes ill-structured problem solving and competence in psychomotor skills.

3 Research Methodology

This research focuses on the design and development of models. The research is divided into 3 steps. In this research, Phase 1 is the development of models. With the objective of designing and developing a network based learning environment model that promotes based on constructivism that promote ill-structured problem solving and competence in psychomotor skills.

3.1 Target Group

The target group in this research consists of Model quality inspection experts 3 People, measurement and evaluation experts 3 People are experts in the design framework assessment and selection of first-year students at high vocational certificate level, Nakorn Khon Kaen Technological College by purposive sampling.

3.2 Research Instruments

The tools used in the Phase 1 study were to develop a model. It consists of tools used to synthesize a theoretical framework, a design conceptual framework. Which the design of the model elements. The model quality assessment was used as follows: (1) Teaching Context Survey (2) Learner Character Survey (3) Teacher Character Survey (4) Designer Character Survey (5) Developer Attribute Survey (6) Developer's Characteristics Interview Form (7) Theoretical Conceptual Synthesis Record Form (8) Design Concept Framework Synthesis Record Form (9) Environmental Model Element Design Record Form Learning that promotes ill-structured problem solving and competence in psychomotor skills for industrial students (10) Notes on the development of a learning environment model that promotes ill-structured problem solving and competence in psychomotor skills for industrial students; and (11) A learning environment model quality assessment that promotes ill-structured problem solving and competence in psychomotor skills for industrial students for experts.

3.3 Data Collection and Data Analysis

Data collection can be divided into three parts: designing and developing a learning environment model that promotes ill-structured problem solving and competence in psychomotor skills for industrial students, the process of designing and developing a learning environment model that promotes ill-structured problem solving and competence in psychomotor skills for industrial students, and to monitor the quality of learning environment models that promotes ill-structured problem solving and competence in psychomotor skills for industrial students: (1) Design and development of a learning environment model that promotes ill-structured problem solving and competence in psychomotor skills for industrial students. Gather information from review of related articles and research. And analyze the data using summaries, interpretations, and analytical lectures. (2) The design and development process of a learning environment model that promotes ill-structured problem solving and competence in psychomotor skills for industrial students. Data is collected from surveys using the synthesis model of notes. And analyze the data using summaries, interpretations, and analytical lectures (3) Quality monitoring of learning environment models that promote promotes ill-structured problem solving and competence in psychomotor skills for industrial students. By collecting data from expert evaluations and analyzing data using summaries, interpretations, and analytical lectures.

4 Research Results

4.1 Theoretical Framework

The synthesis of theory and research reports found that. The theoretical framework consists of the fundamentals 5 as follows: 1) Fundamentals of psychological learning Theory of constructivist And cognitive theory, 2) Fundamentals of Pedagogical Sciences of Constructivist Learning Environment (CLE), Open Learning Environment (OLE), Select Organize Integrate (SOI), 3) Fundamentals of ill-structured problem solving and competence in psychomotor skills is Ill-structured problem solving and Psychomotor Skills, 4) Fundamentals of Media Theory and Technology is Media Theory and Web base Technology, and 5) Contextual Fundamentals is teaching and learning context and learning support Nakorn Khon Kaen Technological College (See Fig. 1).

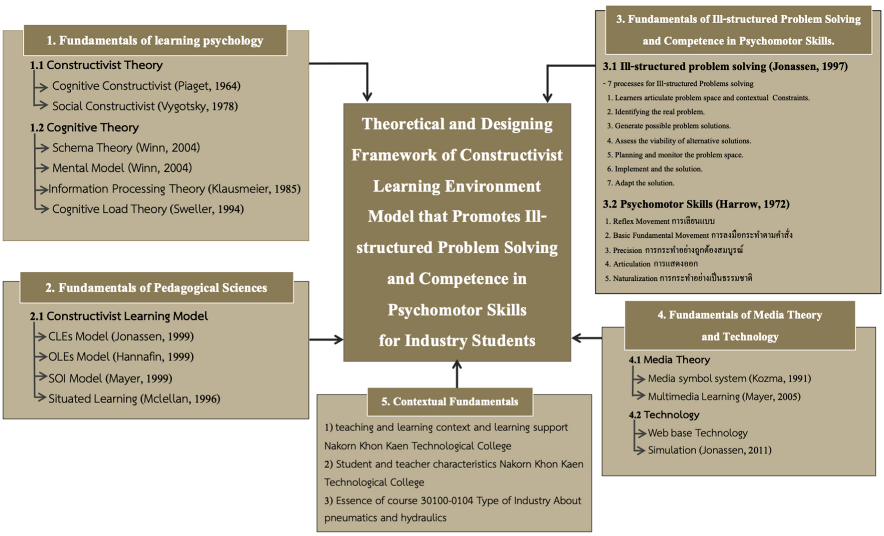


Fig. 1. Theoretical framework of constructivist learning environment model that promotes Ill-structured problem solving and competence in psychomotor skills for industrial students

4.2 Designing a Framework

Theoretical framework and design of Constructivist Learning Environment Model that promotes Ill-structured Problem Solving and Competence in Psychomotor Skills for Industry Students. (See Fig. 2). Show 4 steps as follows:

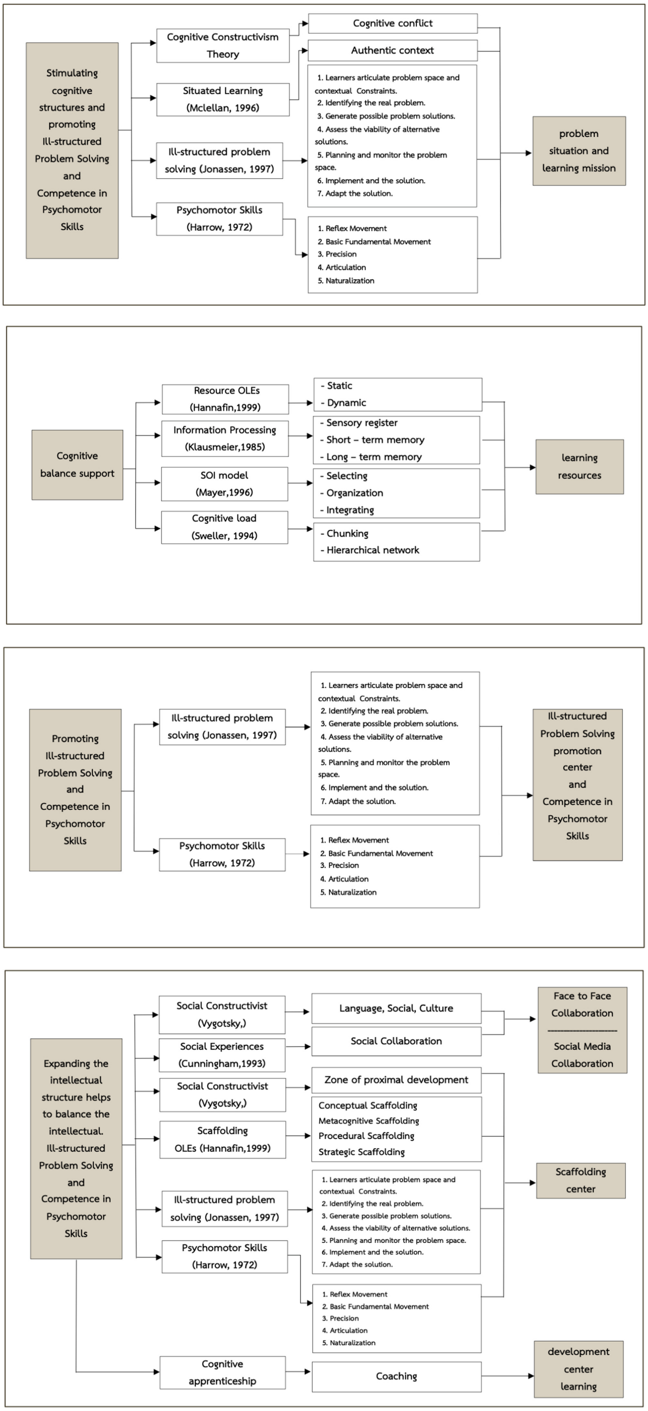


Fig. 2. Designing framework of constructivist learning environment model that promotes Ill-structured problem solving and competence in psychomotor skills for industrial students

1. **Stimulating cognitive structures and promoting Ill-structured Problem Solving and Competence in Psychomotor Skills.** Designed on the basis of Cognitive Constructivism by Piaget, this foundation believes that students inspired by problem situations lead to a state of cognitive conflict, enabling them to strive for intellectual balance. The process of putting it into a learning context or a complex problem is another factor that encourages students to build their knowledge. Students still need to be inspired by structural problem solving. Jonassen (1997) while solving different situations with Functionalist theory. It is what stimulates and promotes problem solving that is poorly structured. All of this is the design of **problem situations and learning mission.**
2. **Cognitive balance support.** This step helps students to balance their cognitive or knowledge building after they are faced with complex situations. Things that encourage students to do include skills, concept of knowledge use of intellectual tools, using the media symbol system Communicate and exchange knowledge between students. These are all important components of learning resources. **Learning resources.**
3. **Promoting Ill-structured Problem Solving and Competence in Psychomotor Skills.** The composition is designed according to Jonassen's problems solving theory which consists of 7 areas: (1) Learners articulate problem space and contextual Constraints, (2) Identifying the real problem, (3) Generate possible problem solutions, (4) Assess the viability of alternative solutions, (5) Planning and monitor the problem space, (6) Implement and the solution, (7) Adapt the solution. And the component is designed according to Harrow's Psychomotor Skills which consists of 5 areas: (1) Reflex Movement, (2) Basic Fundamental Movement, (3) Precision, (4) Articulation, and (5) Naturalization. These skills are essential for students to stimulate their promotes ill-structured problem solving and competence in psychomotor skills. All of this creates the **Ill-structured Problem Solving promotion center and Competence in Psychomotor Skills.**
4. **Expanding the intellectual structure helps to balance the intellectual. Ill-structured Problem Solving and Competence in Psychomotor Skills.** In constructivist social theory It is believed that low-skilled or knowledgeable learners need to be empowered and self-developed. In principle, the Open Learning Environment (OLE) requires students to be assisted in areas including strategies, concepts, metacognition, and procedures. Students need advice or assistance from someone with expertise. All of these are designed as **Face-to-Face Collaboration, Social Media Collaboration, Scaffolding center, development center learning.**

5 Summary and Conclusion

The objective of this study is to synthesize the theoretical framework and design of a constructivist theory-based learning environment to promote poorly structured problem solving and the ability to use mental skills. This research focuses on the synthesis of design processes and the development of learning models. The results showed that the elements of the theoretical framework consisted of 5 components: 1) Fundamentals of learning Psychology Constructivist Theory and Cognitive Theory, 2) Fundamentals of Pedagogical Sciences of Constructivist Learning Environment (CLE), Open Learning Environment (OLE), Select Organize Integrate (SOI), 3) Fundamentals of ill-structured problem solving and competence in psychomotor skills., 4) Fundamentals of Media Theory and Technology is Media Theory and Web base Technology, and 5) Contextual Fundamentals that consists of Jonassen's problems solving theory principles and the Psychomotor skills principles of Harrow. The design framework had 4 key goals: 1) stimulating cognitive structures and promoting poorly structured problem solving and mental skill abilities; It was designed on the basis of Intellectual Constructivism by Piaget, this foundation believes that students inspired by problem situations lead to a state of cognitive conflict, enabling them to strive for a consistent cognitive balance. The process of putting it into a learning context or a complex problem is another factor that helps students build their knowledge. Students are also encouraged to solve poorly structured problems (Jonassen 1997) while solving situations with Functionalist theory. It is what stimulates and promotes ill-structured Problem Solving. 2) Cognitive balance support. This step helps students to balance their cognitive or knowledge building after they are faced with complex situations. What students are encouraged to do are skills. concept of knowledge use of intellectual tools Using the media symbol system Communicate and exchange knowledge between students. 3) Promotes ill-structured problem solving and mental skill abilities. The components are designed according to Jonassen's problem solving theory, which consists of 7 aspects: (1) Learners articulate problem space and contextual Constraints, (2) Identifying the real problem, (3) Generate possible problem solutions, (4) Assess the viability of alternative solutions, (5) Planning and monitor the problem space, (6) Implement and the solution, (7) Adapt the solution. And the component is designed according to Harrow's Psychomotor Skills which consists of 5 areas: (1) Reflex Movement, (2) Basic Fundamental Movement, (3) Precision, (4) Articulation, and (5) Naturalization. These skills are necessary for students to stimulate them promotes ill-structured problem solving and competence in psychomotor skills. And 4) Expanding the intellectual structure helps to balance the intellectual. Ill-structured Problem Solving and Competence in Psychomotor Skills. In constructivist social theory It is believed that low-skilled or knowledgeable learners need to be empowered and self-developed. In principle, the Open Learning Environment (OLE), students are encouraged in areas including strategy, concepts, metacognition, and procedures. Need advice or help from a professional. All of these are designed as Face-to-face Collaboration, Social Media Collaboration, Scaffolding center, Development learning center.

Acknowledgements. This research was supported by Ph.D. Program in Educational Technology, Faculty of Education, Research Group for Innovation and Cognitive Technology, Khon Kaen, University, and Research and Technology Transfer Affairs Division, Khon Kaen University which hereby giving the thankfulness all through this.

References

Brown, J., Collins, A., Duguid, P.: Situated cognition and the culture of learning. Educ. Res. **18**(1), 32–42 (1989)

Chaijaroen, S., Samat, C.: Design and development of learning environment to enhance creative thinking and innovation skills for teacher training in the 21st century. In: 23rd International Conference on Computers in Education, pp. 667–672. Asia-Pacific Society for Computers in Education, Hangzhou (2015)

Jonassen, D.H.: Instructional design models for well-structured and ill-structured problem-solving learning outcomes. Educ. Technol. Res. Dev. **45**, 65–94 (1997)

Duffy, T.M., Cunningham, D.J.: Constructivism: implications for the design and delivery of instruction. Handb. Res. Educ. Commun. Technol. **30**(2), 111–115 (1996)

Duffy, D., Jonassen, D.: Constructivist and Technology of Instruction: a Conversation. Erlbaum, New Jersey (1999)

Kim, J.Y., Lim, K.Y.: Promoting learning in online, ill-structured problem solving: the effects of scaffolding type and metacognition level. Comput. Educ. **138**, 116–129 (2019)

Kozma, R.B.: Learning with media. Rev. Educ. Res. **61**, 179–212 (1991)

Mayer, R.E. Designing Instruction for Constructivist Learning. Instructional Design Theories and Model: A New Paradigm of Instructional Theory Volume II. Lawrence Erlbaum Associates, New Jersey (1996)

Richey, R.C., Klein, J.D.: Design and Development Research: Methods, Strategies, and Issues (2007)

Wattanachai, S. Development of constructivist web-based learning environment model to foster problem solving and transfer of learning. Doctor of Philosophy Thesis in Education Technology, Graduation School, Khon Kaen University (2010)

Chaijaroen, S.: Constructivism theory. Education Technology, Graduation School, Khon Kaen University (2002)

Jithitikulchai, T.: Labour skills, economic returns, and automatability in Thailand. Southeast Asian J. Econ. **8**(2), 43–76 (2020)

The Framework of Development of Constructivist Learning Environment Model to Changing Misconceptions in Science for High School Students

Taksina Sreelohor(✉), Sarawut Jakpeng, and Sumalee Chaijaroen

Department of Education Technology, Faculty of Education, Khon Kaen University, Khon Kaen, Thailand
S_taksina@kkumail.com

Abstract. This study focused on the synthesis development of the theoretical and designing framework of the constructivist learning environment model to change misconceptions in science for high school students. Research results showed that theoretical framework design consists of 5 main stages. The first stage is a psychological base followed: (1) Constructivist theory (cognitive constructivist and social constructivist). (2) Cognitive theory (schema theory, mental model, metacognition theory, and information processing). The second stage is Pedagogies based on were follows: (1) Open learning environments, OLEs model, (2) Constructivist learning environments, CLEs, (3) Situated learning environments, SLE, and (4) SOI model). The third stage is misconceptions and concept change theory base. The next stage is the media theory base: (1) media symbol system, (2) learning with multimedia and technology base. Furthermore, the last stage is contextual base followed: (1) The education core curriculum, (2) 21st-century skills (3) the scope of chemistry for high school students. The designing framework consists of 4 main stages (1) The activation of cognitive structure, (2) Supporting cognitive equilibrium and enhancing cognitive structure, (3) Supporting cognitive structure and Concept change (4) Supporting and encouraging knowledge.

Keywords: Constructivist learning environment · Misconceptions · Constructivist

1 Introduction

The study presented from the first stage, developing a theoretical framework design of a constructivist learning environment model to change misconceptions in science (atomic structure) for high school students (15–18 years of age), which is fundamental in chemistry. The second stage was developing the design framework of the constructivist learning environment model. This study has operated under the constructivist paradigm. That focuses on learners seeking knowledge, exploring, investigating through various methods, and creating knowledge. Relying on prior knowledge makes the learner understand and meaningful learning. Creating knowledge of our world is the process of reflection on

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 195–200, 2022.
https://doi.org/10.1007/978-3-031-15273-3_22

previous experiences. The knowledge created by individual learners is called the mental model [1].

Science learning focuses on the conceptual model [2]. The learner's individually created knowledge, understanding, and ability to apply scientific knowledge to everyday life [3] and explain phenomena that students can see but learning science is complicated and can lead to misconceptions. If not correcting the wrong concept will affect the learning of science. This causes the learners to accept correct concepts in a science learning higher-level decrease [4].

The approach to solving the problems requires Instructional design. That encourages learners to investigate and create knowledge by themselves which the theoretical principles that the body of knowledge corresponds to such characteristics are constructivist theory focusing on learners creating knowledge by themselves. And the study of the effect of teaching support under the constructivist learning environment found that Teaching in a learning environment supports the student concepts. that can encourage knowledge creation [5].

For the reasons mentioned above, the researcher recognizes the importance of designing and developing the theoretical and designing framework of the constructivist learning environment model to change misconceptions in science for high school students, designed based on the theory (instructional design).

2 Methodology

Model research is the principal methodology of this research [6]. The first phase is model development through document analysis. It focuses on the process of designing and developing a model of constructivist learning environment model to change misconceptions in science. The design process begins with document analysis. Examine learning, teaching, and context. The next step is to analyze the relevant principles and theories based on learning theory, constructivist theory, cognitive theory, misconceptions, and media and technology theory.

Furthermore, the last step is synthesis to obtain a theoretical framework of the constructivist learning environment model to change misconceptions in science, which is designed based on the theory (instructional design). After obtaining a theoretical framework, the next step is to synthesize and design a design framework based on a theoretical framework, which is designed based on the theory (instructional design) same as the theoretical framework.

In this research, the target group consists of 3 experts for the evaluation of the designing and development of the theoretical and designing framework.

3 Results and Discussion

The results of designing and developing a constructivist learning environment model to change misconceptions in science. Starting from the design of a theoretical framework consisting of 5 main stages, the first is the base of psychology. It examines the contexts involved in teaching and learning to serve as the basis for designing a learning environment model. Allows design to meet workforce requirements. Feature development and problem-solving skills are as follows: (1) Constructivist theory (cognitive constructivist [7] and social constructivist [8]). (2) Cognitive theory (schema theory [9], mental model [9], metacognition theory [10] and information processing [11]).

The second is the base of pedagogies. A constructivist learning environment model was as follows: (1) Open learning environments, OLEs model [12], (2) Constructivist learning environments, CLEs [13], (3) Situated learning environments, SLE [14], and (4) SOI model [15]). The third is the base of misconceptions and concept change theory base [16].

The next stage is the media theory base were follows (1) media symbol system [17], (2) learning with multimedia [18], and technology base.

And the last stage is contextual base followed: (1) The education core curriculum, (2) 21st-century skills, (3) the scope of chemistry for high school students. (See Fig. 1).

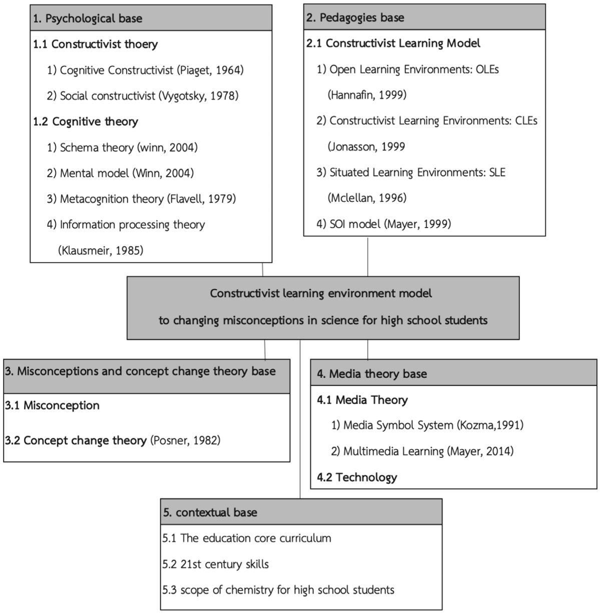


Fig. 1. Theoretical framework for development of constructivist learning environment model to changing misconceptions in science for high school students.

After obtaining a theoretical framework, The next step is to synthesize and design a design framework based on a theoretical framework, which is designed based on the theory (instructional design) same as the theoretical framework. The results of designing and developing a model of a constructivist learning environment model. Starting from the design of a design framework consisting of 4 main stages. The first stage is the activation of cognitive structure, causing cognitive conflicts, which is the source of the problem base.

The second stage is supporting cognitive equilibrium and enhancing cognitive structure. It is to encourage learning by the constructivist learning environment model. Furthermore, the next stage is supporting cognitive structure and concept change. It is an important stage because the learners will change their concepts at this stage.

The last stage in designing a design framework is supporting and encouraging knowledge with a scaffolding center and coaching center to help the learners learn. (See Fig. 2).

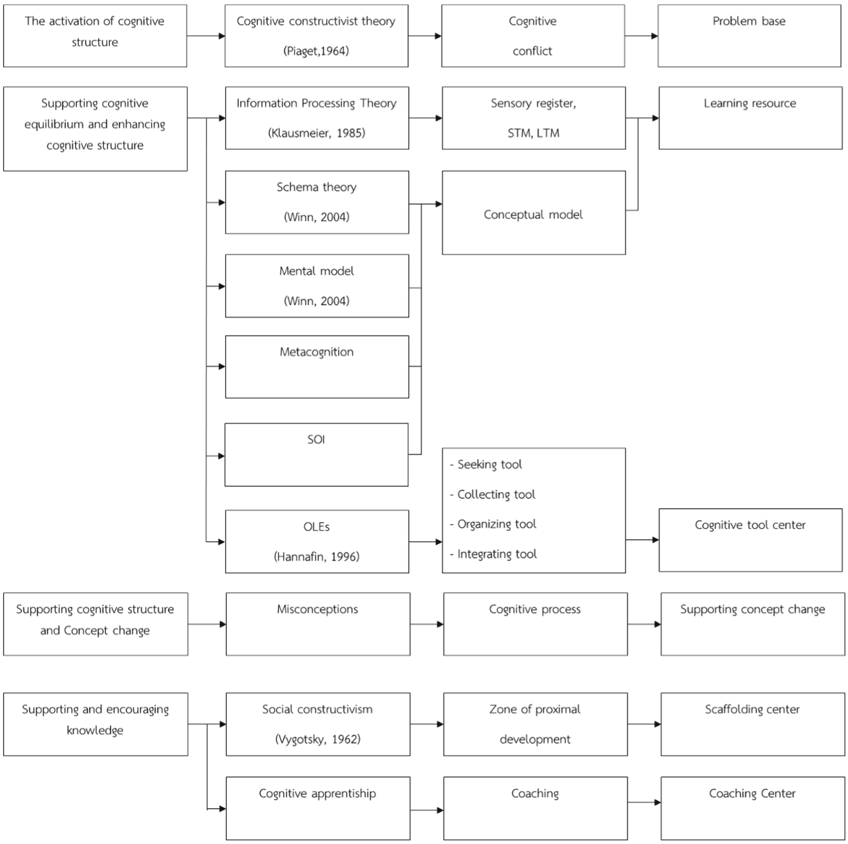


Fig. 2. The designing framework for development of constructivist learning environment model to changing misconceptions in science for high school students.

This is shown in the framework of both. This may help the learner to foster correcting the wrong concept and affect the learning of science. Besides, experts validated the theoretical validity of the design framework of the constructivist learning environment model. as mentioned above. The findings could support the design framework of a constructivist learning environment model to change misconceptions in science.

The design framework is recognized as an integral part. Because it can support and help designers to design efficiently and clearly. Without this theoretical framework, the design may not be as efficient as it could be [19].

4 Conclusions

Theoretical framework design consists of 5 main stages. The first stage is a psychological base followed: (1) Constructivist theory (cognitive constructivist [7] and social constructivist [8]). (2) Cognitive theory (schema theory [9], mental model [9], metacognition theory [10] and information processing [11]). The second stage is Pedagogies based were follows: (1) Open learning environments, OLEs model [12], (2) Constructivist learning environments, CLEs [13], (3) Situated learning environments, SLE [14], and (4) SOI model [15]). The third stage is misconceptions and concept change theory base [16]. The next stage is the media theory base were follows (1) media symbol system [17], (2) learning with multimedia [18], and technology base. Furthermore, the last stage is contextual base followed: (1) The education core curriculum, (2) 21st-century skills (3) the scope of chemistry for high school students.

The designing framework consists of 4 main stages (1) The activation of cognitive structure, (2) Supporting cognitive equilibrium and enhancing cognitive structure, (3) Supporting cognitive structure and Concept change, and (4) Supporting and encouraging knowledge.

Acknowledgements. Ph.D. supported this research. Program in Educational Technology, Faculty of Education, Research Group for Innovation and Cognitive Technology, Khon Kaen University, and Research and Technology Transfer Affairs Division, Khon Kaen University, which at this moment gives the thankfulness all through this.

References

1. Gilbert, J.K.: Model in explanations, part 1: Horses for courses? Int. J. Sci. Educ. **20**(1), 83–97 (1998)
2. Rosalind, D.: Students' conceptions and the learning of science. Int. J. Sci. Educ. **11**, 481–490 (1989). Special issue
3. Han, V., Henny, K.: The use of animations in chemical education (2003)
4. David, F.T., Reinders, D.: Conceptual change: a discussion of theoretical, methodological and practical challenges for science education. Cult. Stud. Sci. Educ. **3**, 297–328 (2008)
5. Hardy, I., Jonen, A., Moller, K., Stern, E.: Effects of instructional support within constructivist learning environments for elementary school students' understanding of "floating and sinking." J. Educ. Psychol. **98**(2), 307–326 (2006)
6. Richey, R.C., Klein, J.D.: Design and Development Research Methods Strategies and Issues. Lawrence Erlbaum Associates, New Jersey (2007)
7. Piaget, J.: Judgment and Reasoning in the Child Translated by Marjorie Warden. Routledge & Kegan Paul, London (1989)
8. Vygotsky, L.: Interaction between learning and development. In: Gauvin, M., Cole, M. (eds.) Readings on the Development of Children. Scientific American Books, New York (1978)

9. Winn, W.: Cognitive perspectives in psychology. In: Jonassen, D.H. (ed.) Handbook of Research on Educational Communications and Technology, 2nd edn., pp. 79–112 Lawrence Erlbaum Associates, Mahwah (2004)
10. Flavell, J.H.: Metacognition and cognitive monitoring: a new area of cognitive–developmental inquiry. Am. Psychol. **34**(10), 906–911 (1979)
11. Klausmeir, H.J.: Educational Psychology, 5th edn. Harper & Row, New York (1985)
12. Hannafin, M., Land, S., Oliver, K.: Open learning environments: foundations, methods, and models. In: Reigeluth, C.M. (ed.) Instructional Design Theories and Models Volume II : A New Paradigm of Instructional Theory. Lawrence Erlbaum Associates, New York (1999)
13. Jonassen, D.H.: Designing constructivist learning environments. In: Reigeluth, C.M. (ed.) Instructional Design Theories and Models: A New Paradigm of Instructional Theory, pp. 217–239. Lawrence Erlbaum Associates Inc, Mahwah (1999)
14. Brown, J.S., Collins, A., Duguid, P.: Situated cognition and the culture of learning. Educ. Res. **18**, 32–42 (1989)
15. Mayer, R.E., Wittrock, M.C.: Problem-solving transfer. In: Berliner, D.C., Calfee, R.C. (eds.) Handbook of Educational Psychology, pp. 47–62. Macmillan, New York (1986)
16. Posner, G.J., Strike, K.A., Hewson, P.W., Gertzog, W.A.: Accommodation of a scientific conception: toward a theory of conceptual change. Sci. Educ. **66**, 211–227 (1982)
17. Kozma, R.B.: Learning with media. Rev. Educ. Res. **61**(2), 179–211 (1991)
18. Mayer, R.E.: Cognitive theory of multimedia learning. In: Mayer, R.E. (ed.) The Cambridge Handbook of Multimedia Learning, pp. 43–71 (2014)
19. Samat, C., Chaijaroen, S.: Design and development of learning environment to enhance creative thinking and innovation skills for teacher training in the 21st century. In: Proceedings of the 23rd International Conference on Computers in Education, ICCE 2015, pp. 667–672 (2015)

Development of Web-Based Learning Environment to Promote Problem Solving on Problem Solving in Computational Science for Secondary School

Anutra Phoosamrong[1], Charuni Samat[2](✉), and Pornsawan Vongtathum[2]

[1] Master of Education Program in Science and Technology Education, Faculty of Education, Khon Kaen University, Khon Kaen, Thailand

[2] Division of Computer Education, Faculty of Education, Khon Kaen University, Khon Kaen, Thailand

scharu@kku.ac.th

Abstract. The objectives of this research were to develop a networked learning environment that promoted solving problem and to study solving problem of learners who learned this research in Computational Science for secondary school, grade 7. The target group of this research was 34 students of grade 7 in semester 2, academic year 2021. This research used the Development Research by using basic statistical in analysis mean ($\bar{x}$) and standard deviation (S.D.).

The research showed that 1. There are 6 components of the result of design and develop a networked learning environment in Computational Science for secondary school, grade 7 namely 1) problem situation, 2) resource, 3) collaboration, 4) analytical solving problem room, 5) scaffolding and 6) coaching. 2. The result of student who learned about this research showed that 34 students who had solving problem passing the criteria 60%, representing 100% in total number of students. The average mean ($\bar{x}$) was 28.27 and standard deviation (S.D.) was 1.08 which was higher than specified criteria at 60% .

Keywords: Learning environment · Problem solving · Web-based learning

1 Introduction

21st Century Education Challenges. Preparing students for life in the 21st century is an important aspect of the 21st century social transformation trend affecting the way people live in society. Teachers need to be alert and prepared to manage learning for students with the skills for living in a 21st century world. The most important skill is Learning Skill, which has resulted in a change in learning management so that children in the 21st century have the knowledge, abilities, and essential skills.

It corresponds to problem solving, a thinking skill that is important to learners' development [1]. The difference in the past was caused by many changes in various fields. Especially technology that has changed by leaps and bounds. As a result, learning

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 201–210, 2022.
https://doi.org/10.1007/978-3-031-15273-3_23

as the center of understanding how to create knowledge independently and via problem-solving. It's not just thinking and using your brain, or it's a skill aimed at improving your intelligence solely. It is also a skill that can develop attitudes, thinking methods, values, knowledge, and understanding of social situations which the education system must focus on development and training youths to have more opportunities to practice problem-solving skills [2].

From the problematic situation, to support consistent problem-solving, the learning management solution must be adjusted with the learning environment at its core. Task skills help students develop their own knowledge, capture the most important knowledge points so that learners can connect important knowledge with other relevant knowledge. This is the creation of knowledge for learners to learn anywhere and at any time. This learning management method is consistent with the constraint theory. Knowledge is connected with the surrounding things from past experience to form a cognitive structure. The learning environment approach helps learners expand their intellectual structure. Understanding the production process begins with understanding about the environment. Through students' thinking, conflict will be resolved in this study. When students are experiencing issues, it is believed that learners will use these strategies to solve problems. In the learning process, this supports the thinking process of learners' knowledge creation. The management of learning environment is called learning environment based on Constructivism [3, 4].

This approach is therefore highly consistent with the nature of technology (computational science) on problem solving, grade 1 emphasizes computational thinking and analytical thinking, think problem-solving in a systematic and step-by-step manner, analyze, synthesize and apply information to solve real-life problems and work together creatively due to the aforementioned causes. The development of web-based learning environments to foster problem solving in computational science for secondary school is therefore a topic that interests the researcher. in order to use the research results to continue support effective learning management. As a game based learning environment, it is an educational strategy that helps promote thinking skills and learning processes for players. Currently playing games, it is an entertainment that is hidden with substance and promoting learning is very useful. The researcher sincerely hopes that this research will enhance students' problem-solving skills.

2 Research Objectives

1. To development of web-based learning environments to promote problem solving on problem solving in computational science for secondary school.
2. To study the students' problem-solving thinking through a web-based learning environments to promote problem solving on problem solving in computational science for secondary school.

3 Research Scope

This research was Development Research [5] focused to study design and develop model including document research, a study context of teaching management, synthesis of pattern design conceptual frameworks, designing and creating learning environment, and improving quality. Details of research operations are as follows.

4 Research Method

The design and develop learning environment were in 1st process and 2nd process which focused on design and develop learning environment. In these processes included document research, a study context of teaching management, synthesis of pattern design conceptual frameworks and create framework for theorizing the creation of a networked learning environment while enhancing quality. The contributors in development were various experts such as Theorists, Designers, Developers, Evaluators, Researchers and Learners.

4.1 Target Group

That use in this research is grade 1, in the amount 34 students who study Wor 21105, Technology (Computational sciences), 2nd semester in academic year 2021, Kham Kaen Nakorn School, Muang district, Khon Kaen.

4.2 Researching Tools

1. A web-based learning environments to promote problem solving on problem solving in computational science for secondary school.
2. Problem-solving measurement, built on the framework of Polya.

4.3 Collecting Data

1. Perform document analysis (Document analysis) by carrying out studies and analyzing the theories and principles relating to the design of the learning environment model, consisting of the following fundamentals: psychological base, pedagogies base, problem-solving base, media base, technologies base, and contextual base to be used as the basis for synthesising the theoretical framework for the development of learning environment on the network [6, 7].

2. Theoretical framework creates a conceptual framework based on study and analysis of theoretical principles, research, variables, linking the relationship between theoretical principles and this research study was based on the principle of relevant research and theories can be synthesized from the theoretical framework from the basic theory is as follows. Fundamentals of problem solving Fundamentals of Media Theory (Media Symbol System), Fundamentals of Technology (Web base technology, Interactive), Fundamentals of Pedagogical Sciences, Fundamentals of Learning Psychology (Cognitive constructivist, Social constructivist, Information processing), and Fundamentals of Media Theory. Contextual basis, cognitive apprenticeship, and constructivist learning environment [4, 10]
3. Study the context of teaching and learning in the course Wor21105, Technology (Computational Science), which consists of content analysis. The subjects used in the research were on the topic of problem solving and the study of learner contexts, results of the study, contexts related to teaching and learning in the course Technology (Computational Science).
4. Synthesis of a design framework from the results of a theoretical conceptual framework study and the study of the context, it can be used as a basis for synthesizing a conceptual framework for designing a learning environment which will be the elements of the learning environment model. Then used to develop the knowledge environment on the network and assess the efficiency of the learning environment by adopting the learning environment model propose to an advisor to check.
5. Bring the learning environment on the network that have been evaluated by experts to be tested in real context.

4.4 Data Analysis and Statistics Used

1. Checking the quality of the format by experts in content, media, and measurement and evaluation. Data analysis was performed using interpretive summaries.
2. The student's problem-solving thinking obtained from the student's problem-solving measure. Data were analyzed using statistics such as percentage, mean and standard deviation.

5 The Result of Research

1. Theoretical framework construct a conceptual framework based on the study and analysis of theoretical principles, research, and variables to make a link between the theoretical principles and this research study. Relevant research and theories can synthesize conceptual frameworks (Fig. 1).

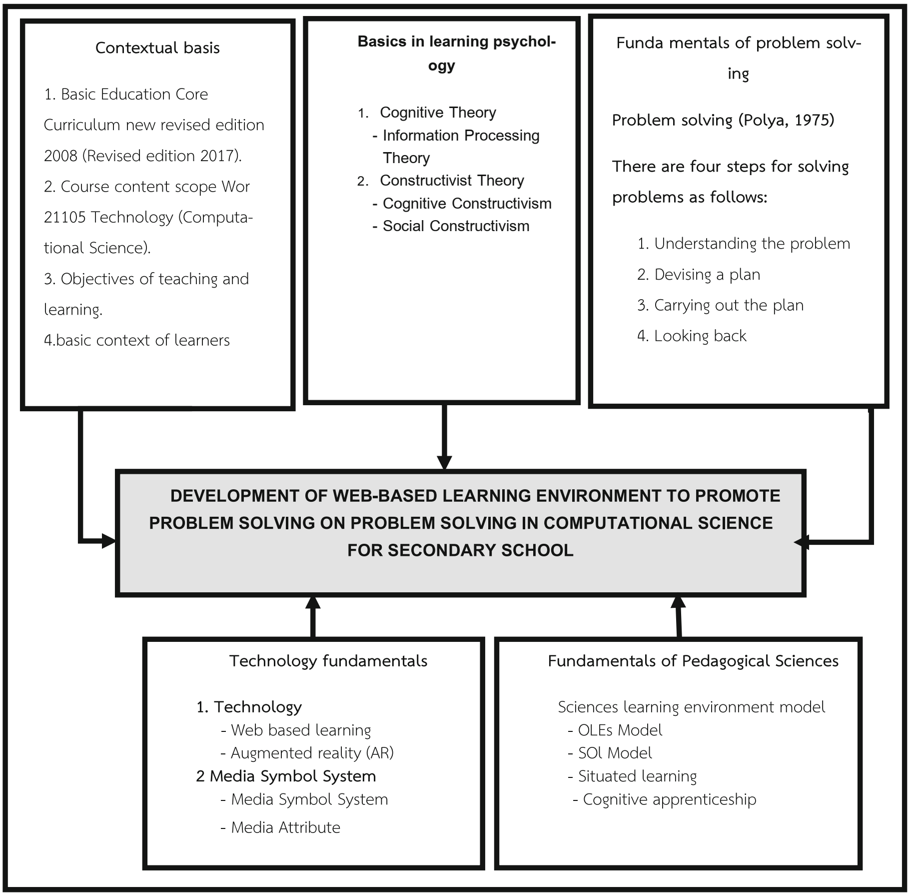


Fig. 1. A theories framework for designing a web-based learning environment.

2. The design framework for a web-based learning environment to support problem solving in computational science for secondary school is synthesized from the theoretical foundation. [9] as the foundation for developing a conceptual framework for constructing web-based learning environments that encourage problem solving in computational science for secondary school. as shown in Fig. 2.

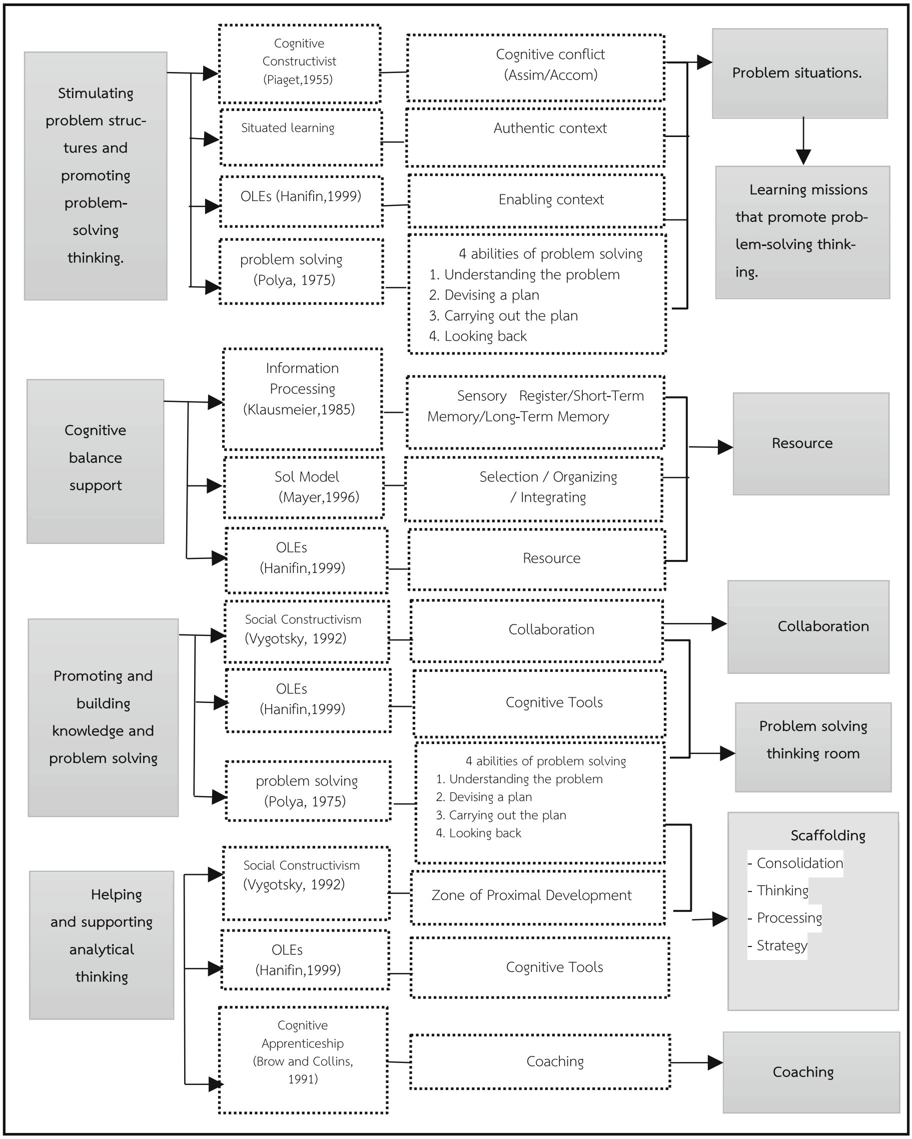


Fig. 2. A framework of web-based learning environment model.

There is a development of web-based learning environments to promote problem solving on problem solving in computational science for secondary school as follows:

(1) Problem situation and learning missions to promote problem-solving thinking It is a situation/task that allows learners to connect their experiences and problem-solving skills to apply them in real life. Problems are tied to create a learning task (Learning Task) for students to go down to solve problems by focusing

on the learners to develop problem-solving skills, emphasizing the importance of the appropriate learning context (Situated Learning) based on the authentic contexts, in which the problem situations aim to promote problem solving thinking is like a gateway through which the learner will enter the content to be learned (enabling context), based on the concept of Cognitive Constructivist's belief that learning takes place when the learner is stimulated with a problem and when students lose their intellectual balance therefore try to adjust the intellectual structure to enter the state by absorption (Assimilation) Intellectual structure and modifying the intellectual structure (Accommodation) is a link to the original intellectual structure or previous knowledge with new information and learners can adjust the intellectual structure into a state of equilibrium or be able to create new knowledge, known as learning itself. Based on Hannifin's Principles of Open Learning Environments (OLEs).

(2) Resources are sources of information. Content information that learners will use to solve problems in problem situations and tasks which from the situation that the problem will cause the learner to lose balance, it is a support for intellectual balancing by linking the learner's original cognitive structure with the new knowledge gained from the learning environment. open learning environment design principles (OLEs), we design learning resources where learners can research resources for solving problems by using the SOI model, it can be linked to the main focus of the cognitive processes in constructivist learning as well as the use of Information Processing Theory as a theory that describes the process of information processing occurring in the human brain. It is a process of sensory register, short-term memory and long-term memory, focusing on the study of cognitive processes in the hierarchy of information processing and various knowledge calls from long-term memory to be used effectively.

(3) Collaboration is based on the Social Constructivism [10] which emphasizes social interaction in learning. It is another element that encourages learners to share experiences with others to expand their perspectives. Problem Solving Collaboration encourages learners, tutors, and experts to discuss their opinions with others for designing collaborative problem solving while building knowledge. Collaborative problem solving is also an important part of modifying and preventing misunderstandings from occurring while learning, including expanding the concept.

(4) Problem Solving thinking room open learning environment design principles (OLEs) as cognitive tools to support student problem-solving processes to act as a medium to support, enhance or expand thinking and to help encourage students' problem solving thinking that consists of dealing with problems, problem solving planning, Polya's troubleshooting and investigation steps.

(5) Scaffolding is based on the theory of social constructivism who believes that if learners are below the zone of Proximal Development, they cannot learn on their own. The need for help is called Scaffolding, where the help base supports learners in problem solving or learning in case of being unable to complete the mission by yourself which the assistance will consist of concept building

support base Methodological assistance base Process support base and strategic support base.

(6) Coaching is based on the principles of the Cognitive Apprenticeship Model,based on Situated Learning constructivism that has changed the role of an instructor who is responsible for transferring knowledge or imparting knowledge to a "coach" that provides assistance and advice for learners to train learners by educating learners in an objective manner giving the creation of wisdom.

3. Developing the knowledge environment on the network from the model for a learning environment as seen in the accompanying screen, the researcher turned it into a web-based learning environment to encourage problem solving in computational science for secondary school (Table 1).

Table 1. The results of the analysis of the problem solving measure test.

	Undestanding the problem	Devising a plan	Carrying out the plan	Looking back	Total
					Show total
$\overline{x}$	11.53	5.59	6	5.15	28.27
S. D	0.51	0.50	0.00	0.36	1.08
Percentage	96.08	93.17	100	85.83	93.77
Total students (person)					34
Number of students with a passing score of 60 percent (person)					34
Percentage of students with a passing score of 60 percent (18 points)					100
Student grade point average ($\overline{x}$)					28.27
Standard Deviation (S.D)					1.08

* means a passing score of 60 percent or more (18 points)

6 Summary and Discussion

6.1 The Result of Developing of Web-Based Learning Environments to Promote Problem Solving on Problem Solving in Computational Science for Secondary School

Design and creation of web-based learning environments for secondary school students that encourage problem solving in computational science in this research study based on development by applying from has carried out a development research model (Developmental Research) results from research, design and development process, consisting of document research, a conceptual framework for design study of the teaching and learning management context, planning and building a model of the learning environment, and enhancing the standard. The study's findings showed that a number of learning theories and principles, including the constructivist learning environment, cognitive apprenticeship, Polya's problem-solving thinking, cognitive constructivism, social constructivism, information processing, media symbol systems, and interactive web technology, support problem-solving thought processes. The conceptual framework and components for the design of the learning environment were derived from the study's findings during the design phase. Importantly, there are (1) problem situations (2) learning resources (3) collaborations (4) Problem solving thinking room (5) scaffolding (6) coaching [11, 12].

6.2 The Results of Problem Solving in Solving Computer Science Problems at the Secondary School

A study of the outcomes of learners using a learning environment on a network that promotes problem-solving thinking, a study of the problem-solving thinking of learners who learn through web-based learning environments to promote problem solving on problem solving in computational science for secondary school. According to Polya's problem-solving framework, the components are: (1) understanding the problem (2) Devising a plan (3) Carrying out the plan (4) Looking back. In summary, the results of the study of problem-solving thinking of students studying in a web-based learning environment that promotes problem-solving as a result of the problem-solving questionnaire with a 4-scenario test, found that problem-solving thinking of learners who studied in a web-based learning environment that promotes problem-solving thinking of 34 students with a total score of 30 on a 30-point test, 34 students with a score of 18 up which accounted for 100 percent of the total number of students. The result of student who learned about this research showed that 34 students who had solving problem passing the criteria 60%, representing 100% in total number of students. The average mean ($\bar{x}$) was 28.27 and standard deviation (S.D.) was 1.08 which was higher than specified criteria at 60% [3]. The design and development of network-based learning environments that encourage problem-solving thinking were influenced by the study of the aforementioned studies. Encourage thinking and problem-solving in your students. Additionally consistent with constructivist theory's guiding principles, which emphasize how students construct their own bodies of knowledge by connecting what they already know with what they acquire from the environment's organized learning resources. Learning and the students' habit of methodically and sequentially solving problems Let's begin by thoroughly examining the issue. Planning for solving problems evaluation, inspection, and troubleshooting Through the use of a networked learning environment, students share knowledge and experiences to solve difficulties.

7 Suggestion

1. Should study designing a learning environment on a web-based that promotes problem solving among learners in other ways by considering that model to be consistent and appropriate to promote problem-solving thinking of learners.
2. The learning environment should be arranged in accordance with the ability to think and solve problems in each area.

Acknowledgments. This work was supported by the Research and Creative Educational Innovation Affairs, Faculty of Education, and the Department of Master of Education Program in Science and Technology Education, Faculty of Education, Khon Kaen University.

References

1. Vongtatham, P.: Creation of problem solving thinking in 21st century learning. Educ. J. Khon Kaen Univ. **38**(2), 112–117 (2015)
2. Noisim, S., Wattanachai, S.: Effects of the learning environment on the networkalong the constructivist that promotes analytical thinking programming in C programming language regarding control orders for students in grade 5. J. Grad. Stud. **17**(77), 50–61 (2020)
3. Chaijaroen, S., Kanjug, I., Samat, C., Wonganu, P.: Outcomes of problem-solving using constructivist learning environment to enhance learners' problem solving. In: Huang, T.-C., Wu, T.-T., Barroso, J., Sandnes, F.E., Martins, P., Huang, Y.-M. (eds.) ICITL 2020. LNCS, vol. 12555, pp. 591–597. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-63885-6_64
4. Samat, C., Chaijaroen, S., Wattanachai, S.: The designing of constructivist web-based learning environment to enhance problem solving process and transfer of learning for computer education student. In: Rønningsbakk, L., Wu, T.-T., Sandnes, F.E., Huang, Y.-M. (eds.) ICITL 2019. LNCS, vol. 11937, pp. 117–126. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-35343-8_13
5. Richey, R.C., Klein, J.: Design and Developmental Research. Lawrence Erlbaum Associates, New Jersey (2007)
6. Chaisomboon, P., Samat, C.: Design framework of construcitvist web-based learning environments to enhance problem solving on c programing language for secondary school. J. Educ. Technol. 700–704 (2017)
7. Hannafin, M., et al.: Open learning environments: foundations, methods, and models. In: Reigelith, C.M. (ed.) Instructional Design Theories and Models: A new Paradigm of Instructional Theory, vol. II. Lawrence Erlbaum Associates (1999)
8. Wongchiranuwat, S.: The effect of the learning environment of virtual technology on the network in line with constructivism that promotes creativity about graphic design for students in grade 3. J. Khon Kaen Univ. (2016)
9. Samat, C., Chaijaroen, S.: Design and development of the constructivist web-based learning environment that enhances creative thinking of undergraduate students. J. Mahasarakham Rajaphat Univ. **5**(2), 37–47 (2009)
10. Vygotsky, L.S. Mind in Society: The Development of Higher Psychological Processes. Harvard University Press, Cambridge (1978)
11. Srimuang, C.: Developing a learning environment on a network that promotes analytical thinking for students in grade 4 at Kudruea Kapittayakan School. J. Fac. Educ. Khon Kaen Univ. (2019)
12. Vongtathum, P., Samat, C., Wattanachai, S.: A development of smart coding creative kit to enhance creative problem solving thinking for children. In: Huang, Y.-M., Lai, C.-F., Rocha, T. (eds.) ICITL 2021. LNCS, vol. 13117, pp. 333–342. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-91540-7_35

Pedagogies to Innovative Technologies and Learning

Familiarization Strategies to Facilitate Mobile-Assisted Language Learning in Unfamiliar Learning Environments: A Study of Strategies Development and Their Validation

Rustam Shadiev[1](✉), Meng-Ke Yang[2], Dilshod Atamuratov[3], Narzikul Shadiev[4], Mirzaali Fayziev[4], Elena Gaevskaia[5], Anna Kalizhanova[6], and Nurzhamal Oshanova[7]

[1] Nanjing Normal University, Nanjing, China
rustamsh@gmail.com
[2] Shengli No.1 Middle School, Dongying, China
[3] Urgench State University, Urgench, Uzbekistan
[4] Samarkand State University, Samarkand, Uzbekistan
[5] Saint Petersburg State University, Saint Petersburg, Russia
[6] Karaganda Buketov University, Karaganda, Kazakhstan
[7] Abai Kazakh National Pedagogical University, Almaty, Kazakhstan

Abstract. Educators and researchers design mobile-assisted language learning (MALL) activities in authentic learning environments so that language learners are able to practice their skills there. However, some of such environments are unfamiliar to learners (e.g. zoo) because they visit them seldom. Unfamiliarity with learning environments may hinder language learning and not many MALL studies focused on this problem. In this study, familiarization strategies were developed in order to familiarize language learners with unfamiliar learning environments and to facilitate their mobile-assisted language learning in unfamiliar learning environments. A focus group was carried out with eight English teachers of seventh grade to explore their opinions and suggestions regarding developed strategies. The results showed that familiarization strategies can be useful for familiarization with unfamiliar learning environments. Based on a focus group some strategies were modified and some were deleted.

Keywords: English · Environment · Familiarization strategies · MALL · Unfamiliar

1 Introduction

Mobile-assisted language learning (MALL) is type of language learning that is supported by mobile devices such as cell phones, personal digital assistants, smartphones, pads or pods [1]. MALL gained its popularity in the last years because of its flexibility, low cost, small size and user-friendliness [2–4]. Scholars argued that mobile technology can ensure learning anywhere and anytime [2, 3, 5, 6]. Multimedia tools of mobile

The original version of this chapter was revised: minor error in the author name was corrected. The correction to this chapter is available at https://doi.org/10.1007/978-3-031-15273-3_57

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 213–217, 2022.
https://doi.org/10.1007/978-3-031-15273-3_24

technology can help learners create and share learning content. Furthermore, language learning supported by mobile technology can become seamless when learners have learning experiences across various learning contexts [7]. For example, they may acquire new knowledge in classroom first and then apply what they learned to the real world [2, 3, 5].

Educators and researchers create authentic learning environments using mobile technology [1]. For example, while learning food related vocabulary, language learners in Hwang and Chen [8] visited school cafeteria and practiced their language skills using those situations that occur during lunch. In such learning environment, learners are situated in real contexts where learning resources, situations and scenarios around them are authentic. Learning and practicing language skills in such learning environment becomes relevant and meaningful to learners.

However, some authentic learning environments can be both familiar and unfamiliar to learners [1]. According to Shadiev et al. [9], the familiar environment refers to the environment associated with learners' background and previous experience. School cafeteria in the study of Hwang and Chen [8] was definitely familiar to learners. However, a zoo which language learners visited in [10] to practice animal-related vocabulary was not familiar to learners and so it was unfamiliar learning environment.

Scholars argued that familiarity with learning environments is beneficial for learning, especially if their learning tasks are to describe surroundings and available resources there such as people, objects, situations and scenarios [9, 11, 12]. On the other hand, unfamiliar environments can impede learning [13]. The reason is because familiarity helps cognitive processes such as information processing and managing cognitive load, e.g. when a learner arrives to a familiar environment to learn, he/she does not need to get acquainted with available resources in surrounding contexts, and thus, there is no reason to spend any cognitive effort in processing such information because of his/her familiarity with contexts. On the contrary, language learners need to spend cognitive resources to become knowledgeable about unfamiliar environments and available resources for learning there. Therefore, in this study, we aimed to develop familiarization strategies to facilitate mobile-assisted language learning of learners who learn in unfamiliar learning environments.

2 Method

Following general recommendations from related studies, e.g. [14, 15], a set of strategies was developed (available from this URL: https://disk.yandex.ru/i/5OgbdaaACphRyw). For example, Strategy 1.2.1 "Use electronic map" could help language learners find an address and see pictures of an unfamiliar environment or even visit it virtually. Strategy 1.1.1 "Check characteristics of locations" helped language learners learn about the characteristics and available resources of an unfamiliar context.

To explore the usability of familiarization strategies a focus group was carried out. According to Krueger and Casey [16], a focus group is called so because there is a focus. It involves a small number of demographically similar people. Researchers study their reactions to questions. In this study, a focus group with 8 seventh grade English teachers was carried out. A moderator, who was a researcher of this study, lead a focus group. Based on their perspective and suggestions, this study summarizes the issues that students of grade seven middle school level should focus on when using familiarization strategies. And, the familiarization strategies were also modified to fit the characteristics of the seventh-grade students. The following questions were used: Your self-Introduction. How do you get familiar with the unfamiliar environment in your daily life? Please describe your first impressions of familiarization strategies. Do you think the familiarization strategies can improve seventh grade students' familiarity with the unfamiliar environment? Why? Which of the familiarization strategies are suitable for seventh grade students? Which are not? Please suggest other strategies to help seventh grade students get familiar with the unfamiliar environment. Please present your advice to make the familiarization strategies more suitable for seventh grade students.

In this study, about 4 h of audio were recorded. Audio file was transcribed and content analysis was then carried out based on the thematic coding method. Two researchers were involved in the coding process and followed the inductive coding approach. They agreed upon the coding protocol and strategy and ensured that the coding schemes were in line with the related literature. They read transcribed content, coded the data by labeling the concepts of interest based on the coding schemes, and then grouped the codes into categories and identified the properties of each category independently. Coding outcomes were then compared and when a disagreement occurred about the appropriate code or category, the researchers discussed them until a consensus was reached.

3 Results and Discussion

The results showed that the teachers believed that the familiarization strategies can improve seventh grade students' familiarity with unfamiliar environments. For example, Teacher A said "I think these strategies are very simple and clear. The developers of familiarization strategies define each strategy in a way that is not ambiguous. And, each strategy is simple and achievable." Teacher E said "I think the familiarization strategies are very comprehensive." and Teacher G said "the strategy developers have given examples for each strategy, and when I'm confused about the strategy, I look at the column of example. The detailed explanation gave me a quick idea of how to do it".

The results demonstrated that some strategies were not suitable for seventh-grade students and suggestions how to modify them were proposed. For example, Teacher B said "The amount of information that students can find on the Internet is very large, and some students have poor retrieval ability, and it is difficult to find valuable information. But there is no denying that some students are very good at information retrieval". Teacher C said "Since some students have strong retrieval ability and some students have weak retrieval ability, the students can be divided into heterogeneous groups so that the students with strong information retrieval ability can help the students with weak information retrieval ability".

English teachers gave two suggestions on new strategies. All the teachers' suggestions emphasized the teachers' help to the students. For example, teachers can design surveys or tests of the target environmental to help students consolidate their familiarity with unfamiliar environments. And the second is that teachers can help students get familiar with the environment by designing activities when they enter the unfamiliar environment. For example, teachers can set rewards at key locations in unfamiliar environments. When students come to these locations, they can get a reward after they know the information about this location.

Based on the results of the focus group, the study adjusted the familiarization strategies to better suit the characteristics of the seventh-grade students. The original familiarization strategies were revised and three strategies were deleted. The changes are mainly reflected in group cooperation and teacher participation, e.g. Strategy 1.1.1 was changed to “Before you go, retrieve address, characteristics, available resources of this place through online resources with the help of group”. The deleted strategies are due to the safety of minors, e.g. Strategy 1.7.1 “Go to that place alone, enter the real context and get familiar with it”. Going alone to an unfamiliar environment is too risky and so this strategy was deleted.

The familiarization strategies developed in these study were developed and then validated by seventh grade English teachers. The strategies can be used when educators and researchers design mobile-assisted language learning activities in authentic but unfamiliar learning environments so that language learners are able to practice their skills there. Not many MALL studies focused on this research problem.

Some limitations need to be acknowledged. For example, the focus group was conducted with small number of participants and the participants were from a non-diverse background. These limitations need to be addressed in the future. For example, future studies may consider recruiting more participants. In the future, researchers may also consider piloting the familiarization strategies in real situations when seventh grade students learn in class and then practice in authentic learning environments (some of which can be unfamiliar to learners). The pilot study can show if the familiarization strategies are really applicable in real situations to help language learners of seventh grade to become knowledgeable about unfamiliar learning environments. Furthermore, the effectiveness of the familiarization strategies in enhancing language learning can be tested in the experiment in future studies.

References

1. Shadiev, R., Liu, T.Y., Hwang, W.Y.: Review of research on mobile-assisted language learning in familiar, authentic environments. Br. J. Edu. Technol. **51**(3), 709–720 (2020)
2. Huang, Y.M., Shadiev, R., Sun, A., Hwang, W.Y., Liu, T.Y.: A study of the cognitive diffusion model: facilitating students’ high level cognitive processes with authentic support. Educ. Tech. Res. Dev. **65**(3), 505–531 (2017)
3. Hwang, W.Y., Chen, H.S.L., Shadiev, R., Huang, Y.M., Chen, C.Y.: Improving English as a foreign language writing in elementary schools using mobile devices in familiar situational contexts. Comput. Assist. Lang. Learn. **27**(5), 359–378 (2014)
4. Viberg, O., Grönlund, Å.: Mobile assisted language learning: a literature review. In: 11th World Conference on Mobile and Contextual Learning (2012)
5. Cavus, N., Ibrahim, D.: Learning English using children’s stories in mobile devices. Br. J. Edu. Technol. **48**, 625–641 (2017)
6. Tingir, S., Cavlazoglu, B., Caliskan, O., Koklu, O., Intepe-Tingir, S.: Effects of mobile devices on K–12 students’ achievement: a meta-analysis. J. Comput. Assist. Learn. **33**(4), 355–369 (2017)

7. Chai, C., Wong, L.-H., King, R.: Surveying and modeling students' motivation and learning strategies for mobile assisted seamless Chinese language learning. J. Educ. Technol. Soc. **19**, 170–180 (2016)
8. Hwang, W.Y., Chen, H.S.: Users' familiar situational contexts facilitate the practice of EFL in elementary schools with mobile devices. Comput. Assist. Lang. Learn. **26**(2), 101–125 (2013)
9. Shadiev, R., Hwang, W.Y., Huang, Y.M.: Review of research on mobile language learning in authentic environments. Comput. Assist. Lang. Learn. **30**(3–4), 284–303 (2017)
10. Chang, C.C., Warden, C.A., Liang, C., Chou, P.N.: Performance, cognitive load, and behaviour of technology-assisted English listening learning: from CALL to MALL. Comput. Assist. Learn. **34**(2), 105–114 (2018)
11. Nazemi, M., Rezvani, E.: Effects of task familiarity and task repetition on Iranian EFL learners' engagement in L2 oral performance. Contemp. Res. Educ. Engl. Lang. Teach. **1**, 45–56 (2019)
12. Othman, J., Vanathas, C.: Topic familiarity and its influence on listening comprehension. Engl. Teach. **34**, 19–32 (2017)
13. Shadiev, R., Huang, Y.M., Hwang, W.Y., Liu, T.Y.: Facilitating application of language skills in authentic environments with a mobile learning system. J. Comput. Assist. Learn. **34**(1), 42–52 (2018)
14. Chang, C.C., Tseng, K.H., Tseng, J.S.: Is single or dual channel with different English proficiencies better for English listening comprehension, cognitive load and attitude in ubiquitous learning environment? Comput. Educ. **57**(4), 2313–2321 (2011)
15. Chu, H.C.: Potential negative effects of mobile learning on students' learning achievement and cognitive load—a format assessment perspective. J. Educ. Technol. Soc. **17**(1), 332–344 (2014)
16. Krueger, R.A., Casey, M.A.: Focus Groups: a Practical Guide for Applied Research. Sage, Thousand Oaks (2000)

Exploring the Collaborative Design Process at Conventional Design Studio

Upeksha Hettithanthri[1,2](✉), Preben Hansen[1], and Harsha Munasinghe[3]

[1] Department of Computer and Systems Sciences, Stockholm University, PB 7003, SE-164 07 Kista, Sweden
{dilini,preben}@dsv.su.se

[2] Department of Design Studies, NSBM Green University, Pitipana, Homagama, Sri Lanka
upeksha@nsbm.ac.lk

[3] School of Architectural Studies, George Brown College, Toronto, Canada
hmunasinghe@georgebrown.ca

Abstract. Collaborative engagement and collaborative practice are key components in Architectural design practice. The design studio motivates collaboration, but it may have some limitations. The technology and use of digital devices have encroached on architectural design education and have made many productive moves. This study aims at understanding how digital devices and technology could impact collaborative learning utilized in architectural pedagogy. This study was carried out in a conventional design studio context with the involvement of 40 Interior design undergraduates. Interior design students were selected based on the convenience sampling methodology and they were clustered into 8 collaborative groups. They were assigned a design task and 12 studio hours were allocated to collect data. Data collection was done by naturalistic observation carried out by the researcher and interviews were conducted to get the reflections of students. The data was analyzed through six phased Thematic analyses based on Grounded Theory. The study resulted in the impacts generated by the technology and digital devices on the design process of interior design students. The results depict that overexposure to technology and digital devices have made students individual-centric while being in a collaborative group. Moreover, it made students less empathetic towards user requirements. Further being device-centric made students less empathized with the user and the context and it has impacted the design process by avoiding some key initial steps which are necessary to get more functional human-centric solutions.

Keywords: Design process · Conventional design studio · Collaboration · Technology and digital devices · Empathizing

1 Introduction

In the educational domain of Architecture, collaborative learning has been placed at a higher level. Architectural education is based on design studio engagement and design studio is placed at the heart of architectural education. A conventional design studio is

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 218–230, 2022.
https://doi.org/10.1007/978-3-031-15273-3_25

a place where design students engage in design studies [4]. Moreover, a Conventional Design studio context is a dedicated design space which is specially allocated for the task of designing [13, 17]. The pedagogical approach of a design studio is trying to replicate the real practice by adopting project-based learning [1]. Students are provided real projects to engage with, however, those design solutions will not be built on real grounds. Students are analyzing, observing and assuming all the aspects and challenges in real-world scenarios when designing. Design tutors are allocated to give reflective feedback to students. The reflective practice is a core feature embedded within the design studio process [19]. Students are getting the reflections from their peer learners and from their design tutors to get their design refinements [21]. The design process is open for several iterations and refinements. The conventional design studio context has created a collaborative design set-up to develop design solutions through active involvement and collaboration [5]. The conventional design studio context which is located within a university set up consists of the physical infrastructure to collaborate, brainstorm, and peer learning [3]. The students are assigned design tasks, and they bring those problems to the CDS context to find solutions by going through the design process which is commonly applied in architectural studies. The design studio motivates collaborative learning. Further, the design studio allows students to get multiple reflections from students and tutors. In architectural learning domain collaboration happens in multiple ways. Usually, the collaboration happens in-between students and design tutors. The collaboration gives the opportunity to learn and grow mutually [18]. Moreover, it brings, different points of view in to one platform where the members in collaborative team could, reflect, agree or argue upon.

1.1 Technologies Applied in Architectural Studies

The rapid development of technology has made drastic changes in architectural design studio education. The technology got integrated with the design studio education and it has shown many positive impacts on teaching and learning. The internet has networked the knowledge domains and students. It has given access to students to explore the architectural practice happening across the globe. Moreover, the internet has made students closer to architectural masterpieces and it has given much inspiration to students in developing novel design solutions. Looking for precedents, and exploring special, functional, and social characteristics of architectural masterpieces done by world reputed architects, are embedded within the design practice as a part of their design process. Not only that, updated knowledge on materials, construction technologies and methodologies are easily accessible on the internet.

Drafting, Prototyping and testing are key essentials in the architectural study domain. Architectural students are motivated to draft or sketch manually. But manual sketching and drafting have been replaced by software which transferred the drawing and drafting digitally on a computer screen. Students have to test their design ideations through paper prototyping two-three decades ago in architectural studies. Paper modeling was a very popular methodology applied by architectural students. With the development of software, students tend to obtain the support of software for drafting, modeling and prototyping. This technology adaptation has made a significant replacement of skill levels adopted in the design studio context. There is a certain number of digital tools, which have been integrated with architectural studies. Thus, students utilise individual laptops, mobile devices, tabs, and mobile phones as learning tools within the design studio context.

1.2 Architectural Design Process

The architectural design process is a unique practice which has specific characteristics. The design process is a set of actions which is surrounded by relevant tools and techniques which are necessary while engaging in the design activity [15]. According to Banu [10], Architectural Design Process (ADP) is a composition of intermingled actions which consists of synthesizing and analysing, problem identification and giving and testing possible solutions. According to R.Rahbarianyazd [16] (Fig. 1), ADP is starting with a problem analysis. The design process starts with a given specific scope which needs to be solved through developing novel design solutions. The analysis process supports identifying the background of the space-related problem. The analysis of the user, user behaviour and requirements, site (context) and its demands, client, his requirements and limitations are essential areas which need to be analyzed prior to developing design ideations.

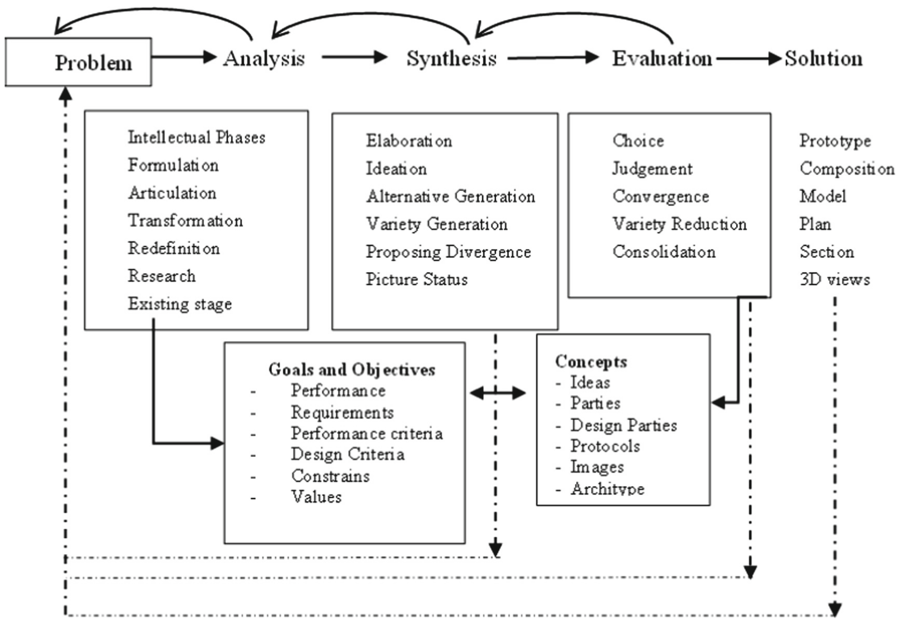


Fig. 1. Typical design process of architectural practice [12]

Synthesizing is the second phase which allows the designer to develop design ideations which could help in solving the problems and limitations identified in the very first phase of analysis. Evaluation comes as the third phase, which supports refining the design idea and arguing several factors related. Design solution comes after all those phases and the solution need to be tested and refined several times until it gives the best fit solution to the problems identified at the analysis phase.

1.3 Problem Statement

Collaboration is a key practice adopted in Architectural Design studio learning [7]. Even though the design studio setup has been created to support collaboration, it is important to observe how collaboration is happening in real practice. The level of collaboration and motivational incentives to collaborate are important factors which need more attention and research. It is believed by many, that internet has networked the people around. But this study has shown how the students have become very individual-centric even by being in collaborative groups. This study is focused on how the usage of the internet has impacted the collaborative design process of students in the CDS context.

The design process needs to be supported by the collaboration of students. Not only that, the reflective practice needs to be strengthened while being in a collaborative group. However, the role of the design student has been changed from the form of the master apprentice model. Due to the advanced networks and the internet, students have become more individual-centric, less empathetic and biased towards what they see on the internet. The design solutions need to address the real needs of the user and the collaborative design process should be supportive of refining the design to get a more user-friendly solution because it gives ample room to reflect. However, the design solutions which are generated in the CDS context, are having many problems. Most of the time, students are proposing architecturally pleasing design solutions which look appealing by their appearance. But the practicality and real-life operational factors are not addressed in-depth, during the design process, which is risky in the real context. This fact made us curious to identify what causes students to make solution-centric decisions even though they were assigned to work in collaborative groups, which could provide multiple reflections to refine the design well.

1.4 Research Questions

1. How did students collaborate within their assigned groups?
2. How did collaboration impact the design process of students?

2 Methodology

For this study, a qualitative methodology was adopted. 40 students in the Interior Design degree program, currently reading in the latter part of their second year, were selected for this study. The reason for selecting second-year undergrads was on the assumption that they possess one-year design maturity in working with the studio process. For the selection, a convenience sampling technique was utilized [8, 9]. The convenience sampling technique is a non-probability sampling technique which allows the researcher to select the sample according to the research need [11]. This particular class is consisting of 23 female students and 17 male students. This class is a composition of good, average and weak performers and it reflects the real skill distribution of a typical architectural studio practice which is practiced in a pedagogic design studio. The reason for selecting one class with a 40 student population by adopting the convenience sampling technique, reflects the realistic student distribution. In an architectural studio, there are multiple types of students. Therefore, selecting a real population of a class will give a reflection of the realistic student distribution.

The students were distributed in random 8 groups with 5 members in one group. Students were numbered 1–8 by using their name list and similar numbers were clustered into one group. Students were assigned a design task. The given task was to design an outdoor exhibition structure for an artist. For this task, 12 studio hours were allocated. There were 6 studio hours per day and for this study, two studio days were utilized. Student design processes were carefully observed by adopting the Naturalistic observation methodology [2, 6, 14].

2.1 Data Collection

Naturalistic observation involves in observation of real-life behavior of a particular situation as a third party without any disturbance made to the natural process of the participants. This method is often called as "fly on wall" observation method which is similar to being a fly on the wall and observing the actions happening [8]. The observation was carried out aiming at finding answers to the RQs generated.

The observation was recorded in a field diary [20]. The records were noted in chronological order. The design process of each group has been recorded in separate sheets with detailed observational notes made by the researcher. Furthermore, the researcher has maintained records by taking photographs of each group's involvement, at hourly intervals. The field diary was segmented into 8 categories labeled under group names. The activities they were engaged in, how they brainstorm, the collaborative methods followed by the group, tools and techniques used by the group, and group outcome were observed and noted down in the field diary as detailed descriptions in hourly intervals. Photographs were taken of the activities involved by the students at hourly intervals.

Students were engaged in 12 h of the collaborative learning process. The expectation of this task is to develop a design solution through collaborative engagement of students. After 12 h of the collaborative design process, which was conducted over two days, participants' reflections were collected through interviews. Open-ended questions were asked from each group. The interviews were conducted to minimize the subjective judgements which could be generated through naturalistic observation.

2.2 Data Analysis

The data generated through observation and interviews were analyzed by adopting six phased Thematic Analysis based on Grounded Theory [12]. Six phased Thematic analysis consists of (i) familiarizing with data, (ii) creating initial codes, (iii) searching for suitable themes, (iv) reviewing the themes, (v) defining the themes and (vi) reporting the themes. The data generated through the observation and Interviews were separately coded in order to generate themes through the thematic analysis process. Coding was done separately for the observation records and interview data. Furthermore, the photographs taken were categorized according to the keycodes generated and they were clustered under relevant categories. The row data was mapped in an affinity diagram by using sticky notes and relevant subcategories, main categories were identified. Finally, the data was fed into MAXQD 11 software. First, the transcribed interview data and observational notes were fed into the software and initial coding was done. Initial codes containing similar values and meanings were grouped into categories. Based on the information identified and reflected through categories key themes were identified for the analysis. The codes and categories identified in thematic analysis generate seven themes and those themes lead the analysis into four major dimensions (See Table 2 Below).

2.3 Results

The observation data has been summarized in Table 1. The observation generated initial codes such as the use of mobile phones, using the internet to search engine inspiration and thereby using the internet as the main source of information. Other codes included active brainstorming, making paper mockups, paper prototyping, testing through paper prototypes, testing through 3D prototyping, designing through paper prototyping, and designing through sketching, for instance, one person is sketching while others are collaboratively supplying ideas (Refer to Table 2).

Table 1. Summary of the observation

Observation summary of collaborative design	
Group 1	They spent more than 3 h browsing on their mobile devices/laptops to find inspiration to start a design Even though it was a group task, students tend to find design ideations individually Two students were leading the group and the others follow their instructions (Collaborative Group Leadership) Internet was the main source of information for them to get some design ideas Heavy usage of Pinterest/Instagram/social media Used paper prototypes for testing
Group 2	The leader proposed to search for inspiration first They use mobile devices to browse inspirations Used mobile devices/laptops/google search engines to do the user analysis Client analysis/client requirements were also gathered through emails and telephone calls - no direct interaction between client and user Used paper prototypes for testing
Group 3	The group leader initiated and had a brainstorming discussion with group members at the beginning Used mobile phones to browse design ideas/inspirations individually Group members were very collaborative and active during the brainstorming session Started designing by making prototypes/testing several prototypes No user analysis was done

(*continued*)

Table 1. (*continued*)

Observation summary of collaborative design	
Group 4	There was one group leader who was able to facilitate and gather group thoughts and contributions effectively They used mobile devices to browse for inspiration and precedents Students were individually active and not much group collaboration was noticed at the beginning Recorded their inspiration by using sketches No user analysis was done Used 3D modeling to make prototypes
Group 5	Discussed at the beginning (brainstorming) They assigned individual tasks among group members to browse for relevant information on the internet They used inspiration they found on the Internet to develop a design form No user analysis was done Directly started designing by sketching ideas on paper Used paper prototypes for testing
Group 6	Started designing through a brainstorming session They discussed more the form and the architectural appearance of the space Used mobile devices/laptops to browse for inspiration and precedents They assumed how people will use their design – the design proposal is based on the discussion summary Used paper prototyping for testing
Group 7	No user analysis was done Started by searching for inspiration from the internet, using mobile devices and laptops Less collaboration and no key personnel were identified as group leaders Students operated individually within the group Had several individual design ideations Used 3D and paper mock-ups for prototyping
Group 8	Highly collaborative, three students were very active in brainstorming Active discussions and brainstorming were done Had discussions on the materials and the form of the design Used mobile phones to browse design ideas Paper-based Started the design process by transferring design ideations to rough sketches They shared their ideas through rough sketches No user analysis was done They browsed the internet to obtain technical details and inspiration

The data recorded through observation and interviews were summarized in the below table. The reflections of students who were in collaborative groups were collected through interviews. Students' reflective feedback was coded accordingly for the analysis.

Table 2. Initial codes, categories and themes generated from interview summary and observational notes

Dimension	Themes	Categories	Initial codes from observation	Initial codes from interview
Device Centric approach	Being biased towards the Internet	Internet – The key source of information	Using the internet to search engine inspiration	We need to check available designs in the real world at the beginning, we used a mobile phone to browse the internet
			Internet as the main source of information	Google, safari and Pinterest has given us many design inspirations
	Excessive usage of mobile phones		Use of mobile phones	We decide to spend some time searching for possible design ideas individually
Individualistic design approach	Individualizing within collaborative groups	Being individualized due to excessive usage of mobile phones and personal laptops	Device-centric individual approach within the group	We were individually active on the given task, we distributed responsibilities at the beginning
	Fewer group inputs		Less interpersonal discussions	The use of the mobile phone is very easy to reach databases
Non-empathetic design approach	Non addressed user concerns	Placement of the user	No effort was taken on analyzing the user	We assume the user
			Less attention to the location analysis (site analysis)	We could not make many discussions on user

(*continued*)

Table 2. (*continued*)

Dimension	Themes	Categories	Initial codes from observation	Initial codes from interview
	Assumption based user analysis		Gathering information through emails	We didn't think about a particular user, we gave a common solution for all
			Gathering information through telephone calls	The user was not concerned, we were worried about the form of the design
			No direct interaction with a client or the user	We did not check on the user, we assumed
Solution-oriented approach	Prototyping and sketching as modes of developing ideas	Collaborative methods	Active brainstorming	We did models to get a form
			Recording the important facts by using sticky notes	We develop several paper models
		Paper Prototyping as a mode of idea development	Making paper mockups paper prototyping	We modified the best design idea selected by the group
			Testing through paper prototypes	
			Start designing through paper prototyping	
		Sketching as a mode of Idea development	Started designing through sketching	We did rough sketching
			Rough sketches were done by individuals in the group	

(*continued*)

Table 2. (*continued*)

Dimension	Themes	Categories	Initial codes from observation	Initial codes from interview
			One person is sketching while others are collaboratively giving ideas	One of our group members did sketching
			Individual design idea development through rough sketches and refined through group involvement	We did sketching to remember the initial ideas generated
		3D visualization	Testing through 3D prototyping	We used sketch up to develop the finalized form

3 Discussion

We identified 17 major codes through the data generated from the interviews and 20 major codes from observational notes. Those codes were subdivided into 7 major categories. Six codes were supportive of generating the category 1: Internet – the key source of Information. Four codes were leading to category 2: Being individualized due to excessive usage of mobile phones and personal laptops. Ten codes have generated the category 3: Placement of the user. Four major codes have generated category 4: Collaborative methods. Another four codes were generated the category 5: Paper Prototyping as a mode of idea development. Seven major codes were supportive of identifying the category 6: Sketching as a mode of Idea development and the 7th category: 3D visualization was generated through two major codes identified.

3.1 Answering RQ1: How did Students Collaborate Within Their Assigned Groups?

The codes, categories, themes and dimensions generated through thematic analysis have showcased a clear overview of the answers to the Research Questions constructed. The thematic analysis generates 7 key themes and 4 major dimensions. Among those, the following themes are answering the RQ 1 created. Being biased towards the internet, excessive usage of mobile phones, individualizing in collaborative groups, fewer group inputs, prototyping and sketching as a mode of developing ideas are the themes which provide a direct reflection on the methods they followed in collaborating. The results depict that students who were clustered in groups were more focused on searching for design ideations through external sources. They engaged in this task being self-centric, rather being group centric. It made them less empathetic. The activities such as searching for ideas from the internet and using social media platforms to search for ideas made them individual-centric even within a collaborative group. Further, the mobile devices and easy access to the internet made students distant from the group members and it made them more device-centric rather than group-centric. Seven groups out of eight started browsing ideas individually. Only the eighth group had a strong brainstorming session at the beginning. They argue on several design types they could generate and some materials they could utilize at the beginning.

The results indicate that active collaboration was limited at the beginning of the design process due to overexposure to the internet and mobile devices. The information they received from the internet, made them biased towards what they could see on the web without arguing the fact. This has made them less empathetic towards real user requirements. The information received from the internet was directly transferred into the design process, by adopting similar forms and similar materials. Pinterest, Instagram and search engines such as Google, and Safari diverted students away from realistic conditions and made them less collaborative. It was noticed that idea-sharing and active involvement between group members were limited due to excessive usage of devices such as mobile phones and laptops.

3.2 Answering RQ 2. How did Collaboration Impact the Design Process of Students?

The codes categories and themes generated are showing a lineup of activities students have followed. 5/8 Groups started the design process by connecting to the internet individually, browsing for possible inspirations and precedents after a very short discussion. They spent nearly the first 2–3 h searching for possible design ideations. The design process started with searching for suitable ideations. The design images identified from the internet were taken into the discussion and brainstorming happened based on the ideations found on the internet. Students tend to save the design ideations in their devices individually.

According to R. Rahbarianyazd [16] (Fig. 1), the architectural design process starts with analyzing the problem at hand. This analysis process consists of several intellectual phases accompanied by redefining the current issue. Articulation and sufficient research on the problem domain will help the designer or design team to analyze the problem at hand. In collaborative design activity conducted in the CDS context, students have started the design process directly synthesizing the ideation. That is a one-step skip, which made the students empathise less with the problem at hand. The analyzing process offers an overview to start the design, by providing a solid understanding of the problem at hand. The scope needs to be well understood by the design student and they need to dig into the real requirement of the user and the context. However, the engagement process used by the students in the collaborative design process, made them blind to the user requirements. The themes generated such as "assumption-based user analysis" and "non-addressed user concerns" display the lack of focus given to the user during the collaborative design process.

Being device-centric and individualized within the assigned group has made the design process more complex. The process they followed makes the design process solution-centric. Students were focused on identifying the best fit formation and ideation for the design that they could propose. 6/8 groups did not conduct any discussions on the user, user behavior and user requirements. Non-discussions made on the user made them blind to the real requirements. This made the design solutions very hypothetical. Further, they have taken the risk of assuming the user requirements. In their collaborative process, 7/8 groups assumed the requirements and another group conducted a quick analysis through telephone calls. Those methods are not reliable user analysis methods to follow in order to provide user-centric design solutions. Being device-centric, made students less empathetic, adversely impacting the design process by supplying aesthetically pleasing but less functional design solutions at the end of the process.

Moreover, being less empathetic could create many problematic situations. The user is an important stakeholder and the voice of the user is a powerful and valuable input which could contribute to shaping the design into a more functional manner.

4 Conclusion

This study was conducted to understand how students collaborate within a CDS context, and to understand the impacts on the design process due to the collaborative mechanisms followed. We noticed students have become individual centric even within collaborative groups due to the over exposure to digital devices. This made them device centric, resulting in less empathetic design solutions because they skipped certain important steps in the design process. Moreover, they made biased assumptions on the information they received from the internet and other social media platforms. Such assumptions prevented them from analysing real life problem scenarios. User concerns were not addressed and assumed. It is essential for design students to be grounded and sensitive to real life situations, thus further exploration and collaboration is paramount. Furthermore, being device centric and biased towards information received through devices, has limits the creative collaboration which is a significant requirement for architectural studies. This process will create less empathetic designers and it is a problematic situation which needs to be addressed.

Technology is indeed supportive for education. We noticed much research was dedicated to investigate the positive impacts of technology. This study, however, has identified negative impacts which could be generated through advanced technologies and digital devices. Moreover, there is a void in research, investigating the impacts of technology on the architectural design process. This study, therefore, caters to that void we identified in the architectural research domain. We believe, this gap needs to be addressed and further research is required to investigate the impacts of technology in the architectural educational domain.

References

1. Abdelmonem, M.G.: From propagation to negotiation of ideologies in the architectural design studio: critical insights in student-centred strategies for interactive learning. J. Des. Res. **14**(1), 1–21 (2016). https://doi.org/10.1504/JDR.2016.074781

2. Allen, M.: The SAGE Encyclopedia of Communication Research Methods (2020). https://doi.org/10.4135/9781483381411
3. Al-Mogren, A.A.S.H.: Architectural learning: evaluating the work environment and the style of teaching and management in design studio. AEJ – Alex. Eng. J. **45**(5), 603–616 (2006)
4. Ardington, A., Drury, H.: Design studio discourse in architecture in Australia: the role of formative feedback in assessment. Art Des. Commun. High. Educ. **16**(2), 157–170 (2017). https://doi.org/10.1386/adch.16.2.157_1
5. Ismail, A.M., Soliman, M.H.: Integrating multi-grade collaborative learning pedagogy into design studios. Archnet-IJAR **4**(2/3), 201 (2010). https://doi.org/10.26687/archnet-ijar.v4i2/3.105
6. Charmaz, K., Henwood, K.: The SAGE Handbook of Qualitative Research in Psychology. Presented at the, 55 City Road, London 26 February 2019. https://doi.org/10.4135/9781526405555
7. Cho, J.Y., Cho, M.-H., Kozinets, N.: Does the medium matter in collaboration? Using visually supported collaboration technology in an interior design studio. Int. J. Technol. Des. Educ. **26**(4), 567–586 (2015). https://doi.org/10.1007/s10798-015-9322-3
8. Cohen, L., et al.: Research Methods in Education. Routledge, New York (2018)
9. Daniel, J.: Sampling Essentials: Practical Guidelines for Making Sampling Choices. Thousand Oaks (2019). https://doi.org/10.4135/9781452272047
10. Garip, B., Garip, E.: Addressing environmental design in interior architecture education: reflections on the interior design studio. Presented at the World Conference on Design, Arts and Education (DAE-2012) (2012). https://doi.org/10.1016/j.sbspro.2012.08.272
11. Given, L.: The SAGE Encyclopedia of Qualitative Research Methods. (2019). https://doi.org/10.4135/9781412963909
12. Hoskyns, S.: Thematic analysis. In: Collected Work: Music Therapy Research, 3rd edn. Barcelona, Dallas (2016). (AN: 2016-21423)
13. Ismail, M.A., et al.: Digital studio vs. conventional in teaching architectural design process. Proc. – Soc. Behav. Scie. **64**, 18–25 (2012). https://doi.org/10.1016/j.sbspro.2012.11.003
14. Kellett, M.: How to develop children as researchers: a step-by-step guide to teaching the research process. Presented at the, London 16 March 2021. https://doi.org/10.4135/9781446212288
15. Kurak Acici, F.: A studio study on re-interpret the comments of a brand in the design training. Presented at the 4th World Conference on Educational Technology Researches (WCETR-2014) (2015). https://doi.org/10.1016/j.sbspro.2015.04.769
16. Rahbarianyazd, R., Nia, H.: Aesthetic cognition in architectural education: a methodological approach to develop learning process in design studios. Int. J. Cogn. Res. Sci. Eng. Educ.-IJCRSEE **7**(3), 61–69 (2019). https://doi.org/10.5937/IJCRSEE1903061R
17. Rodriguez, C., et al.: Collaborative learning in architectural education: benefits of combining conventional studio, virtual design studio and live projects. Br. J. Educ. Technol. **49**(3), 337–353 (2018)
18. Safin, S., et al.: The interplay between quality of collaboration, design project evolution and outcome in an architectural design studio. CoDesign **17**(4), 392–409 (2021)
19. Schon, D.A.: Educating the Reflective Practitioner. Toward a New Design for Teaching and Learning in the Professions. The Jossey-Bass Higher Education Series (1987)
20. Tracy, S.J.: Qualitative Research Methods: Collecting Evidence, Crafting Analysis, Communicating Impact. Wiley-Blackwell, Chichester (2013)
21. Webster, H.: Facilitating critically reflective learning: excavating the role of the design tutor in architectural education. Art Des. Commun. High. Educ. **2**(3), 101–111 (2004)

How Does the Shift from Handwriting to Digital Writing Technologies Impact Writing for Learning in School?

Lisbet Rønningsbakk(✉)

UiT the Arctic University of Norway, Langnes, Box 6050, 9037 Tromsø, Norway
Lisbet.ronningsbakk@uit.no

Abstract. The shift from handwriting to using writing technologies are widespread in today's schools. And where handwriting still is the most used method, it is supported with digital writing technologies. My aim in this article is to show and discuss some aspects on how digital writing technologies impacts learning in school. Writing is a frequent activity in all education and the shift from handwriting till keyboarding brings significant changes. The linear form of text production that characterizes handwriting is replaced by a flexible and non-linear form. Keyboarding enables the writer to start any place in the document and edit constantly without having to start over. For students in school, it is also a benefit that they can write long texts even before their handwriting skills are developed. This seems to stimulate motivation for writing and producing texts in school. The study showed that digital writing technology improved writing skills but not text skills. Therefore, using digital writing technology prerequisite emphasis on supervising the writing process to develop good text strategies.

Keywords: Digital writing technology · Digital writing in school · Technology supported learning · Teaching with technology

1 Introduction

Writing is a main activity in all learning work in school. The ability to write fluent and legible is essential for students' learning. Thus, the aim for this article is to present and discuss the changes that occur when shifting from handwriting to keyboarding in school based on results from a phd-study that investigate how technology impact different aspects of learning in school [1].

Using digital writing technology changes the writing process from a linear process to a process where all parts of the text can be produced and changed along the way. It allows texts to be saved and shared in ways that have not been possible before. This leads to questions about if and how the teachers should change their ways of teaching to adapt these changes. The research question in the study targets these challenge, asking "how does the use of digital writing technologies impact learning work in school"? This paper will try to give some answers, based on what my research revealed about writing.

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 231–240, 2022.
https://doi.org/10.1007/978-3-031-15273-3_26

2 Key Concepts and Theoretical Framework

Writing is defined as a basic skill for learning in the Norwegian curriculum LK-20 [2]. Writing for learning can be viewed as an ongoing dialogue, mostly between student and teacher but also with peers and others, supporting the dynamic movement between feedback and feed forward that drives all learning processes [3, 4]. Feed forward is the expectations of future learning and feedback is the conception of the previous learnt. From the learning point, the expected future knowledge change, due to changes in prior knowledge. What you learn changes the way you see what you already know. In this way, adding something new to the prior knowledge, changes both feed forward and feedback. Hence, the dynamics between feed forward and feedback is a driving force in all learning, and writing is an essential activity mediating this movement [3, 4].

However, the student needs basic writing skills to be part of this written learning dialogue. Hertzberg [5] see writing as dependent of two different types of strategies; writing strategies and text strategies. Writing strategies are the connected with the technical part of writing, such as forming letters, writing fluently, spelling and grammar, while text strategies are connected with the ability to compose a text for a certain purpose. Berninger et al. [6] describes four components in basic writing: text generation, transcription, working memory and executive functions. Both theories can contribute to understanding of writing as a phenomenon for learning, pointing both at basic skills and functions that are related to a more contextual perspective on learning. To study how technology affects writing as learning work, the gaze must therefore be directed both at the writing tool itself and the students' writing strategies, and towards the purpose of the text and the students' text strategies.

Vygotsky also describes the writing process as an abstract and complicated skill that implicates an interaction of various cognitive processes [7]. He explains the challenges of writing by comparing between what can be called oral and written speech. Written speech is a separate linguistic function that differs from the spoken language both structurally and functionally [7]. Children struggle to express themselves in writing, even if they have well developed vocabulary and master the grammar of speech because they are two different processes. While oral speech is quoted in a social context where the situation itself supports what is said and creates meaning for those who participate, the written speech is detached from its context or situation [7]. A written text must therefore include all the information necessary for the reader to interpret the meaning of the text as intended by the writer.

Ricoeur refers to language as an exterior of inner experiences, a way to make them available to others [4]. Salomon et al. also point that writing forms and refines thoughts and ideas that enable us to see things in new ways [8]. The activity to write is thus far more than just using a tool, it must consider its future purpose which is to convey something to others.

All these theories have been useful to understand both the technical part of writing: the writing strategies [5] or the text generation and the transcription [6] and the higher functions that is needed: text strategies [5] and working memory and executive functions [6], which are all important to understand writing as learning work in school when changing writing technology, or writing mode, from handwriting to keyboarding.

3 Method

The paper is based on a multi case study of 25 students from two classes and two schools: 15 students from 4th grade (9–10 years old) from Southam school and 10 students in 10th grade (15–16 years old) from Norwick school. The study took part during one academic year, using participating observations as main access to the field. In addition, the study had access to students' text productions during the year of observation [1].

The choice of multi case study as research strategy gave access to collect a wide range of data about the empiric field of study [9, 10]. I could select cases within my network of teachers and schools which were innovative using technology, and the observations cover a period of one academic year, represented by five weeks of participation in the two schools. I observed teaching with and without technology support and aimed to identify all kinds of changes that occurred in the students' learning work. Data were generated through writing, coding with NVivo[1], rewriting and refining reflections from the observations, before presenting them in narratives. As I studied a field I knew well as former teacher, I needed a hermeneutic approach to the observations to avoid biased perceptions [11]. Therefore, all data were approved by all participants (parents, teachers, school leaders) as a reliability check [1]. I also had access to students' texts on Learning Management System (LMS) which were analysed to support the impressions of every student's written performance. The results will be presented with use of narratives to illustrate findings.

4 Results

In general, the study showed that writing was a frequent method in all the theoretical subjects, and that students used both handwriting and keyboarding as writing modes. Writing was often linked to activities that followed an introduction or a social learning dialogue in class, with the purpose of processing knowledge, practicing subject-specific skills, or getting general writing training. There was also some writing related to the students' homework All texts could be understood within the frame of functioning as a dialogue between (mostly) teachers and students, but with more emphasis on social learning when the text production used digital technology.[2]

The study showed that students both in 4th and 10th grade were motivated for writing using keyboarding. It also showed that the students wrote long texts and that they wrote more efficient. It also eased the writing for students who were reluctant writers. The positive effect of keyboarding seemed to be mostly connected to writing strategies or the technical parts of the writing. However, it seemed that keyboarding did not have the same positive impact on students' text strategies.

[1] NVivo is a well-known tool for qualitative data analysis: Qualitative Data Analysis Software | NVivo (qsrinternational.com/).

[2] This article will not include multi media texts, which also were frequent in the observations. But social learning processes increased when students worked with multi media, a finding which is supported by other studies [6, 12].

4.1 Motivation for Writing Increased with Digital Technology

The study showed that the fourth graders seemed very motivated to write. They had functional and fast typing strategies on the keyboard, and they wrote long texts. They had used Trageton's method[3] of learning to read by digital writing tools [13] and were familiar with the digital writing technologies. Research suggests that the use Trageton's method develop better writing skills with better content quality, grammar, and orthography [14]. Reports also states that students write faster and more correctly and are more motivated to write when using writing technology in early literacy training [15]. Feng et.al. also showed in their meta-analytic review that students' wrote faster and longer texts using keyboarding [6]. The same tendency seems to be supported by Williams & Beams' research review which states that motivation seems to increase and that that reluctant writers benefit from keybording [12].

The tenth graders started using digital technology when I first met them. Most of the writing in all subjects were keyboarding and all work was organised in the LMS[4] so they had to change a nine-year old handwriting practice. But they rapidly embraced the new technologies and changed the way they worked. In relatively short time their motivation to write increased and they wrote efficiently and produced long texts.

The increased motivation can be explained by the fact that the writing itself was changed. Since writing is complex and demanding [7], writing for learning can bring negative experience. Since negative motivation is often connected to the situation where the reluctance arose [16] negative experiences with writing can be crucial for learning. Negative emotions tend to replenish the functions of consciousness so that there is no room for the reflection required to learn [17].

Several narratives from the study seem to be about motivation. Fourth class wrote scary stories and Yunus and Vera had failed to save their text. When the class continued writing they had to start over from the beginning. While the other students could continue working on their drafts, Vera and Yunus have no visible results of their first attempts. One might have expected that Vera and Yunus would have reacted with frustration and protests. But they started writing new drafts, rather untouched and without being tracked down. Self-regulated learning theory shows that students can opt out of learning, when they do not believe that they will succeed because investing also implies the risk of failure [18]. The loss of work that has already been done could lead to experiencing failure. Motivation can be further weakened if the students perceive themself without guilt for the loss of work. It could easily have happened with these two, at least with Yunus, who did not work as independently and efficiently as Vera. When they both started over without a problem it was clear that the motivation for writing seemed to be present and resilient.

The theory of self-regulated learning was also important for another situation. Stanley was keen to compare himself to Vivien while they were working on a science assignment. Boekaerts points out that students' motivation can be fundamentally mastery- or performance-oriented. Performance-orientation can lead students to being more concerned with comparing themselves to others than focusing on their own learning [18].

[3] Trageton's method is developed by Norwegian Arne Trageton and involves using digital writing technology to learn to read.

[4] They used Moodle as Learning Management System (LMS).

This was typical for Stanley. His focus changed from the task itself to the length of the text when he found the word count function on the computer. He was obviously stressed by the fact that Vivien, who he often compared with, could have written more words than he. It is difficult to say for sure how this affected Stanley's motivation for the task at hand, but it may be suggested that the focus on performance and comparison with Vivien would go beyond his academic work there and then. At the same time, an external level of performance may also trigger the desire to succeed because the competition with the others become important. Boekaerts say that performance-oriented students can try to avoid resistance or struggle in their learning work because they dare not take the chance of failure [18]. However, there is no basis for considering performance motivation as a critical factor in the current observation of Stanley. Stanley seemed positive and content in every way in the situation, and his competitive motive may have been a more stable attribute of his personality. As Boekaerts notes, performance orientation increases in students with age [18], so this is also a natural part of the students' development. However, teaching can inhibit or promote performance orientation through the way the teacher handles feedback to individual students in classroom publicity. Teachers who emphasize mastery instead of achievements, which focus on approaches and not the right answer, and that legitimize making mistakes, can counteract performance orientation in the learning environment [19, 20].

Although Stanley was derailed by Vivien, it was clear that writing was less available for comparison when students were using digital writing technology. Stanley could compare himself to Vivien because she was sitting beside him. However, he did not have immediate access to the other students and could not keep up with how their work. The location in front of each computer could mitigate the tendency for comparison between students, compared to sitting in groups in the classroom with possibilities to overlook each other's workbooks. This is also something that teachers have experienced from other situations using computers in classrooms [15]. Digital writing technology can thus be positive for students who are easily derailed by comparing themselves to others.

Using digital writing technology seems to work positive in various ways for students' motivation to write. Even when students are performance oriented, the use of technology levels out differences in performances in ways that eases the impact they have on each other because the differences become less visible.

4.2 Digital Technologies Change Writing Strategies

Using digital writing technologies change the course of writing. Students get tools that able them to write perfect even before they have developed a functional handwriting. Traditional text has a linear form from the beginning to the end. When using digital writing technology, the linear form is no longer necessary [8]. The writing can start wherever wanting and jump forth and back in the text. This is more in line with the way students' think when learning [7].

The changes in the writing course were obvious when tenth grade changed from handwriting to digital writing tools. They stopped drafting before writing when they experienced the differences. They were able to adjust, rewrite and reorganize the texts during the writing process and could plan the text along the process, not before starting [8]. The writing process gets more flexible and open for the students' choices and adaptions along the work. Thus, the digital writing technology has impact on both the writing strategies and the text strategies [5]. The writing went easy, and the text were looking good when not written by hand. This freed capacity to work with the content, or for working memory and executive functions [6]. When writing is freed from the linear form which handwritten texts are bounded to, the students got more freedom to adapt writing to their own writing- and text strategies. This requires that they have developed an automatised use of the keyboard [7], which seemed to be the situation for most of the students in 4th and 10th grade, probably because they used keyboarding in a large scale outside of school, using SoMe and phone messaging.

The word processor can also provide direct feedback on spelling and grammar, which will be of great help to students who are struggling with this part of writing. Spelling and grammar might occupy the students' feed forward feedback processes. When technology provides automatic corrections, students do not have to reflect on whether they write correctly as they type. Just as if the students had internalized the spelling so that it becomes a habit, technology has taken over this task. The spelling is not habituated in the traditional way, but the result is the same: the functions of consciousness are released for tasks other than spelling. When students receive direct feedback on spelling from the computer, and can correct errors themselves, they will not need the teacher's review of the orthography. They can concentrate on developing other aspects of the text, such as storytelling (text strategies). Having access to strategies that enable them to help themselves makes students more independent and self-driven in their learning work.

One observation of a writing exercise is from an assignment where the 4th grade students wrote scary stories. The assignment was designed as process-oriented writing and the students had individual supervisions with the teacher along the work. Content, grammar, and orthography were discussed, based on what they had decided to focus on. Since I served as a teacher in the class I also participated actively in this work. I want to highlight the dialogue I had with Linda and with Carl.

Linda appeared academically clever, independent, and generally self-driven in her learning work. She was also a little modest and did not show herself much in the class publicity. Linda wrote quickly and her text was long. The class had not had much focus on spelling in previous years because the teachers were concerned with developing the joy of writing. But in 4th grade there was an increasing focus on spelling in the students' writing assignments. Linda was one of those who wanted to have correct orthography. At the same time, I saw that she had some challenges with grammar which I also brought up in the supervision. Linda's feed forward was linked to developing a correct writing and she wanted feedback on grammar so that she got a flawless product. In this situation, there was a correlation between the student's own experience of potential for improvement and what the teachers were concerned about. Her feed forward feedback loop [3, 4] ensured that the learning work drove the learning object [20] in the right direction. Thus, it seemed that the teaching was well adapted to her proximal zone of development.

Carl had previously told me about challenges that made him find the learning work demanding. In supervising Carl, it was therefore important to focus on promoting positive experiences from the learning work [17, 18]. For students who find the school particularly demanding, my experience is that the joy of learning quickly becomes damaged. The dialogue between Carl and me was characterized by closeness and mutual recognition.

It gave Carl the opportunity to show his mastery and get feedback on his work based on what he wanted with his text (feed forward). He showed great commitment to his work, and I saw the dialogue as a support for strengthening Carl's feed forward feedback processes related to striving which is an important requisite for learning [3, 4].

Such learning dialogues can be conducted without the writing taking place in digital devices. In other words, they are not dependent on the use of technology. But there was more space between the students in the computer room and easier to supervise without the other students hearing. In addition, the threshold for making changes was low, because of the digital writing tool. It seems that students' learning in the form of feed forward feedback processes could be stimulated and directed towards developing writing and text strategies when using digital tools.

4.3 Digital Writing Technologies Demands New Text Strategies

Students in tenth grade needed new text strategies when they switched to digital writing tools. This was evident in a situation where Ann, Camilla and Diana were collaborating on process-oriented writing. In process-oriented writing, the students will work with the text in different phases, supported by responses from other students (and teachers). The collaboration between the students gives them both valuable input to their own texts and training in identifying good ideas that could be further developed. In addition, they can suggest ways in which this can be done, while also exercising their critical ability to assess both their own and others' texts [19]. The teachers were used to using this way of working, but I quickly realized that Ann, Diana and Camilla were not. They showed each other what they had written, but the comments confined themselves to positive affirmations, as "nice." They also compared the length of their texts, concluding who had come the furthest in the writing process based on the number of words. They did not have the prerequisites to ask critical questions about each other's texts and give constructive feedback on the choice of topic, disposition, language, and dissemination. The learning activity did not become the feed forward feedback [3, 4] process they needed to reflect on how they could improve their own texts. They did not seem to see the purpose (feed forward) of doing the activity, because they lacked concepts that could form the basis for such an activity (feedback). Neither Ann, Camilla nor Diana made changes to their texts while the activity was going on, nor did they give each other concrete input that might be captured and taken to the completion of the texts that they were going to do at home. Their text strategies [5] seemed not to be developed for this purpose.

Process-oriented writing is often associated with digital writing technology because it is so much easier to make changes along the way in the text when it is produced digitally. The teaching in tenth grade must therefore be changed in terms of how the students were prepared for the new ways of working, by teaching them strategies that make the learning work feel meaningful.

4.4 Writing Long Texts is not the Same as Writing Well

In tenth grade, students were expected to have correct orthography and grammar and to have developed understanding of writing as dissemination. Access to the student work in their LMS provided an opportunity to look at the quality of the texts they wrote. Among other things, the students wrote film reviews. This assignment worked well for assessing and comparing students' texts. The film review was a to part task, where the first part was to give a summary of the film. Conveying a written summary of a film requires that the text not only refers what is going on, but also provides sufficient information about the situation and context. In film, it is often the dialogue that drives the action, at least if the film does not have a clear narrative role. When the students are to convey the film's content in what Vygotsky calls written speech, it is required that the students be able to distinguish it from the oral speech that the dialogue conveys. The written speech differs from both what Vygotsky calls inner speech and oral speech and requires a higher level of abstraction [7]. Written speech must fully explain the situation to be understandable [7]. Therefore, some textual steps are necessary that can help to explain the situation fully to be understandable [7]. This requires text strategies [5].

The texts gave the impression of how and to what extent the different students had made the content of the film available to the reader. The students' texts varied considerably in length: Betty had written 2532 words, Diana had written 1558 words, Ann had written 1359 words, Arnold's text was 872 words, Elsie had 647 words, Chris had written 506 words, while Daniel ended up with 149 words. Betty, who had written the longest text, conveyed the content of the film as a summary of what she saw on the screen, but provided minimal information about context that could make it possible to imagine the situation in which the film took place. She was thus unable to make the dissemination an exterior of her inner experiences, or context independent [4, 7]. Diana, who had 1,000 fewer words, on the other hand, succeeded quite well with the dissemination. She had made sure to describe the situation as early as the first sentence, where she explained who the film is about. Ann and Elsie delivered texts like Bettys', characterized by a lack of context description, while Chris and Daniel accounted for the circumstances of the action in the film, like Diana. Arnold's text was relatively long and excellent when it came to solving the assignment. The texts showed the variation among the students. Some of them lacked good text strategies even though they wrote long texts, and some wrote only short but good texts.

As the observation above shows, there was a mismatch between the qualities of the texts and their length. While some texts appeared to be good written expressions, some also looked more like oral speech. In this study, it is not possible to say anything certain about this. It seems that the easily accessible digital writing tools able students to write ling texts. Thus, there is nothing here that points to students' texts getting better when using technology.

5 Conclusion

Using keyboards change the way students write in several ways. The course of the writing is changing from a linear form to a flexible form which is able to adapt to students' various preferences. Students can start where they want, change what they want under ways, and they do not have to plan the text before starting. They do not have to start over when the work goes astray. This seems to ease motivation for writing. It also seems that digital writing makes it easier for students not to compare with each other because the texts look more alike when they write, and thus preventing performance motivation in class.

Using digital writing technologies help students to better writing strategies. They can write texts without having developed a functional handwriting. Thus, they can produce more texts, helping the dynamic movement of feedback and feed forward between teacher and student to learning.

Better motivation and eased writing strategies free cognitive capacity for other learning tasks, like developing text strategies. It seems that use of digital writing technology does not have impact on students' text strategies, ability to tell a story, to disseminate in a proper way according to the genre.

With the use of digital writing technologies, methods like process-oriented writing, work well in class. The flexibility that comes with digital writing, are efficient tools for making changes in the texts without having to start over. This requires learning necessary strategies for process-oriented writing, like drafting, presenting ideas, questioning drafts and ideas, critical reviewing and so on. Thus, motivation for writing can be maintained, providing more possibilities for learning when students can use keyboarding.

References

1. Rønningsbakk, L.: Når didaktikken møter de digitalt innfødte: teknologistøttet læringsarbeid i skolen i lys av tradisjonell og nyskapende undervisning. UiT Norges arktiske universitet, Tromsø (2019)
2. Utdanningsdirektoratet: Overordnet del av læreplanverket. Retrieved from 2.3 Grunnleggende ferdigheter (udir.no). Utdanningsdirektoratet (2019). Accessed 12 May 2022
3. Hermansen, M.: Omlæring. Klim forlag, Århus (2003)
4. Hermansen, M.: Motivasjon og den gode læring. In: Postholm, M. B., Tiller, T. (eds.) Profesjonsrettet pedagogikk, pp. 8–13. Cappelen Damm akademisk, Oslo (2014)
5. Hertsberg, F.: Skrivekompetanse på tvers av fag. In: Elstad, E., Turmo, A. (eds.) Læringsstrategier. Søkelys på lærernes praksis, 2nd edn. Universitetsforlaget, Oslo (2008)
6. Feng, L., Lindner, A., Ji, X.R., Joshi, R.M.: The roles of handwriting and keyboarding in witing: a meta-analytic review (2017)
7. Vygotskij, L.S.: Tenkning og tale. Gyldendal akademisk, Oslo (2001)
8. Salomon, G., Kosminsky, E., Asaf, M.: Computers and writing. In: Nunes, T., Bryant, P. (eds.) Handbook of children's literacy. Kluwer, London (2003)
9. Yin, R.K.: Case Study Research: Design and Methods, 3rd edn. Sage publications, Thousand Oaks, California (2003)
10. Blaikie, N.: Designing Social Research. Cambridge Polity Press, Cambridge (2000)
11. Gilje, N., Grimen, H.: Samfunnsvitenskapenes forutsetninger. Universitetsforlaget, Oslo (1993)
12. Williams, C., Beam, S.: Technology and writing: review of research. In: Computers & Education, vol.128. Elsevier (2019)
13. Trageton, A.: Å skrive seg til lesing: IKT i småskolen. Universitetsforlaget, Oslo (2003)
14. Bjarnø, V., Giæver, T. H., Johannesen, M., Øgrim, L.: DidIKTikk. Digital kompetanse i praktisk undervisning. Fagbokforlaget Vigmostad & Bjørke AS, Bergen (2009)
15. Berrum, E., Hallmrast, H. H., Helle, M., Lønvik, K.: Erfaringer i skoler som opplever å ha lykkes med bruk av nettbrett og/eller pc i sin grunnleggende lese-og skriveopplæring. Senter for IKT i Utdanningen, Oslo (2016)
16. Boekaerts, M.: Understanding students' affective processes in the classroom. In: Schutz, P., Pekrun, R. (eds.) Emotion in Education. Elsevier Academic Press, San Diego (2007)

17. Rønningsbakk, L.: Hva Ida lærte oss. Emosjonenes betydning for tilpasset opplæring. In: Tiller, T., Jakhelln, Leming, T. (eds.) Emosjoner i forskning og læring, vol. 1/2009. Eureka forlag, Tromsø (2009)
18. Boekaerts, M.: Motivation to learn. International Academy of Education in cooperation with International Bureau of Education (UNESCO), Geneva, Switzerland (2002)
19. Meyer, D.K., Turner, J.C.: Scaffolding emotions in classrooms. In: Schutz, P., Pekrun, R. (eds.) Emotions in Education. Elsevier Academic press, San Diego (2007)
20. Hauge, T.E., Lund, A., Vestøl, J.M. (eds.): Undervisning i endring. IKT, aktivitet, design. Abstrakt forlag, Oslo (2007)

Classroom Digital Technology Integration – A Double-Edged Sword? Engaging and Practical yet Harmful

Doris Kristina Raave(✉), Eric Roldan Roa, Margus Pedaste, and Katrin Saks

University of Tartu, 51009 Tartu, Estonia
doris.raave@ut.ee

Abstract. Despite the prominence of technology in contemporary education, studies on technology-enhanced learning are most focused on barriers affecting technology's integration. Overshadowed by this mainly unilateral approach, a precursory question of why technology should be integrated into the classroom has often been overlooked. However, without knowledge of this sort, we cannot underpin the need for classroom digital technology integration (CDTI). This study aims to gain exploratory insight into teachers' perceptions of CDTI that allow advocating for CDTI. We conducted a qualitative study with inductive content analysis with data collected from semi-structured interviews with 18 teachers to understand better the deemed effects of CDTI and what it might depend on. Generally, the main reasons for the CDTI lay in its affordance to improve engagement and practicality in teaching-learning processes. CDTI's main detriment was its hindering effect on health and fine motor development. These results imply CDTI's beneficence, and hence it should be supported. To minimise CDTI's hindering effects, we recommend reconsidering how technology is integrated into the process.

Keywords: Classroom digital technology integration · Technology-enhanced learning · Primary school · Secondary school

1 Introduction

Classroom digital technology integration (CDTI) is a prominent aspect of contemporary education, rendering CDTI an increasingly common practice among educators [1], also supported by educational policies [2, 3]. The commonality of CDTI implicitly indicates that it somehow benefits the learning process [1, 4], advocating hence for technology-enhanced learning. Previous studies suggest that the successful CDTI is foremost defined by enhancing student learning outcomes [5], and research on the evaluation of CDTI is mainly focused on its effect on learning [6].

Technology-mediated learning theory proposed by Brower in 2019 posits that technology serves only as a mediator of users' intents [7]. The latter indicates the importance of studying stakeholders' underlying aims when using technology to enhance learning. Previous studies suggest that teachers are the key stakeholders in determining CDTI, e.g., [8, 9] and that there is an alignment between teachers' pedagogical reasoning and

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 241–251, 2022.
https://doi.org/10.1007/978-3-031-15273-3_27

practices, e.g., [10–12]. Therefore, researchers in the field are increasingly focusing on teachers' pedagogical reasoning, e.g., [11, 13–16], which could be regarded as the key commencement for facilitating purposeful CDTI's practices to support technology-enhanced learning. For example, previous research has found that teachers value CDTI's affordance to facilitate content presentation, support knowledge acquisition, and motivate students [5, 15–17]. Equivalent aspects of optimisation and qualitative and quantitative improvement of the teaching and learning processes have been identified as characteristics of technology-enhanced learning [18], indicating a shared perspective of CDTI's affordances for teaching and learning processes.

Nevertheless, previous research posits that contextual and personal factors cause teachers to have different views on CDTI [14, 19, 20]. The same technology may be perceived and used differently by teachers due to their personal characteristics such as knowledge, experience, and dispositions, e.g., beliefs and attitudes [8–11, 17], as well as context-specific characteristics, such as grade, subject, and school [12, 14, 19–21]. Cultural context can further be seen as a relevant context-specific characteristic worth considering when seeking insight into teachers' perceptions of the CDTI [10, 21, 22]. Commonly researched factors affecting CDTI have been noted at the student, teacher, and institutional levels, indicating, for example, aspects related to resource availability and digital competence [16].

Research suggests also looking into why teachers do not practice CDTI to understand better different teachers' perceptions for a more holistic understanding of the field [16]. Understanding better the underpinnings of CDTI and how to better support this process serves as valuable information for stakeholders when considering and evaluating CDTI for technology-enhanced learning. Teachers' reasonings for CDTI contribute to supporting and changing teachers' practices of CDTI and considering technology's different affordances to support students' learning [11, 15, 16, 21].

This study aims to contribute to the growing research on factors affecting CDTI by offering an exploratory insight into Estonian teachers' perceptions of CDTI. In Estonia, using digital technology in teaching and learning is a part of teachers' professional standards framework [23]. Digital readiness is high amongst Estonian teachers [22], and CDTI is a relatively common practice [24]. Estonia's education system is among the best-performing, according to PISA 2018 results [25]. For these reasons, it is considered interesting to investigate the perceptions of CDTI in Estonia as it may shed light on the relationship between CDTI practices and achievement. More specifically, this study, adopting an exploratory qualitative study design, seeks to find answers to the following research question: what are Estonian primary and secondary school teachers' perceived benefits, detriments, and challenges of CDTI?

2 Method

2.1 Context and Sample of the Study

This study seeks to gain exploratory insight into the perceived benefits and detriments of CDTI. An exploratory qualitative research design with inductive content analysis was adopted to this end. This study is part of piloting studies of a larger research project, namely Digiefekt. The Digiefekt project has adopted purposive sampling to ensure a diverse study sample. The recruited schools were from different regions across the country. Amongst these schools, there were both high- and low-performing schools in terms of students' results in academic tests, school results in the school's satisfaction survey and self-assessment of digital competence conducted among teachers, students, and parents. From each school, the end grades teachers at each school level, primary and lower secondary school, i.e., the third (9–10 y/o), sixth (12–13 y/o) and ninth (15–16 y/o) grade, were recruited. Within these grades, we further selected teachers in the subjects of Estonian, mathematics, and natural sciences.

For this study, a smaller sample of volunteering schools and teachers to participate in pilot studies of their interest were recruited from the research project's sample. This study includes a convenience sample of teachers from five Estonian primary and lower secondary schools with different levels of digital competence. The end sample consists of 17 in-service teachers with varying times of service. In-service teachers have been found to hold more varied perceptions of CDTI due to more experience in the field [16]. To that end, their insights may be considered a richer data source than pre-service teachers' perceptions.

2.2 Data Collection and Analysis

Data were collected through semi-structured interviews by the first author, whose research expertise lies in purposeful CDTI to support subject-specific learning outcomes. The first author is also an in-service teacher in Estonia, which was also made known to the participants to diminish perceptions of power differences and thus increase openness [26]. Further, as the first author has five years of experience in CDTI, this contributes to her competence to interpret the answers given, acknowledging and embracing thus the subjectivity often critiqued in qualitative studies [26].

One interview lasted for an average of 15 min. The participants were asked questions about their perceived benefits, detriments and challenges regarding CDTI. When necessary for better comprehension, the interviewer asked further specifying questions. For trustworthiness, as suggested by Thomas in 2006 [27], member checks were done during the interviews where the interviewer summarised the interpretations of the collected data to allow respondents to specify their answers.

Following the coding process in the inductive analysis presented by Thomas in 2006 [27], meaningful utterances, i.e., utterances related to the research questions, were identified and transcribed for coding. In total, 160 utterances were noted. Around one-third of these utterances (50 in total), directly translated from English to Estonian by the first author, underwent an independent parallel coding to create inductive categories by the first two authors of this study. Inductive content analysis was adapted as it allows unrestricted insight into a topic [27]. The authors, however, acknowledge that the qualitative data analysis might have been, and likely was, influenced by the findings in the previous research. However, as similar results have been noted on multiple occasions, the authors do not consider the possible influences as limitations as these contribute to a more convergent understanding of the topic.

The preliminary codes were then discussed, evaluated and overlaps, commonly named. Moreover, utterances with similar content were grouped into relevant (sub)categories. In total, 29 different codes were identified; these codes were followingly grouped under eight subcategories that made up three larger categories: beneficial effects of CDTI, detrimental effects of CDTI and challenges related to CDTI.

3 Results

Our data collected via semi-structured interviews with 17 Estonian primary and secondary school teachers consisted of 160 transcribed utterances. Teachers' demographics and their input to the data can be seen in Table 1 below.

Table 1. Teachers' demographics and utterances percentage.

Teacher ID	School ID	Grade	Subject	Utterances %
1	1	3	Estonian, Natural sciences, Mathematics	2
2	1	6	Natural sciences	5
3	1	6	Mathematics	2
4	1	6	Mathematics	3
5	1	6	Estonian	5
6	2	3	Estonian, Natural sciences, Mathematics	6
7	2	3	Estonian, Natural sciences, Mathematics	5
8	2	6	Estonian	3
9	3	3	Estonian, Natural sciences, Mathematics	8
10	3	9	Mathematics	8
11	3	9	Estonian	4
12	4	3	Estonian, Natural sciences, Mathematics	12
13	4	6	Mathematics	8
14	4	9	Natural sciences	9
15	4	3	Estonian, Natural sciences, Mathematics	12
16	4	6	Estonian	5
17	5	9	Natural sciences	4

Teachers noted several benefits and detriments of CDTI on teaching-learning processes (see Table 2). The results are further discussed in the categories below. It is also relevant to note that some utterances belonged simultaneously to various groups as they touched upon diverse aspects of CDTI.

Table 2. The benefits, detriments, and challenges of CDTI.

Category	Subcategory	Codes
Benefits	Improved practicality (in teaching & learning)	Time-saving, flexible, convenient
	Improved engagement	Facilitating different activities, motivational, change in routine
	Improved learning opportunities	Deeper understanding, digital competence, personalisation, collaborative learning, discovery-based learning
Detriments	Negative effects on health	Mental health, physical health
	Hinders development	Cognitive development, fine-motor development, social development
	Hinders classroom management	
Challenges	Digital competence (teachers' & students')	Attitudes, know-what, know-how
	Resources (digital content & devices)	Resource availability, resource quality

Amongst benefits, teachers mentioned improved practicality, engagement and learning opportunities. Regarding detriments, teachers commented on adverse health, development, and classroom management consequences. As challenges, teachers pointed out insufficient digital competence, both teachers' and students', as well as low quality and availability of suitable digital content and devices.

3.1 Benefits of CDTI

By the teachers, the most mentioned benefit of CDTI was improved engagement (45.2% of all the teachers' utterances fell under this category). Teachers noted that CDTI captures students' attention by facilitating different activities, like hands-on and practical tasks and gamification. Moreover, CDTI offers a change in routine and is motivating for students. One teacher noted that "*… seeking information by themselves in digital devices raises their interest in the topic*".

The second most mentioned benefit of CDTI was its improved practicality (35.5% of the utterances). Under this category fell utterances referring to operational improvements for both teaching-learning processes. The CDTI was mostly viewed as time-saving, flexible and convenient.

For teaching, time-saving aspects principally commented were in relation to automated control. Teacher 14 specifies that "Checking students' answers is way easier, faster and more convenient with digital devices". Also, premade materials were commented as time-saving, as specified, for example, by Teacher 17 "When I can't bring in "the real thing", I can easily look up and showcase some videos or photos to illustrate whatever". Flexibility and convenience were illustrated by the teachers' habits in their teaching practice, e.g., Teacher 1 commented, "I integrate digital technology in the classroom because it is really comfortable and habitual for me as I am used to it".

For learning, the time-saving was primarily seen in faster and smoother task completion, information availability (e.g., Teacher 16: "*It's an instant source of a lot of information that students can find fast.")* and instant feedback. Teacher 3 noted the latter's importance: "*They can see instantly if they answered incorrectly. It's better this way because if some time passes, then they don't remember or sometimes even don't care about the feedback really"*. Regarding flexibility and convenience, Teacher 9 commented that with the support of digital devices, "*Students can work independently without needing the teacher"*.

The least frequently mentioned was CDTI's affordance to support learning opportunities (19.3% of the utterances). Under this category, teachers said CDTI endorses the development of digital literacy, personalisation, and collaborative and discovery-based learning and facilitates more profound understanding. One teacher commented as follows: "*With videos, photos, etc. I can show the students the organisms in their environment. This is vital for making them understand how ecosystems work"*.

3.2 Detriments of CDTI

The most commonly (50% of the utterances) mentioned detriment was related to health. Here, effects on physical and mental health were commented on. Regarding the former, adverse impact on the eyesight, posture and hand muscles were mentioned. E.g., Teacher 14 noted that posture is affected by "being seated in one forced position when using a digital device", and Teacher 16 commented that "*Students' hand muscles have gotten weak as they use them in a rather limited way"*.

Concerning mental health, teachers noted that digital devices could scare and intimidate some students, mainly ones who are not that accustomed to using them. Teacher 9 pointed out that "*... tools cause stress to the students, who are by their nature a bit more anxious"*. Teachers also mentioned cyberbullying and some emotional consequences of gamification, e.g., Teacher 10 commented, "*Gaming platforms like 99math do not support the weak ones. It is a competition of strong ones and losing affects students emotionally"*.

In addition to concerns related to health, teachers (on 37.5% of the utterances) pointed out that digital technology can impede development, namely fine motor, cognitive and social development. Concerning fine-motor development, teachers brought out suffering handwriting. Teacher 17 made a connection between fine motor skills and cognitive abilities: "*Activities requiring fine motor skills are directly related to brain development.... When using digital devices, we use our hands in a very limited manner, just one or two fingers, tapping or scrolling movements"*.

Furthermore, teachers noted that digital devices hinder cognitive development. Mostly, teachers referred to developing different skills, like reading and writing, but also hampering acquisition, in general, was mentioned. Teacher 10 explained, "*learning on a computer does not cause a permanent change in the brain, which requires effort"*.

In addition, aspects related to social development were mentioned, mainly regarding the form of communication shifting from the real world to the virtual, which hampers students' skills to interact. Teacher 11 commented on the issue as follows: "*They don't* *know how to communicate with each other anymore, they are always on their phones,…. And not only to each other, they are not able to make proper sentences or explain their ideas orally. So, I want to use the classroom time to give them at least some opportunities to speak, especially to each other"*.

Moreover, teachers stated that CDTI affects classroom management (12.5% of the utterances) as it embodies a distraction. Teacher 17 commented, "*Students don't really focus on the task at hand. They often use social media or do other things they are not supposed to"*. Teacher 9 pointed out a different nuance: "*Students get restless with digital devices. And students who have limited use of digital use at home want only to play, they don't perceive used study environments as a play, so they want to open games they have used or heard of, and then it's really hard to get them to do the task at hand"*.

3.3 Challenges of CDTI

In the interviews, teachers pointed out CDTI's challenges related to resources and digital competence. The most common challenge noted was the availability and quality of resources. Under availability, teachers mainly mentioned that bringing the device to the classroom is not easy. Often, schools have only one set of tablets that need to be pre-booked and thus "needs and extra effort", as noted by Teacher 3, or only one computer classroom. Further, computer classrooms do not sometimes have space for every student in the classroom, resulting in mixing and matching computers and laptops, which, as Teacher 17 points out, "creates inequity". Furthermore, "… going to the computer classroom takes away a lot of time from the actual lesson", as commented by Teacher 12. Moreover, not all students have their own digital devices with an unlimited volume of mobile data, challenge pointed out by example by Teacher 13 "*… not every student has their own device that they could use so when adopting this strategy instead of "fighting" for a computer class, some students are still left out"*.

Furthermore, it is hard to find suitable premade materials amid all the available content; thus, including digital content in the lesson is often very time-consuming as teachers need to surf for a long time or create it themselves. Teacher 19 comments that her CDTI practices are challenged by a lack of "*… available suitable resource list to use to facilitate easy access for teachers to the learning materials"*. Moreover, appropriate digital content usually costs and is thus out of reach for the teachers.

Both digital devices and digital content's qualities were noted concerning the quality of resources. Teachers pointed out that available digital devices are often old and slow, and thus their use is frustrating. Furthermore, teachers noted limitations in digital content's affordances, e.g., teacher 2 noted that "*Automated control is very helpful for teachers, but there is no automated control for high-level thinking exercises which actually show me something about how the student is doing"*. Moreover, the limited affordances of digital devices for mathematical languages were mentioned on multiple occasions, noting that drafting mathematical tasks on a piece of paper is more efficient than on a digital device. The latter may also be seen as an attitude toward the CDTI.

Attitudes related to digital devices are regarded as one of the dimensions of digital competence, besides know-what and know-how. Teachers also expressed other negative attitudes to CDTI regarding energy and time costs. For example, teacher 12 noted that "*… it takes too much energy and time to get into what and how to use. There are just too* *many platforms to handle, it gets confusing"*. Teacher 10 commented that she does not believe that CDTI "helps with anything". Teachers further pointed out that often they lack or do not feel comfortable about their skills and knowledge for CDTI. Teacher 2 precises "*... I really feel like I don't know the possibilities for CDTI. I have too limited experience using it"*.

As one of the challenges for CDTI, teachers also remarked on students' lack of know-how in working with a digital device, e.g., how to look at and critically assess information and generally how to use tools, programs, and platforms. Teachers noted that students have very different skill sets, but in-class time barely leaves room for teaching these. Teacher 12 commented: "*Students need guidance on how to use programs and platforms. I can teach them as much as I know, but it takes away the time from the content, and not all the students need the extra guidance"*.

4 Discussion and Conclusion

This study aimed to gain exploratory insight into teachers' perceptions of CDTI to contribute to knowledge for underpinning the need for classroom technology integration for technology-enhanced learning and how to support this process better. For that aim, exploratory qualitative research with inductive content analysis was conducted. From semi-structured interviews with 17 teachers of different grades and subjects (Estonian, mathematics, and natural sciences; 3rd, 6th, and 9th grades), benefits, detriments and challenges related to CDTI were found.

In the interviews, teachers pointed out the several benefits, detriments, and challenges of CDTI. As benefits, teachers perceived improved practicality, both teaching and learning-related, and improved engagement and learning opportunities. Under enhanced practicality, teachers noted aspects regarding efficiency demonstrated in time-saving, flexibility and convenience. As improved engagement, teachers mentioned digital technologies affordances to facilitate different activities, provide a change in routine and motivate. Comments related to learning approaches, such as personalisation, discovery-based and collaborative learning, and notions on facilitating deeper understanding and supporting digital competence development were categorised as improved learning opportunities. These results advocate for CDTI, indicating an argument for the affordances of digital technologies to enhance teaching and learning processes.

Regarding detriments, adverse effects on health (physical and mental) and development (fine motor, cognitive and social) were mentioned. Furthermore, teachers noted CDTI's hindering effect on classroom management. These results may indicate the need to rethink the use of CDTI to minimise the adverse effects of its implementation. Considering challenges, limitations related to resource availability and quality and teachers' and students' digital competence were noted, indicating issues still needed to be tackled to support CDTI.

Obtained results provide insight into understanding the underpinnings of CDTI in Estonia, one of the top-performing countries in K-12 settings [25], where CDTI is a relatively common practice [24]. Therefore, these insights are of value to support CDTI as they serve as information for stakeholders when considering and evaluating CDTI for technology-enhanced learning. Insights to teachers' CDTI reasonings support other teachers' CDTI practices by helping them consider digital technology's additional affordances in teaching-learning, contributing to changes in their practices [11, 15, 16, 21]. Moreover, based on our results, we can still posit the need to (i) provide accessible and good-quality resources (both devices and content) and (ii) support the development of both teachers' and students' digital competence.

The emerged categories on the benefits, detriments, and challenges of CDTI were similar in their content to the results presented by previous related studies, e.g., [5, 15–18], which indicates a validation of these results across different subjects and grades as were included in the scope of this study. Furthermore, these results contribute to a convergent understanding of the state-of-art grasp of perception of CDTI.

We acknowledge that our study has certain limitations. First, regarding the limited sample size, as perceptions of CDTI may differ from teacher to teacher, it would be more insightful to get opinions from more teachers on the matter. Furthermore, the teachers did not evenly represent different contexts (school, grade, subject), nor were their input even when considering the percentage of total utterances, which may have led to somewhat biased results. Even if results cannot be thus generalised, these limitations may contribute to evaluating the transferability of this study's results to different settings by providing light on the study's population and context [26].

Second, owing to the inductive qualitative design of this study, this study might have limitations regarding the researchers' subjectivity. Although the subjectivity was noted and embraced throughout the study by drawing upon the authors' experience and expertise in the field, we nevertheless acknowledge the likely, somewhat biased data collection and interpretation. To tackle this, we adopted member checking and included two coders with acceptable inter-rater reliability in the analysis process.

Suggestions for future research are threefold. As previous research posits that teachers may have different context-specific perceptions of the CDTI [10, 13] that are related to their practices [14], we recommend researching (i) the associations between the perceptions and the implementation of CDTI, (ii) distinguishing profiles of teachers regarding their perceptions and practices of CDTI, and to (iii) measure the possible effects of the CDTI to make the connection between the perceptions, the implementation (regarding the use and its purpose), and the actual effect on the learning outcomes, which ultimately contributes to understanding how to better support meaningful and purposeful CDTI.

References

1. Bower, M.: Design of Technology-Enhanced Learning: Integrating Research and Practice. Emerald Group Publishing, Bingley (2017)
2. EMER (Estonian Ministry of Education and Research), Education strategy 2021–2035 (2020). https://www.hm.ee/et/sites/default/files/haridusvaldkonna_arengukava_2035_kinnittaud_vv_eng_0.pdf%2C. Accessed 15 May 2022
3. European Commission, Directorate-General for Education, Youth, Sport and Culture, McGrath, C., Frohlich Hougaard, K., O'Shea, M.: Supporting key competence development: learning approaches and environments in school education: input paper. Publications Office of the European Union, Luxembourg (2020). https://data.europa.eu/doi/10.2766/8227. Accessed 15 May 2022

4. Yeung, K.L., Carpenter, S.K., Corral, D.: A comprehensive review of educational technology on objective learning outcomes in academic contexts. Educ. Psychol. Rev. **33**(4), 1583–1630 (2021)
5. Kohler, E.A., Molloy Elreda, L., Tindle, K.: Teachers' definitions of successful education technology implementation. J. Res. Technol. Educ. 1–20 (2022)
6. Lai, J.W., Bower, M.: Evaluation of technology use in education: findings from a critical analysis of systematic literature reviews. J. Comput. Assist. Learn. **36**(3), 241–259 (2019)
7. Bower, M.: Technology-mediated learning theory. Br. J. Educ. Technol. **50**(3), 1035–1048 (2019)
8. Adov, L., Must, O., Pedaste, M.: Attitudes towards mobile devices in estonian basic education: using the framework of the UTAUT model. In: Zaphiris, P., Ioannou, A. (eds.) LCT 2017. LNCS, vol. 10296, pp. 319–329. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-58515-4_25
9. Adov, L., Pedaste, M., Leijen, Ä., Rannikmäe, M.: Does it have to be easy, useful, or do we need something else? STEM teachers' attitudes towards mobile device use in teaching. Technol. Pedagog. Educ. **29**(4), 511–526 (2020)
10. Ertmer, P.A., Ottenbreit-Leftwich, A.T., Sadik, O., Sendurur, E., Sendurur, P.: Teacher beliefs and technology integration practices: a critical relationship. Comput. Educ. **59**(2), 423–435 (2012)
11. Tondeur, J., Van Braak, J., Ertmer, P.A., Ottenbreit-Leftwich, A.: Understanding the relationship between teachers' pedagogical beliefs and technology use in education: a systematic review of qualitative evidence. Educ. Tech. Res. Dev. **65**(3), 555–575 (2017)
12. Backfisch, I., Lachner, A., Stürmer, K., Scheiter, K.: Variability of teachers' technology integration in the classroom: a matter of utility! Comput Educ. **166**, 104159 (2021)
13. Aubrey-Smith, F.: An exploration of the relationship between teachers' pedagogical stance and the use of ICT in their classroom practice. Doctoral Dissertation. The Open University. Milton Keynes (2021)
14. Holmberg, J., Fransson, G., Fors, U.: Teachers' pedagogical reasoning and reframing of practice in digital contexts. Int. J. Inf. Learn. Technol. (2018)
15. Forkosh-Baruch, A., Phillips, M., Smits, A.: Reconsidering teachers' pedagogical reasoning and decision making for technology integration as an agenda for policy, practice and research. Educ. Tech. Res. Dev. **69**(4), 2209–2224 (2021)
16. Hughes, J.E., Cheah, Y.H., Shi, Y., Hsiao, K.H.: Preservice and inservice teachers' pedagogical reasoning underlying their most-valued technology-supported instructional activities. J. Comput. Assist. Learn. **36**(4), 549–568 (2020)
17. Alberola-Mulet, I., Iglesias-Martínez, M.J., Lozano-Cabezas, I.: Teachers' beliefs about the role of digital educational resources in educational practice: a qualitative study. Educ. Sci. **11**(5), 239 (2021)
18. Kirkwood, A., Price, L.: Technology-enhanced learning and teaching in higher education: what is "enhanced" and how do we know? A critical literature review. Learn. Media Technol. **39**(1), 6–36 (2014)
19. Chen, C.H., Tsai, C.C.: In-service teachers' conceptions of mobile technology-integrated instruction: tendency towards student-centered learning. Comput. Educ. **170**, 104224 (2021)
20. Wallace, R.M.: A framework for understanding teaching with the internet. Am. Educ. Res. J. **41**(2), 447–488 (2004)
21. Pozas, M., Letzel, V.: Do you think you have what it takes?– exploring predictors of pre-service teachers' prospective ICT use. Technol. Knowl. Learn. 1–19 (2021)
22. Schmitz, M.L., Antonietti, C., Cattaneo, A., Gonon, P., Petko, D.: When barriers are not an issue: tracing the relationship between hindering factors and technology use in secondary schools across Europe. Comput. Educ. **179**, 104411 (2022)

23. Pedaste, M., Leijen, Ä., Poom-Valickis, K., Eisenschmidt, E.: Teacher professional standards to support teacher quality in Estonia. Eur. J. Educ. **54**(3), 389–399 (2019)
24. Pedaste, M., Leijen, Ä., Kallas, K., Raave, D.K.: How to increase the potential of digital learning in achieving both cognitive and non-cognitive learning outcomes? CO:RE Short Report Series on Key Topics, Hamburg (2022)
25. OECD: PISA 2018 Results (Volume V): Effective Policies, Successful Schools. OECD Publishing. Paris (2020)
26. Olmos-Vega, F.M., Stalmeijer, R.E., Varpio, L., Kahlke, R.: A practical guide to reflexivity in qualitative research: AMEE guide, vol. 149, pp. 1–11 (2022)
27. Thomas, D.R.: A general inductive approach for analysing qualitative evaluation data. Am. J. Eval. **27**(2), 237–246 (2006)

A Proposed Framework for Learning Assessment Ontology Generator

Martinus Maslim[1,2](✉) and Hei-Chia Wang[1]

[1] National Cheng Kung University, No. 1, Dasyue Rd, East District, Tainan City 701, Taiwan
martinus.maslim@uajy.ac.id, hcwang@mail.ncku.edu.tw

[2] Universitas Atma Jaya Yogyakarta, Babarsari Street, No. 44, Daerah Istimewa Yogyakarta, Indonesia

Abstract. Different institutions have shown interest in standardizing the learning result. It may be used in the same way to assess students' learning status. The teacher must quantify the learning outcomes for evaluation purposes. It often requires a great deal of time and effort to do paper tasks. Additionally, this activity prevents instructors from concentrating on the learning process. Teachers are continuously burdened with administrative responsibilities that should be alleviated using technology that adheres to the current framework. The Bloom Taxonomy, a widely used framework for defining learning outcomes, allows for the assessment of learning outcomes at several levels. The purpose of this research is to provide a framework that will assist the instructor in completing the evaluation more quickly and accurately. This study provided an algorithm for adapting ontology and text classification technologies to detect correlations between words and keywords to aid in evaluation. It is anticipated that the categorization findings will assist in shortening the time required to complete the evaluation.

Keywords: Learning outcome · Assessment · Ontology

1 Introduction

In recent years, the educational system has transformed because of new norms or principles [1]. One of the educational system's objectives is to perform learning outcome assessments. Assessment of learning outcomes is a critical component of every learning environment [2, 3]. The word "assessment" refers to the overall quality of all evaluation procedures, not just the quality of a particular assessment [4]. This term seems to be included into a growing number of higher education programs [5]. The outcomes aid students in discovering the course's intended objectives. Additionally, it helps instructors keep on track and ensures that students understand what they will accomplish at the end of the semester. Additionally, learning outcomes assist instructors and students in determining the optimal course of action [6].

The learning outcomes should describe the fundamental and significant components of the course or program. By defining learning outcomes, we may reflect on the major factors that contribute to learners acquiring these knowledge and abilities. Consideration

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 252–261, 2022.
https://doi.org/10.1007/978-3-031-15273-3_28

of (1) the course's key terms, (2) the intended forms of learning, and (3) the environment in which the course's knowledge and skills will be employed, including projected applications, establishes the foundation for establishing learning outcomes [12]. According to a widely used framework, Bloom Taxonomy, a framework should relate to three distinct learning domains: cognitive, psychomotor, and emotional. Each domain comprises levels that are used to construct courses [7]. Formulate the learning outcomes to determine the breadth and depth of a course. A course with learning outcomes enables the technical quality of the outputs to be assessed [5]. Precision and effort may be used to the generation of learning outcomes by incorporating input from important stakeholders in a prescribed manner [8].

To guarantee good learning results, a guide is essential. The Bloom Taxonomy is a regularly used reference. The Bloom's Taxonomy of educational goals is particularly effective since it associates certain verbs with various stages of learning. While Bloom's Taxonomy is hierarchical, each level of aim may make a major contribution to a course's performance [12]. It is intended to explain the learning process and has therefore shown to be an effective tool for assisting in the development of learning outcomes [9]. Within each area of the bloom taxonomy, there are several tiers. This level describes the method through which students' skills are developed during the educational process.

According to Bloom Taxonomy, the following are some strategies for implementing learning outcome evaluations. To begin, we may evaluate learning outcomes by examining students' evaluation grades [2]. On the other hand, students' replies to tests, assignments, and examinations are evaluated. Additional evaluation may be based on instructor comments concerning students' emotional well-being. The current problem is that the technique for evaluating results is complicated. This issue arises because the lecturer is accountable for determining the specific results reached by each student. This consequence may influence students' test replies or the notes they take during the classroom learning process. Not infrequently, instructors make mistakes in assessing student achievement, jeopardizing the validity of the outcome evaluation. Another area of research involves evaluating student replies without regard for Bloom's taxonomy levels. However, no research has classified lecturer notes on student behavior in class into the emotional realms of Bloom's taxonomy. The challenge in tackling this problem is choosing the suitable algorithm to assure accurate classification results. Additionally, the algorithm must encompass the process of classification in the cognitive and affective dimensions that are the subject of this research.

While several techniques may be employed to categorize text, the phrases used in evaluation reports may vary. To resolve these issues, a word correction standard known as ontology is used. Ontology is a strategy for resolving this issue. Ontologies are clear and formal representations of prevalent conceptualizations of concepts and their connections [22]. The paper's objective is to demonstrate how to develop an ontology using Bloom's Taxonomy levels and keywords. Ontology may simplify the classification process for student responses and lecturer notes by detecting the relationship between words and keywords. Additionally, the ontology may regard levels and concepts in the cognitive and affective domains as children. This project will provide a framework for constructing an ontology capable of classifying student replies and lecturer comments according to Bloom's Taxonomy levels. This classification may aid in the process of assessing educational results. The ontology will be generated from the course learning outcomes that have Bloom's Taxonomy structure. From the data, we can collect the keywords of Bloom's Taxonomy level and generate into the ontology structure.

2 Literature Review

2.1 Learning Outcome Assessment

Nowadays, many stakeholders in academic institutions put a priority on learning outcomes. Curriculum designers must understand the actual meaning and significance of the statements of Program Educational Objectives (PEOs), Program Outcomes (POs), and Course Outcomes (COs) while building the curriculum [8]. Course outcomes will be determined along with the definition of program goals. COs are acronyms for the criteria that a student must satisfy to pass the course [15]. Consequently, developing standards for learning outcomes becomes a popular issue [10]. Learning outcomes are a critical discussion topic, especially considering the expected skills of university graduates or new employees who will eventually support society [11]. Learning outcomes place a consideration on the context and potential applications of students' knowledge and skills, aid students in linking learning across settings, and facilitate assessment and evaluation [12]. The word "learning outcomes" refers to the characteristics, knowledge, and skill set acquired by a student following successful completion of a course [13]. The learning outcomes are more concerned with the growth of the learner than with the content of the course. Additionally, it supports instructors, teachers, and facilitators in establishing and planning beneficial student-centered learning activities [10]. Learning outcomes, in general, are statements that explain what each learner should know or be able to do after a learning experience [14].

The educational process is dependent on evaluation. Teachers and school administrations who embrace an assessment culture use data on students to generate new understandings about what works and why, share their discoveries with colleagues, and increase their ability to fulfill the diverse learning needs of their students [16]. Assessment is a systematic and ongoing process of collecting, assessing, and acting on data about the goals and outcomes established to support the institution's mission and purpose. The evaluation process begins with the establishment of objectives. Measurable results need the expression of the assessment cycle's first three components: outcome, assessment method, and success criteria [17]. Most evaluation tools analyze student achievements on a course-by-course basis. They must also be consistent with program learning objectives (PLOs) to give an overall assessment of students' achievement of these objectives [18]. Assessment supports the incorporation of learning objectives into the course design and delivery. Multiple choice or short answer questions may be used to evaluate an outcome that requires students to recollect crucial events leading up to a historical event. In comparison, an outcome that requires students to evaluate many policy models may be evaluated by a debate or written essay [12]. The similarities between grading with percentages and grading by learning goals in an assessment is that both methods offer an overall mark indicating proficiency [21].

2.2 Bloom Taxonomy Standard

Returning to Bloom's Taxonomy of educational goals is one strategy to align results with suitable means of evaluation. Bloom's Taxonomy was developed in 1956 and modified in 2001 by Bloom's associates Lorin Anderson and David Krathwohl. The educational process and often used framework for producing learning outcomes are shown by Bloom's Taxonomy. The framework categorizes learning objectives as cognitive, emotional, or sensorimotor/psychomotor. The authors of the new taxonomy underline this dynamic by using verbs to denote the taxonomy's divisions and subcategories. The cognitive domain is concerned with identifying facts, skills, and concepts to help pupils develop their knowledge and abilities. The affective area is where excitement and feeling occur. The psychomotor domain is involved with the physical development of the body [19]. The cognitive results of students were compared to the amount of knowledge and intellectual talents gained and mastered. External assessment tools such as user data, questionnaires, interviews, and observations were employed to analyze different aspects of participant learning [20].

2.3 Ontology Construction

Ontologies provide an ideal setting for the functioning of intelligent services. Ontologies, for instance, may enhance intelligent online search, information filtering, intelligent information integration, and knowledge management. Ontology alignment is crucial for developing information-based systems [23, 24]. The ontology has a lot of semantic information that may be used to effectively reduce conceptual ambiguity and help in the execution of a variety of text processing activities [25]. The ontology development approach is meant to assist developers in developing ontologies that follow to required specifications and essential procedures that have a direct impact on the ontology's knowledge representation and logical reasoning. When selecting ontology generation strategies, we should either pick the method that is most relevant for the current situation or combine the advantages of many ways to improve and optimize the existing methods [26]. Collaborative ontology is becoming more popular as a way for developing ontologies. The process of constructing ontologies from a variety of current data sources has emerged as a key topic of research and is crucial for ontology development [27]. Within this framework, programmers and domain specialists must collaborate with mutual understanding. By evaluating the validity of envisioned knowledge embeddings, domain experts contribute significantly throughout the ontology creation cycle [28].

Currently, ontology is widely used in a variety of text processing activities, including information retrieval, information extraction, information integration, data management, information recommendation, text classification and clustering, and question and answer systems [25]. Some study in education makes use of ontology to address problems. In teaching and learning processes, ontology is employed to construct a cognitive conversational agent. Numerous studies in education use the ontology as question-and-answer generators [9, 29–31]. The research serves as the foundation for a question-answering system for measuring students' domain understanding, providing natural-language explanations for students' errors, and designing adaptive quizzes [29]. Other study indicates that ontology may provide a variety of various sorts of feedback in response to an inquiry [32]. Not only can ontology be used to produce questions and answers, but it may also be utilized to assist in the development of a curriculum [33].

The ontology's story is described by the fact that it establishes the relationship between reusable competences categorized according to Bloom's taxonomy and Knowledge Topics in the field of Computer Sciences [34]. According to the other studies, ontology represents notions that aid pupils' thinking processes. It offers a mechanism for resolving often reported issues that learners have while using a web-based learning system [35]. In 2021, the study included the learning result into a relevant course by quantitative assessment and cluster analysis [21].

The growth of ontology research has resulted in the presentation of numerous semi-automatic and automated construction strategies, some of which have been utilized to produce ontologies from textual data [22, 36]. To begin, ontology learning takes concepts from a variety of textual sources and establishes taxonomic and non-taxonomic relationships between them [22]. Now, automatic ontology building from plain text captures most hierarchical relationships. After harmonizing the concepts from these diverse ontological frameworks, these phrase ontologies are integrated to create an ontology for the whole text [37].

3 Proposed Framework

This section will discuss how to create an ontology schema and how to categorize student responses according to Bloom's taxonomy levels. The procedure is shown in Fig. 1.

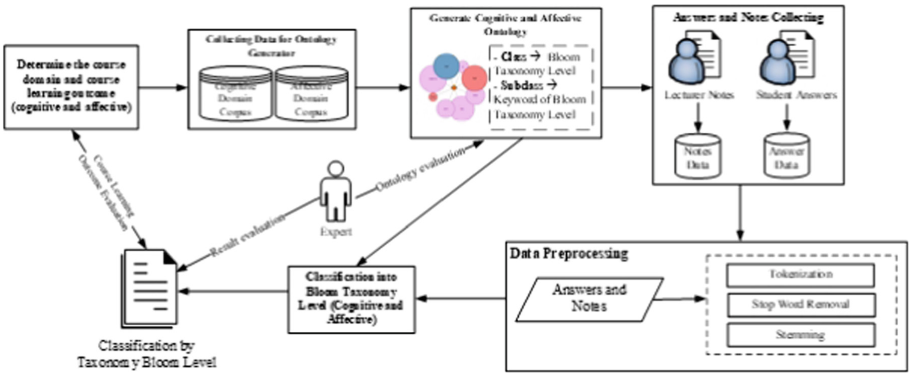


Fig. 1. Proposed framework for learning assessment ontology generator

3.1 Data Collection

The first step determines the scope of the research. The data for this research will be gathered from a sample of chosen courses. Additionally, we analyze the learning outcomes of cognitive and affective domains. Following that, we will collect data through a series of procedures. We gather questions and answers from various courses for the cognitive domain. We use lecturer notes to describe each student's emotive recall. These data will provide a corpus from which the ontology will be constructed.

3.2 Ontology Construction

The ontology is separated into parent and child classes. Bloom's taxonomy level is defined by its parent classes. Keywords linked with each bloom taxonomy category are included in the child classes. At this step, we will create the ontology using Lexical Semantic Analysis (LSA). We may use LSA to find phrases that are synonyms with bloom taxonomy keywords. As is the case with a bachelor's degree, this research concentrates only on four taxonomy flowering levels in the cognitive domain: remember, understand, apply, and analyze. On the other hand, this research will include all Bloom taxonomy levels for the emotional domain: attention, response, value, organization, and generalization. On Fig. 2, we can see the example of Bloom Taxonomy cognitive ontology scheme.

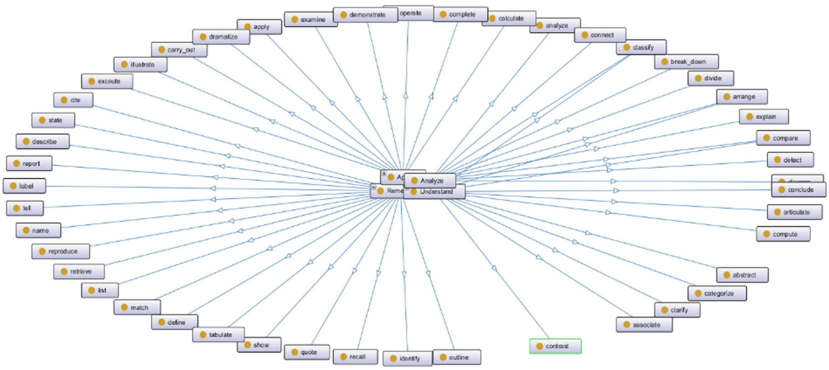


Fig. 2. Example of bloom taxonomy cognitive ontology scheme

3.3 Data Preprocessing

The next stage is to gather answers in accordance with the cognitive and emotional domains as part of the data collection process. We collect course-specific questions and answers, as well as lecturer notes for the emotional domain. Following then, the system is made up of several steps for pre-processing the questions and replies. This phase generates a dataset of questions and responses that has been classified in the succeeding stage. Three executable processes are included in this Sect. (1) Tokenization is a process that divides a corpus of text into smaller units called tokens. In this scenario, tokens may be words, characters, or subwords. Thus, tokenization may be classified in broad terms as follows: word tokenization, character tokenization, and subword tokenization (n-gram characters). (2) A stop word is a series of words that are often used in a language. Stop words in English include "a", "the", "is", and "are." Stop words are often used in Text Mining and Natural Language Processing (NLP) to remove keywords that are overused and contain little useful information. (3) Stemming is the process of reducing a word to its word stem, which is connected to suffixes and prefixes or to the root of words known as a lemma. Natural language understanding (NLU) and natural language processing rely heavily on stemming (NLP).

3.4 Classification

This classification process takes use of the ontology we developed to facilitate categorization and deep learning model. We compare the pre-processed data set to the ontology. For this research, we use word2vec embedding approach with neural network to do the classification tasks. The classification process, we can use Recurrent Neural Network (RNN) model. RNNs have been effectively used in machine translation and natural language processing applications. They are divided into three layers: an input layer, a hidden layer, and an output layer. The input and output layers perform the same function [38]. A RNN is a sort of architecture in which individual neurons have recurrent connections. Like feedback loops in biology, such designs facilitate memory storage to a certain degree. For sequence classification, the most often employed recurrent architectures are Long-Short Term Memory (LSTM) cells (see Fig. 3) and Gated Recurrent Units (GRUs) [39]. A single LSTM cell is composed of three primary gates: input, output, and forget. Individual LSTM cell activations are defined as sigmoid functions:

$$\sigma(x) = \frac{1}{1 + e^{-x}} \tag{1}$$

Together, the three gates form a feedback loop that preserves gradients throughout training. The primary advantage of LSTMs for sequence learning is that they partially address the vanishing gradient issue, which means that long term signals persist in memory, while a basic feedforward architecture is prone to disappearing gradients [39].

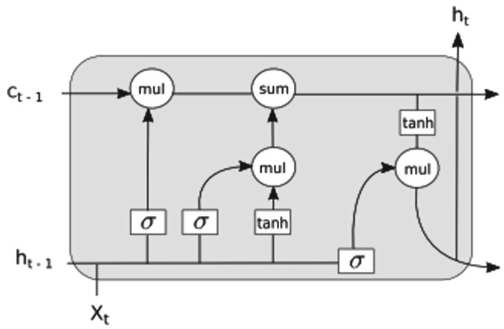


Fig. 3. The LSTM cell [39]

Additionally, this work seeks to connect a term in the ontology with a word in the dataset. Following that, we get Taxonomy Bloom-categorized data for the questions and replies. Following publication, the result must be independently verified by specialists. Education professionals will check the classification to ensure it is correct. After the verification operation is complete, the percentage of classification is shown. Based on this percentage, we may adapt the ontology scheme to get a high rate. The analysis of course results is predicated on previously gathered data. We may determine the subject's success in learning based on the result. Is the learning result of the courses we've created adequate, or are the prerequisites set too high?

4 Conclusions

The educational institutions could benefit from standardizing learning outcomes. They may use learning outcomes to determine a student's degree of accomplishment throughout the learning process. This process takes a lot of time. A helpful tool could save lots of time for lecturers. This paper proposed text mining techniques with ontology to shorten the assessment process. Utilizing Bloom's taxonomy simplifies the process of evaluating learning results. This study should facilitate educational institutions to measure the extent of defined learning outcomes. By using the proposed framework, the learning outcomes should alter the students' skills to produce high-quality graduates.

References

1. de Medeiros, L.F., Kolbe, A., Moser, A.: A cognitive assistant that uses small talk in tutoring conversation. Int. J. Emerg. Technol. Learn. **14**(11), 138–159 (2019)
2. Leeuwenkamp, K., Brinkea, D.J.T., Kester, L.: Students' perceptions of assessment quality related to their learning approaches and learning outcomes. Stud. Educ. Eval. **63**, 72–82 (2019)
3. Coates, H., Zlatkin-Troitschanskaia, O.: The governance, policy and strategy of learning outcomes assessment in higher education. High. Educ. Policy **32**(4), 507–512 (2019)
4. van Leeuwenkamp, K.J.G., ten Brinke, D.J., Kesterd, L.: Assessment quality in tertiary education: an integrative literature review. Stud. Educ. Eval. **55**, 94–116 (2017)
5. Schoepp, K.: The state of course learning outcomes at leading universities. Stud. High. Educ. **44**(4), 615–627 (2017)
6. Mahajan, M., Singh, M.: Importance and benefits of learning outcomes. IOSR J. Humanit. Soc. Sci. **22**(3), 65–67 (2017)
7. Vivek, C.: Outcome based education - a review. Int. Res. J. Eng. Technol. (IRJET) **4**(7), 659–661 (2017)
8. Vaijayanthi, P., Murugadoss, R.: effectiveness of curriculum design in the context of outcome based education (OBE). Int. J. Eng. Adv. Technol. **8**(6), 648–651 (2019)
9. Contreras, J.O., Hilles, S., Abubakar, Z.B.: Automated essay scoring using ontology generator and natural language processing with question generator based on blooms taxonomy's cognitive level. Int. J. Eng. Adv. Technol. **9**(1), 2448–2457 (2019)
10. Abuaiadah, D., Burrell, C., Bosu, M., Joyce, S., Hajmoosaei, A.: Assessing learning outcomes of course descriptors containing object oriented programming concepts. N. Z. J. Educ. Stud. **54**(2), 345–356 (2019)
11. Noda, A., Kim, S., Hou, A.Y.C., Lu, I.J.G., Chou, H.C.: The relationships between internal quality assurance and learning outcome assessments: challenges confronting universities in Japan and Taiwan. Qual. High. Educ. **27**(1), 59–76 (2021)
12. Developing Learning Outcomes: A Guide for University of Toronto Faculty, University of Toronto (2008)
13. Hussain, W., Spady, W.G., Khan, S.Z., Khawaja, B.A., Naqash, T., Conner, L.: Impact evaluations of engineering programs using ABET student outcomes. IEEE Access **9**, 46166–46190 (2021)
14. Matthews, K.E., Firn, J., Schmidt, S., Whelan, K.: A comparative study on student perceptions of their learning outcomes in undergraduate science degree programmes with differing curriculum models. Int. J. Sci. Educ. **39**(6), 1–19 (2017)
15. Naqvi, S.R., et al.: Learning outcomes and assessment methodology: case study of an undergraduate engineering project. Int. J. Electr. Eng. Educ. **56**, 1–23 (2018)

16. C. f. E. R. a. Innovation: Assessment for learning formative assessment. In: OECD/CERI International Conference Learning in the 21st Century: Research, Innovation and Policy (2008)
17. Osters, S., Tiu, F.S.: Writing measurable learning outcomes. In: 3rd Annual Texas A&M Assessment Conference, Texas (2008)
18. El-Hassan, H., Hamouda, M., El-Maaddawy, T., Maraqa, M.: Curriculum-based exit exam for assessment of student learning. Eur. J. Eng. Educ. **46**(6), 849–873 (2021)
19. Kumar, R., Sarwar, N., Maheshwari, K., Lal, P., Dev, K.: An epic technique for learning outcome assessment in obe through bloom's taxonomy. EAI Endorsed Trans. Creative Technol. **6**(18), 1–5 (2019)
20. Wei, X.M., Saab, N., Admiraal, W.: Assessment of cognitive, behavioral, and affective learning outcomes in massive open online courses: a systematic literature review. Comput. Educ. **163**, 24 (2021)
21. Hammond, K.M., Brown, S.: Transitioning to learning outcomes at the coalface: an academic's quantitative evaluation at the course level. Stud. Educ. Eval. **68**, 8 (2021)
22. Sathiya, B., Geetha, T.V.: Automatic ontology learning from multiple knowledge sources of text. Int. J. Intell. Inf. Technol. **14**(2), 1–21 (2018)
23. Amirian, S., Mohammadi, S.: Ontology alignment using wordnet method. Int. J. Comput. Sci. Netw. Secur. **17**(7), 161–167 (2017)
24. Wu, H., Zhong, B., Li, H., Love, P., Pan, X., Zhao, N.: Combining computer vision with semantic reasoning for on-site safety management in construction. J. Build. Eng. **42**, 1–15 (2021)
25. Fei-Liang, R., Ji-Kun, S., Bin-Bin, S., Jing-Bo, Z.: A Review for domain ontology construction from text. Chin. J. Comput. **42**(3), 654–676 (2019)
26. Sun, Z., Hu, C., Li, C.L., Wu, L.B.: Domain ontology construction and evaluation for the entire process of software testing. IEEE Access **8**, 205374–205385 (2020)
27. Zhang, F., Li, Q.: Constructing ontologies by mining deep semantics from XML schemas and XML instance documents. Int. J. Intell. Syst. **37**, 1–38 (2021)
28. Vidanage, K., Noor, N.M.M., Mohemad, R., Bakar, Z.A.: Verifying ontology increments through domain and schema independent verbalization. Int. J. Comput. Sci. Netw. Secur. **21**(1), 34–39 (2021)
29. Anikin, A., Sychev, O.: Ontology-based modelling for learning on bloom's taxonomy comprehension level. In: Samsonovich, A.V. (ed.) BICA 2019. AISC, vol. 948, pp. 22–27. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-25719-4_4
30. Cubric, M., Tosic, M.: Design and evaluation of an ontology-based tool for generating multiple-choice questions. Interact. Technol. Smart Educ. **17**(2), 109–131 (2020)
31. Pastor, D., Arcos-Medina, G., Bonito, V., Cepeda, J.: Design of an adaptive educational application to generate customized tests based on ontology. Int. J. Emerg. Technol. Learn. **16**(3), 171–189 (2021)
32. Demaidi, M.N., Gaber, M.M., Filer, N.: OntoPeFeGe: ontology-based personalized feedback generator. IEEE Access **6**, 31644–31664 (2018)
33. Bussemaker, M., Trokanas, N., Cecelja, F.: An ontological approach to chemical engineering curriculum development. Comput. Chem. Eng. **106**, 927–941 (2017)
34. Goncalves, M.J.A., Rocha, A., Cota, M.P.: Interoperability framework for competences and learning outcomes. J. Univ. Comput. Sci. **21**(8), 1042–1060 (2015)
35. Madhusudhana, K.: The cognitive dimension and course content modeling: an ontological approach. Int. J. Emerg. Technol. Learn. **12**(5), 181–188 (2017)
36. Geng, Q., Deng, S.Y., Jia, D.P., Jin, J.: Cross-domain ontology construction and alignment from online customer product reviews. Inf. Sci. **531**, 47–67 (2020)
37. Arora, A., Singh, M., Chauhan, N.: Automatic ontology construction using conceptualization and semantic roles. Int. J. Inf. Retrieval Res. **7**(3), 62–80 (2017)

38. Farman, A., Amjad, A., Muhammad, I., Rizwan, A.N., Muhammad, H.S., Kyung-Sup, K.: Traffic accident detection and condition analysis based on social networking data. Accid. Anal. Prev. **151**, 1–16 (2021)
39. Škrlj, B., Kralj, J., Lavrač, N., Pollak, S.: Towards robust text classification with semantics-aware recurrent neural architecture. Mach. Learn. Knowl. Extr. **1**(34), 1–15 (2019)

YouTuber's Video as Cross-Cultural Learning Resource for Chinese-as-Foreign-Language Learners – Perspective of Big 'C' and Small 'c' Culture

I.-Lin Kao[1], Chi-Cheng Chang[2], and Wan-Hsuan Yen[2(✉)]

[1] Master's and Doctor's Program in Teaching Chinese as a Second Language, National Chengchi University, Taipei City, Taiwan

[2] Department of Technology Application and Human Resource Development, National Taiwan Normal University, Taipei City, Taiwan

gordonwyen@gmail.com

Abstract. Due to the influence of the global pandemic, online and distance learning has replaced traditional classroom and face-to-face interaction so students can continue learning. Internet mediated self-directed learning also climbed to a new height and foreign language learning from YouTube video is a very popular learning method for many. Furthermore, YouTube videos can supplement cross-cultural knowledge for foreign language (FL) learners, which is a critical yet hard to develop ability for FL teachers. However, unlike for FL textbooks, the cross-cultural elements have not been examined thoroughly for YouTube videos. Therefore, this study analyzed the most subscribed and watched Japanese Chinese-as-FL YouTuber, "Lee Sisters ch", which is also the official representative of HSK (*Hanyu Shuiping Kaoshi*) test. We selected 30 most watched videos and analyzed their contents according to Chastain's Big 'C' small 'c' culture framework. The result showed 86.67% of the most popular 30 videos covered topics about culture: 23.33% of the videos were related to big 'C' culture and 63.33% were about small 'c' culture. Similar to earlier researches on FL textbooks, "Literature" was the main theme of big 'C'. On the other hand, "Everyday living" was the most frequent small 'c' topic, which is a unique phenomenon for YouTube FL channels. Furthermore, not only did the portion of big 'C' and small 'c' cultures match the suggestions of FL scholars, the language used in all videos were also mainly in Japanese that fit the needs of Japanese CFL learners. It is concluded YouTube video may be suitable to learn cross-cultural knowledge for FL learner, especially for Japanese students.

Keywords: YouTuber · Chinese-as-Foreign-Language (CFL) · Japanese learner · Cross-cultural competence · Content analysis

1 Introduction

With the growing adoption of information technology, our world is permeated with electronic media. The advancement of social technology further pushed the interaction from

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 262–271, 2022.
https://doi.org/10.1007/978-3-031-15273-3_29

top-down only as Web 1.0 to bottom-up and beyond. Accordingly, multiple platforms emerged by utilizing the participation, interaction, and sharing functions between content providers and consumers. YouTube is one of the most successful example among all. Not only has YouTube become one of the most popular website among all categories, but it has also given birth to many internet celebrities that have more than several tens-of-thousand followers while making millions of dollars from their fame and popular videos [1]. These internet celebrities are sometimes called YouTubers because they obtained their celebrity status from YouTube. Among YouTubers, those shared mainly knowledge contents are often called knowledge YouTuber.

Some scholars analyzed the educational use of YouTube and found there were a couple of ways to utilize the platform: One obvious way is using video clips from YouTube in classroom to demonstrate supplement materials. Another way is some teachers may ask students to make their own video clips and upload to YouTube for views and comments. Furthermore, due to the influence of global pandemic and enforced quarantine, many people adopted YouTube as learning resource for self-learning [2, 3]. The latest type of YouTube learning has gained lots of research interests among social learning and marketing professionals.

In the field of foreign language (FL) learning, language knowledge and cross cultural awareness/appreciation are both important factors for teachers to transfer to students. However, the requirements for teachers qualifying for such standard might be too difficult to reach. Therefore, supplement materials like information box in textbooks or teacher-picked materials become critical in enhancing students' cross-cultural ability. Additionally, self-directed learning with YouTube video could ease the nerve of Eastern culture students by allowing learners to search and select preferred, proficient, and proper videos to learn from.

Although learning from YouTuber has gained recognition from FL practitioners, the academic study about it is still rare. Additionally, most FL literatures were about English as FL, less about Chinese as FL (CFL). Furthermore, most YouTubers' studies focus on the making of specific YouTuber or their influence on viewers, less on the composition of popular video clips [3]. Last but not least, although cultural elements in FL textbook has been a hot research topic [4, 5], the analysis in FL videos did not get sufficient attention yet. Therefore, this study accordingly analyzed the most popular YouTube contents for Chinese as FL learners under Chastain's big 'C' small 'c' framework [6].

We chose "Lee Sisters ch" because it was one of the most subscribed and watched Japanese CFL channel. Japanese people have huge demand in CFL learning because of Japan's geographical location and its close relationship with Taiwan. However, Japanese's collectivism paradigm as well as conflict and mistake avoidance make Japanese students highly anxious in speaking and heavily rely on mother tongue to learn, causing difficulties in teaching and learning Chinese. Furthermore, the differences and similarities between Chinese and Japanese culture make the mutual understanding more difficult. Japanese CFL learners' avoidance character made the preparation of cross-cultural knowledge critical in learning. Therefore, this research aimed to examine the cross-cultural elements in highly viewed Japanese targeted CFL YouTube videos. We further analyzed the composition of cultures using big 'C' small 'c' framework [6]. The following of the article will cover the literatures about FL learning on YouTube, Japanese learner's learning characteristics, and the big 'C' small 'c' framework. We will then explain the content analysis method for information extraction, followed by results and discussion.

2 Literatures

2.1 Foreign Language Learning on YouTube

YouTube's website was officially launched by three former PayPal employees in 2005 with the original goal to remove the technical barriers non-experts faced when sharing videos on the web [1]. It gradually became the biggest video and music consumption and sharing platform in the world and created the participatory culture around it [1]. As one of the most popular social media, YouTube gave birth to a new breed of influential figures, YouTuber. Influential YouTubers are frequently described as microcelebrities. Since YouTube is widely conceived as a bottom-up social media video platform, microcelebrities do not appear to be involved with the established and commercial system of celebrity culture but rather appear self-governed and independent; which in turn, leads to YouTubers being seen as more relatable and authentic than traditional celebrities. The direct interaction between YouTubers and viewers also facilitates the trust in them [7, 8].

YouTubers can be categorized by their major contents. Some YouTubers upload record of personal life and some upload mostly open-box videos. The YouTubers upload educational and informational video clips are labeled as knowledge YouTubers. Couple researches suggested learning from YouTuber had advantages over traditional ways. Shen, Yang, Mao, et al. [9] found YouTube videos could explain fitness knowledge clearly and professionally, which in turns generated students' learning interests and achievements. Wang and Chen [3] studied the use of YouTuber's video for Taiwanese student's self-regulated English learning and found learning from YouTube was more flexible, more interesting, and more interactive than formal learning in classroom. Kelsen [10] used YouTube video as supplementary material with EFL students and found favorable results because it is interesting, relevant, and beneficial. Watkins and Wilkins [11] believed YouTube remains a valid resource for EFL teachers seeking to enhance their lessons with lively and topical content. Therefore, YouTuber's video may be used to enhance student's FL learning in an interesting and informative way.

2.2 Japanese Learner's Learning Characteristics

Per Benedict's [12] observation, Japanese culture can be labeled as "shame culture" because they feel shameful when being teased at in public or even when perceived of such teasing. This characteristic plays an important role in Japanese FL classroom behavior because they are very cautious about other's reaction and perception toward self, which makes them extremely conservative about practicing orally or speaking publicly [13]. As a result, speaking anxiety is a severe problem in FL learning, especially for Japanese learners [14]. The collectivism culture pattern further prohibits individuals to demonstrate personal specialties and makes Japanese highly rely on mother tongue in communication. To not interfere the classroom' progress, Japanese students may fake even if they do not understand what their teacher or peer say. Furthermore, they tend to act more as observatory and passive roles in classroom and not to speak out their needs directly. Therefore, it is not easy for FL teacher to catch the needs of Japanese FL learner and provide suitable help. As a result, self-directed FL learning for Japanese is important because it allows learner to learn by one self without other's interference. Additionally, the contents of the most popular YouTuber channel may also provide the information that are benefit for Japanese FL learner.

2.3 Big 'C' Small 'c' Culture Framework

Scholars agreed learning about target culture and target language cannot realistically be separated [6]. Matic [6] argued learning about target cultures is integrated with communicative competence (CC), which includes grammatical, sociolinguistic, discourse and strategic competences. With the understanding of target culture, FL learner can then communicate with social effectiveness and appropriateness. Therefore, it has been recognized as essential part of FL learning. For instance, National Standards for Foreign Language Education of the United States clearly included cultural elements in its standard.

One popular way to teach cultural elements in FL learning materials is to divide culture into "Culture with a big C" (big 'C') and "culture with a small c" (small 'c'). Big C consists of things people within a culture make and use, and serve as artifacts. Examples include literature, songs, food, holidays, and art; small c consists of the routine aspects of life, such as the things people know, believe, and do within a culture, and includes styles of communication, conceptions of time, and notions of beauty, goodness, and rightness [6, 15].

There are several studies that have examined and evaluated cultural content in FL materials and textbooks around the world using big 'C', small 'c' framework. For instance, Xiao and Laohawiriyanon [5] found small 'c' culture in the textbook can facilitate learners' intercultural communicative competence by analyzing English-as-Foreign-Language (EFL) text books in China. Matić [6] studied EFL material in Serbia and found small 'c' cultural topics occurred more than big 'C' topics; the most common big 'C' theme was "Literature" and the most prominent small 'c' topic was "Values, beliefs and attitudes". Likewise, Chen and Lee [16] analyzed ten CFL textbooks for business Chinese purpose and concluded small 'c' topics were also more frequent than big "C' topics. They also found "Social-economic circumstance" was the most appearing theme of big 'C' while "Communication style" dominated small 'c' topics. As shown here, although big "C' small 'c' is a widely accepted framework to analyzed cultural elements of FL materials, most studies were done for EFL purpose and the subjects were mainly about textbooks and not the new media or technologies, which are gaining the central stage in today's educational methods. Therefore, we would like to study the below three research questions:

1. Are there cross-cultural elements in CFL YouTube channel?
2. What is the portion between big ‘C’ and small ‘c’ culture in CFL YouTube channel?
3. What is the most frequent topic of big ‘C’ and small ‘c’ culture in CFL YouTube channel?

3 Method

3.1 Subject

The research studied YouTuber “Lee Sisters”, who gained popularity with videos targeting Japanese CFL learners [17]. Lee is the real name of the sisters who are five years old different. The older sister was born in China and lived in Japan and New Zealand and the younger sister was born in Japan and lived in China. Both sisters grew up in environments across different languages and had personal experience as second or third language learner. In November 2018, their YouTube channel “Lee Sisters ch” opened. The trigger of the opening was that the younger sister, Shi-chan, quit the company she was working for at the time and planned a working holiday. When she was watching a learning video on YouTube to study English, she noticed the YouTube channel “Bilingual Girl English Conversation” operated by Chika Yoshida. Shi-chan started posting videos related to China, thinking that there are few YouTube videos that are useful for learning Chinese and that she could make them herself. In the early stages of the activity, the number of views of the video was often less than 100 times, but postings were made steadily. Later, the number of subscribers became 100,000 in the first year of opening and more than 250,000 in February 2021.

In October 2019, the sisters participated in a seminar hosted by the Chinese government-approved language test “HSK (*Hanyu Shuiping Kaoshi*)” as a lecturer. They became the official image character of HSK in 2020, and was an ambassador for HSK-sponsored online study abroad in January 2021 [17]. Therefore, the reason why the YouTuber “Lee Sisters ch” can achieve such a famous and well-respected status is worth understanding.

3.2 Content Analysis

Content analysis, per Berelson [18] defined, as “a research technique for the objective, systematic, and quantitative description of the manifest content of communication”. Krippendorff [19] referred it as “a research technique for making replicable and valid inferences from text (or other meaningful matter) to the context of their use”. Neuendorf [20] considered content analysis as “a summarizing, quantitative analysis of messages that follows the standards of the scientific method (including attention to objectivity-intersubjectivity, a priori design, reliability, validity, generalizability, replicability, and hypotheses testing based on theory) and is not limited as to the types of variables that may be measured or the context in which the messages are created or presented”. Among the above definitions, we can conclude that content analysis is used for the meaningful interpretation of the content studied. This content may include all forms of media such as text, image, sound, or even video.

Hsieh and Shannon [21] categorized content analysis approaches into three groups: conventional, directed, or summative. All three approaches are used to interpret meaning from the content of text data and adhere to the naturalistic paradigm. The major differences among these approaches are coding schemes: coding schemes, and threats to trustworthiness. In conventional content analysis, coding categories are derived directly from the text data. With a directed approach, analysis starts with a theory or relevant research findings as guidance for initial codes. A summative content analysis involves counting and comparisons, usually of keywords or content, followed by the interpretation of the underlying context. Because big 'C' small 'c' culture framework is a widely accepted categorization method, we adopted it as our coding scheme according to Matić [6]:

The list of big 'C' cultural topics included: Art (paintings, sculpture, architecture), Economy (economic system), Education (schools, universities, curriculum), Geography (national geography = 'geographical facts seen as being significant by members', History (national history = 'historical and contemporary events seen as markers of national identity', Institutions (government, politics, state institutions), and Literature (novels, plays, poems, proverbs).

On the other hand, the list of small 'c' cultural topics were: Everyday living (food and drink, meal times, table manners; public holidays, working hours and practices, leisure activities), Living conditions (living standards, housing conditions, welfare arrangements), Interpersonal relations (including relations of power and solidarity), Values, beliefs, attitudes (in relation to such factors as: social class, wealth, regional cultures, Body language (nonverbal communication), Social conventions (e.g. with regard to giving and receiving hospitality), and Ritual behavior.

3.3 Procedure

We firstly chose the 30 most viewed videos from YouTuber "Lee Sisters ch" (on the date of 2022 Jan 21st) then coded their content according to big 'C' small 'c' framework by two reviewers. If the two reviewer disagreed on certain categorization, a discussion will be conducted and an agreement will be reached.

4 Result

4.1 Cultural Content in Selected Videos

Thirty most viewed videos, as on the date of 2022, January 21st, from YouTuber "Lee Sisters ch" were selected. The most viewed video was viewed for over one million times and even the 30th most viewed video was viewed over 300,000 times. The 30 videos' contents according to big 'C' culture, small 'c' culture, and non-culture were analyzed by two reviewers and the interrater agreement is 83.33%. Out of the 30 videos, 26 videos (86.67%) covered topics about culture. Table 1 shows partly examples of the result of the 10 most watched videos:

Table 1. The analytical example of the 10 most viewed videos on YouTuber "Lee Sisters ch"'s channel

	Video title (in Japanese)	Cultural/non-cultural	Big C/Small c	Topic
1	([Chinese see] Is Reiji Nakagawa's Chinese impersonator similar? ?	Cultural	Small c	Values, beliefs, attitudes
2	It's amazing how Chinese come to Japan! I was surprised at that unexpected [chat]	Cultural	Small c	Everyday living
3	Chinese starting from the basics [Lesson 1] A super important single vowel in Pinyin!	non-Cultural	n/a	n/a
4	No longer an urban legend level! 8 surprising things that show the good security of Japan that Chinese people think!	Cultural	Small c	Social convention
5	Do Chinese people understand kanji? How is the Chinese language learned in Japan different from modern Chinese? [Explanation]	Cultural	Big C	Literature
6	If there is a Chinese toilet, how to capture it! [Trivia useful for travel]	Cultural	Small c	Living conditions
7	Listen to it! Chinese starting from the basics [Lesson 1] 30 common kanji!	non-Cultural	n/a	n/a
8	[Recommended] Japanese singer MISIA appears on a popular Chinese song program! What is the reaction in China? !! You can watch it for free!	Cultural	Small c	Everyday living
9	[Learn 3 languages] A turbulent upbringing!	Cultural	Small c	Everyday living
10	[Wasei-kango] Is 70% of modern Chinese true? How much do you actually use? [Explanation by Chinese]	Cultural	Big C	Literature

4.2 Big 'C' and Small 'c' Culture Composition

By further analyzing the combination of cultural topics, we found seven videos (23.33%) were related to big 'C' and 19 videos (63.33%) were about small 'c'. This result echoed previous researches that FL materials that small 'c' culture should be emphasized and it is beneficial for FL leaners.

4.3 Most Frequent Topics of Big 'C' and Small 'c' Culture Related Videos

Last but not least, we calculate the appearance of each cultural topics and summarized the most frequent topics under big 'C' (Fig. 1) and small 'c' culture (Fig. 2). As shown here, "Literature" was the most frequent topic within big 'C' culture and "Everyday living" was the most popular topic within small 'c' culture. Echoing earlier researches, "Literature" is a frequent big 'C' topic in FL materials. On the other hand, the popularity of "Everyday living" video reflected the special nature of consumption of YouTube video, which has not been observed when analyzing FL textbooks.

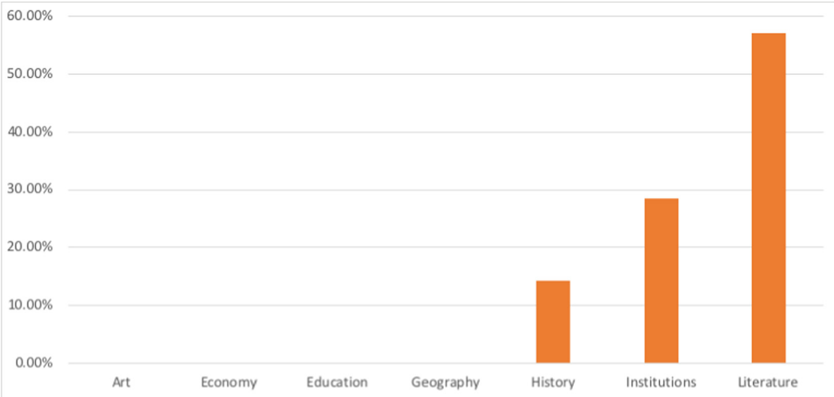


Fig. 1. Distribution of big 'C' cultural topics in the CFL YouTube channel

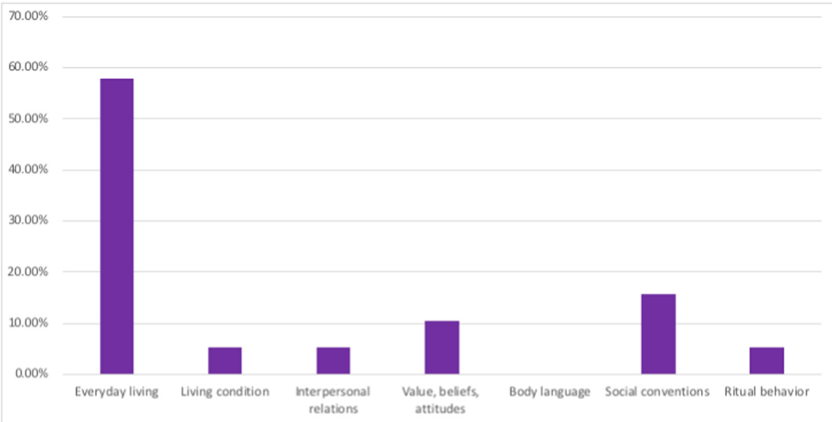


Fig. 2. Distribution of small 'c' cultural topics in the CFL YouTube channel

5 Discussion and Conclusion

We studied the most popular and representable YouTuber channel for Japanese CFL learner, Lee Sisters ch, in this research. By analyzing the 30 most viewed videos using big ‘C’ small ‘c’ culture framework, we examined the types of popular cultural contents that interest Japanese CFL learners most. This research found cultural information were introduced in the majority of the most popular YouTube videos. Under the framework of big ‘C’ small ‘c’ culture, 23.33% of the videos were related to big ‘C’ culture and 63.33% of the videos were about small ‘c’ culture. This result echoed earlier research about culture topics in FL textbooks that small ‘c’ were more frequent and more beneficial to FL learners. As in earlier researches, “Literature” was the main theme of big ‘C’ in FL materials. On the other hand, “everyday living” was the most frequent small ‘c’ topic, which also echoed earlier research about YouTube or YouTuber.

This research revealed the popularity of cultural relating videos for CFL learners, which shows Japanese CFL learners are specifically interested in the subjects about cross-cultural communication. The result aligned with the Japanese culture aspects of not causing inconvenience of others and afraid of losing face if not behaving properly. Furthermore, the language used in the channel is mainly Japanese, which allowed all level CFL learners to understand the content.

The research’s theoretical implications are followed: Firstly, this research expanded the application of big ‘C’ small ‘c’ culture framework to YouTube FL videos. It also echoed the importance of cross-cultural elements in FL learning materials. Additionally, this study revealed the unique aspect of YouTube video as FL learning material under big ‘C’ small ‘c’ framework.

This research’s practical implication includes: Suitable YouTube videos can be used for learning to enhance leaner’s cross-cultural competence. It is also beneficial if teachers are familiar with both kind of cultures to meet FL learners’ needs.

There were several limitations in this research: Firstly, we focused on the aspect of YouTuber and their content only. However, whether these features are also the key influencers students perceived was not examined. Secondly, due to the resource limit, we did not ensure the information maturation and analyzed only limited numbers of videos. More videos and even more YouTubers could be included for further validation assurance.

References

1. Burgess, J., Green, J.: YouTube: Online Video and Participatory Culture. Wiley, Cambridge (2018)
2. Tan, E.: Informal learning on YouTube: exploring digital literacy in independent online learning. Learn. Media Technol. **38**, 463–477 (2013). https://doi.org/10.1080/17439884.2013.783594
3. Wang, H., Chen, C.W.: Learning English from YouTubers: English L2 learners’ self-regulated language learning on YouTube. Innov. Lang. Learn. Teach. **14**, 333–346 (2020). https://doi.org/10.1080/17501229.2019.1607356
4. Liu, S., Laohawiriyanon, C.: Cultural content in EFL listening and speaking textbooks for Chinese university students. Int. J. Engl. Lang. Educ. **1**, 68–93 (2012). https://doi.org/10.5296/ijele.v1i1.2850
5. Xiao, J., Laohawiriyanon, C.: Cultural contents in a university EFL listening textbook in China. Presented at the 2nd International Conference on Humanities and Social Sciences (2010)

6. Matić, J.: 'Big C' and 'Small c' culture in EFL materials used with second year students majoring in English at the Department of English, University of Belgrade. Komunikacija i kultura **6**, 134–146 (2017)
7. YouTuber (2022). https://en.wikipedia.org/w/index.php?title=YouTuber&oldid=1073229892
8. Jerslev, A.: Media times | in the time of the microcelebrity: celebrification and the YouTuber Zoella. Int. J. Commun. **10**, 19 (2016)
9. Shen, C.-C., Yang, C.-C., Mao, T.-Y., Sia, W.-Y., Lin, C.-T.: Do YouTube fitness videos help YouTube user to learn fitness? Int. J. Innov. Creativity Chang. **5**, 93–104 (2019)
10. Kelsen, B.: Teaching EFL to the iGeneration: a survey of using YouTube as supplementary material with college EFL students in Taiwan. CALL-EJ Online **10**(2), 1–18 (2009)
11. Watkins, J., Wilkins, M.: Using YouTube in the EFL classroom. Lang. Edu. Asia **2**(1), 113–119 (2011)
12. Benedict, R.: The Chrysanthemum and the Sword: Patterns of Japanese Culture. Houghton Mifflin Harcourt, Boston (2005)
13. Ohata, K.: Potential sources of anxiety for Japanese learners of English: preliminary case interviews with five Japanese college students in the U.S. TESL-EJ **9** (2005)
14. Woodrow, L.: Anxiety and speaking English as a second language. RELC J. **37**, 308–328 (2006). https://doi.org/10.1177/0033688206071315
15. Bright, A., Gambrell, J.: Calling in, not calling out: a critical race framework for nurturing cross-cultural alliances in teacher candidates (2017). https://www.igi-global.com/chapter/calling-in-not-calling-out/www.igi-global.com/chapter/calling-in-not-calling-out/163988
16. Chen, L.-Y., Lee, H.-H.: Culture study of fundamental business Chinese teaching material. J. Chin. Lang. Teach. **9**, 41–73 (2012)
17. The Lee Sisters ch (2022). https://ja.wikipedia.org/w/index.php?title=%E6%9D%8E%E5%A7%89%E5%A6%B9&oldid=88104522. (in Japanese)
18. Berelson, B.: Content Analysis in Communication Research. Free Press, New York (1952)
19. Krippendorff, K.: Content Analysis: An Introduction to Its Methodology. SAGE Publications Inc., Los Angeles (2012)
20. Neuendorf, K.A.: The Content Analysis Guidebook. SAGE Publications Inc., Los Angeles (2016)
21. Hsieh, H.-F., Shannon, S.E.: Three approaches to qualitative content analysis. Qual. Health Res. **15**, 1277–1288 (2005). https://doi.org/10.1177/1049732305276687

Emotional Responses of Novice Online Learners Towards Online Learning During the COVID-19 Pandemic Period

Clyde A. Warden[1], Judy F. Chen[2(✉)], Wan-Hsuan Yen[3], and James O. Stanworth[4]

[1] Marketing Department, National Chung Hsing University, Taichung, Taiwan
[2] Business Administration Department, Overseas Chinese University, Taichung, Taiwan
jfc@ocu.edu.tw
[3] Department of Business Administration, National Taichung University of Science and Technology, Taichung, Taiwan
[4] Business Administration Department, National Changhua University of Education, Changhua, Taiwan

Abstract. During the COVID-19 pandemic period, as school systems around the world all started to follow suit and go online, factors that hinders online learning adoption became an important issue. Inexperienced online learners, suddenly finding themselves off campus, approached remote learning class with expectations that are complex, subtle, and often contradictory. Accordingly, we attempt to measure emotional responses from novice online learners, pushed to distance learning during the COVID-19 pandemic period, drawing from a fully online class. Results of a sentiment analysis show students accept the flexibility, challenge, and newness of online learning. Nevertheless, the same learners seek to avoid aspects of the online class they feel are slow, difficult, and lacking in opportunities to make new friends. Results of this study provide valuable guidance to both course designers and administrators in easing learner worries and enhancing online learning benefits.

Keywords: Emotional response · Online learning · Approach-avoidance · Adoption · E-teaching

1 Introduction

The pace and volatility of change in the education environment increases throughout the twenty-first century, culminating in the major dislocations of 2020. Miller et al. (2018) assert volatility, uncertainty, complexity, and ambiguity (VUCA) are increasingly common phenomena organizations cope with. Drawing on literatures in organizational behavior and strategic planning within both the business and military domains gives meaning to the volatile, VUCA environment [1, 2]. Educators are increasingly concerned and challenged by the need to prepare students and to function within a VUCA world [3, 4]. The disruption in education caused by the COVID-19 pandemic of 2020 is an extreme

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 272–277, 2022.
https://doi.org/10.1007/978-3-031-15273-3_30

example of VUCA. Such events reinforce the importance of supporting educators to prepare learners for rapid change while assuring transitions that maximize learning and protect learner wellbeing [3].

Although the Technology Acceptance Model (TAM) predicts adoption of a specific technology, it offers little guidance for improving the key dimensions of usefulness or ease of use among target users. For example, TAM's survey questions measuring perceptions of usefulness often draw on the work of Davis [5] that ask respondents to rate the usefulness of a technology along the dimensions of task completion, performance, productivity, and effectiveness. Similarly, ease of use rates on the dimensions of task completion, interaction, and understandability. Within a VUCA environment, where effective adoption depends on rapid feedback loops for improvement, TAM data collection can at best compare test/control designs, i.e., A/B testing [6]. As a sequence, curriculum designers need more information on the specific emotions linked to pedagogical components. In other words, more real-time visibility into usefulness and ease of use constructs is needed in terms of specific emotions relating to technological elements and class integration.

2 Literatures

The spread of COVID-19 has had a devastating impact on society globally [7]. Shutdowns of physical locations forced people to work or learn from home [7–9]. Many countries also rushed transitions to online learning while schools were closed [10, 11]. Nevertheless, the rapid shift to online learning revealed a lack of readiness in infrastructure, teacher, and students [12–15] to the detriment of students' learning opportunities [14]. Taiwan's strong infrastructure, convenient urban environments and high Internet penetration was well-prepared for the move. The readiness, however, of Taiwanese students was questionable as the rate of online class experience, prior to COVID-19, was low at 18.4%, meaning most learners had little experience with online classes [16, p.149].

Feelings and emotions play an important role in learning goals [17, 18]. As Kirkpatirck and Kirkpatirck [19] proposed, feelings like satisfaction are the foundation of four levels of training evaluation. Positive emotion in learning can boost learner engagement and willingness to complete a course [20, 21]. The interaction between cognition and emotion also influences learner task performance [17].

Accordingly, this study investigates the approach-avoidance conflict emotions of inexperienced online learners when beginning a fully online class. Quantifying such emotions demonstrates the complexity of learner emotions while offering actionable input to better facilitate design and easing student concerns.

3 Method

3.1 Subject

This study adopts the recent Approach-Avoidance Theory of Motivated Behavior model [22] since it is a robust synthesis of the three most popular psychological research approach-avoidance theories: Gray's RST, Higgins' Regulatory Focus Theory (RFT), and Elliot's Achievement Goal Theory (AGT). A fully online class was designed in Taiwan for undergraduate students and promoted across colleges. The class topic of negotiation skill was designed for non-business and business majors and co-opened across colleges for credit. Four weeks into the class (less than one-quarter into the 18-week semester), the questionnaire survey was executed, with students having been exposed to all the aspects of the online class at least once.

We started by asking learners to write three reasons, on a paper form, for their being attracted to participate in this online course. Allowing for short answers, respondents were next asked to individually consider the first reason and explain why it is important. Learners were then asked to think of the reason they had just given and explain the significance of the second column explanation. This cycle was repeated for each of the three original reasons. Learners were then asked to think of three reasons why they were pushed away from participating in the online course in order to carry out both an entity level and a sentence level analysis [23, 24]. We then repeated the above procedure to elaborate the rationale for each response.

4 Result

4.1 Cultural Content in Selected Videos

A total of 94 students, 54% male, 23% international (remaining Taiwan learners), average age of 21.2 years, participated in this study. The majority of respondents (79%) had no experience with any online class; a minority (3%) reported experiencing a fully online class, while the remaining (18%) had experience with partially online, blended or flipped, course delivery. The resulting approach tables totaled 1,318 (14 per respondent), while avoid tables totaled 1,090 (11.6 per respondent). Approach and avoid statements were analyzed separately, based on the Bing lexicon, focusing on the top ten occurring tokens. Table 1 shows the most valued aspects of the online class include time, schedule, flexible, study, convenient—all related to the learner's ability to create his/her own timetable. The next five approach tokens (skills, credits, practice, increase, career) are more related to extrinsic end states. In contrast, the avoid tokens reveal concerns about difficulty in learning, coordinating, and generally managing the time and tasks.

Table 1. Ten highest frequency tokens from approach and avoid texts

Rank	Approach		Avoid	
	Token	Frequency	Token	Frequency
1	Time	244	Hard	71
2	Schedule	135	Learning	64
3	Flexible	111	Difficult	55
4	Study	104	Coordination	52
5	Convenient	64	Interaction	52
6	Skills	59	Slow	51
7	Credits	57	Solving	51
8	Practice	54	Time	50
9	Increase	53	Lack	45
10	Career	51	Low	41

We next tested the approach and avoid strings, with the NRC lexicon, which categorizes both overall positive/negative and a range of sentiments. The approach strings exhibits 89% positivity, while the avoid strings exhibited 85% negativity, while all eight sentiments are statistically significantly different, between approach and avoidance, based on chi-square tests, supporting reliability of the approach (Table 2).

Table 2. Eight lexicon sentiment frequencies

NRC	Anger^{n}	Anticipation	Disgust^{n}	Fear^{n}	Joy	Sadness^{n}	Surprise	Trust
Approach	23	429	21	47	80	25	26	209
Avoid	145	153	131	256	49	175	49	127

Note: ^{n} = negative sentiment

The results show students appreciate the adoption of online learning, so they can learn from home. Students also enjoyed the time flexibility since they can pace their own learning progress. Such results echo research published before COVID-19 that online courses can provide time and location flexibility [10, 15]. Furthermore, students considered online courses helpful in preparing for their future careers. On the other hand, we found students consider online learning challenges them in some specific areas: interaction and coordination, problem solving, and technical issues. These emotions frame informants as demotivated by their inability to learn efficiently and effectively.

5 Discussion and Conclusion

Online learning has undergone diffusion for more than two decades [25], low adoption is still an issue. However, assumptions that learners are digital natives [26], and thus comfortable moving online, may not be well-founded [27]. Conflicts between approach and avoidance require attention. Teachers/administrators can prepare a clear and easy-to-understand roadmap of the online class so that students can follow more easily and reduce the negative emotion.

Acknowledgment. The authors are grateful to the Ministry of Science and Technology of the Republic of China, Taiwan, for financially supporting this research under Contract No. MOST 110-2511-H-005-003-MY2.

References

1. Bennett, N., Lemoine, G.J.: What a difference a word makes: understanding threats to performance in a VUCA world. Bus. Horiz. **57**(3), 311–317 (2014). https://doi.org/10.1016/j.bushor.2014.01.001
2. Whiteman, W.E.: Training and educating army officers for the 21st century: implications for the united states military academy. Army War Coll Carlisle Barracks Pa (1998). https://apps.dtic.mil/sti/citations/ADA345812
3. Hadar, L.L., Ergas, O., Alpert, B., Ariav, T.: Rethinking teacher education in a VUCA world: student teachers' social-emotional competencies during the Covid-19 crisis. Eur. J. Teach. Educ. **43**(4), 573–586 (2020). https://doi.org/10.1080/02619768.2020.1807513
4. Laukkonen, R., Biddell, H., Gallagher, R.: Preparing Humanity for Change and Artificial Intelligence. OECD Publishing, Paris (2019). https://doi.org/10.31234/osf.io/g5qwc
5. Davis, F.D.: Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q. 319–340 (1989)
6. Granić, A., Marangunić, N.: Technology acceptance model in educational context: a systematic literature review. Br. J. Edu. Technol. **50**(5), 2572–2593 (2019)
7. Jurcik, T., et al.: Adapting mental health services to the COVID-19 pandemic: reflections from professionals in four countries. Couns. Psychol. Q. **34**(3–4), 649–675 (2020). https://doi.org/10.1080/09515070.2020.1785846
8. Dwidienawati, D., Abdinagoro, S.B., Tjahjana, D., Gandasari, D., Munawaroh: Forced shifting to e-learning during the covid-19 outbreak: information quality, system quality, service quality, and goal orientation influence to e-learning satisfaction and perceived performance. Int. J. Adv. Trends Comput. Sci. Eng. **9**(2), 1518–1525 (2020). https://doi.org/10.30534/ijatcse/2020/93922020
9. Espino-Díaz, L., Fernandez-Caminero, G., Hernandez-Lloret, C.-M., Gonzalez-Gonzalez, H., Alvarez-Castillo, J.-L.: Analyzing the impact of COVID-19 on education professionals. Toward a paradigm shift: ICT and neuroeducation as a binomial of action. Sustainability (Switzerland) **12**(14), 5646 (2020). https://doi.org/10.3390/su12145646
10. Kamal, A.A., Shaipullah, N.M., Truna, L., Sabri, M., Junaini, S.N.: Transitioning to online learning during COVID-19 Pandemic: case study of a Pre-University Centre in Malaysia. Int. J. Adv. Comput. Sci. Appl. **11**(6), 217–223 (2020). https://doi.org/10.14569/IJACSA.2020.0110628
11. Peterson, L., Scharber, C., Thuesen, A., Baskin, K.: A rapid response to COVID-19: one district's pivot from technology integration to distance learning. Inf. Learn. Sci. **121**(5–6), 451–459 (2020). https://doi.org/10.1108/ILS-04-2020-0131
12. Almaiah, M.A., Al-Khasawneh, A., Althunibat, A.: Exploring the critical challenges and factors influencing the E-learning system usage during COVID-19 pandemic. Educ. Inf. Technol. **25**(6), 5261–5280 (2020). https://doi.org/10.1007/s10639-020-10219-y

13. Johnson, N., Veletsianos, G., Seaman, J.: U.S. faculty and administrators' experiences and approaches in the early weeks of the COVID-19 pandemic. Online Learn. J. **24**(2), 6–21 (2020). https://doi.org/10.24059/olj.v24i2.2285
14. Kapasia, N., et al.: Impact of lockdown on learning status of undergraduate and postgraduate students during COVID-19 pandemic in West Bengal India. Child. Youth Serv. Rev. **116**, 105194 (2020). https://doi.org/10.1016/j.childyouth.2020.105194
15. Smoyer, A.B., O'Brien, K., Rodriguez-Keyes, E.: Lessons learned from COVID-19: being known in online social work classrooms. Int. Soc. Work. **63**(5), 651–654 (2020). https://doi.org/10.1177/0020872820940021
16. National Development Council: 2019 Individual Family Digital Opportunity Research Report (2019). https://ws.ndc.gov.tw/Download.ashx?u=LzAwMS9hZG1pbmlzdHJhdG9yLzEwL2NrZmlsZS85MzczMTljNi05NzAxLTRjZDUtOTZlOC0yNmE3OTIyNGRmMzEucGRm&n=MTA45bm05YCL5Lq65a625oi25pW45L2N5qmf5pyD6Kq%2f5p%2bl5aCx5ZGKKOWFrOWRiueJiDAzMTIpLnBkZg%3d%3d&icon=.pdf
17. Kormos, J., Préfontaine, Y.: Affective factors influencing fluent performance: French learners' appraisals of second language speech tasks. Lang. Teach. Res. **21**(6), 699–716 (2017). https://doi.org/10.1177/1362168816683562
18. Leutner, D.: Motivation and emotion as mediators in multimedia learning. Learn. Instr. **29**, 174–175 (2014). https://doi.org/10.1016/j.learninstruc.2013.05.004
19. Kirkpatrick, J.D., Kirkpatrick, W.K.: Kirkpatrick's Four Levels of Training Evaluation, 1st edn. Association for Talent Development, Alexandria (2016)
20. Heidig, S., Müller, J., Reichelt, M.: Emotional design in multimedia learning: differentiation on relevant design features and their effects on emotions and learning. Comput. Hum. Behav. **44**, 81–95 (2015). https://doi.org/10.1016/j.chb.2014.11.009
21. Loderer, K., Pekrun, R., Lester, J.C.: Beyond cold technology: a systematic review and meta-analysis on emotions in technology-based learning environments. Learn. Instr. **70**, 101162 (2020). https://doi.org/10.1016/j.learninstruc.2018.08.002
22. Monni, A., Oliver, E., Marin, A.J.S., Olivetti Belardineli, M., Mulvhill, K., Scalas, L.F.: Approach and avoidance in Gray's, Higgins', and Elliot's perspectives: a theoretical comparison and integration of approach-avoidance in motivated behavior. Pers. Individ. Differ. **166**, 110163 (2020). https://doi.org/10.1016/j.paid.2020.110163
23. Bagozzi, R.P., Bergami, M., Leone, L.: Hierarchical representation of motives in goal setting. J. Appl. Psychol. **88**(5), 915–943 (2003)
24. Bagozzi, R.P., Sekerka, L.E., Hill, V.: Hierarchical motive structures and their role in moral choices. J. Bus. Ethics **90**(4), 461–486 (2009)
25. Zhao, Y., Wang, N., Li, Y., Zhou, R., Li, S.: Do cultural differences affect users' e-learning adoption? A meta-analysis. Br. J. Edu. Technol. **52**(1), 20–41 (2021). https://doi.org/10.1111/bjet.13002
26. Prensky, M.: Digital natives, digital immigrants part 1. On Horiz. **9**(5), 1–6 (2001). https://doi.org/10.1108/10748120110424816
27. Warden, C.A., Yi-Shun, W., Stanworth, J.O., Chen, J.F.: Millennials' technology readiness and self-efficacy in online classes. Innov. Educ. Teach. Int. **59**(2), 1–11 (2020)

Diffusion of Innovative Digital Work Practices

Synnøve Thomassen Andersen(✉)

UiT, The Arctic University of Norway, Follumsvei 31, 9510 Alta, Norway
Synnove.T.Andersen@uit.no

Abstract. The aim of this paper is to highlight use of different digital solutions and systems in two public welfare offices in Norway, and the impact this has on recently graduated students work practices in the public welfare services. This requires new knowledge, theories, methods and ethics related to professional work. In this paper, innovation theory is used to promote the understanding of work practices using technology in public welfare services. When using a qualitative method, the advantages and disadvantages of using current digital practices among newly graduated workers in public sector are analyzed. The results are linked to activities that can contribute to realizing potentials for further innovation in public welfare services through the use of technology. There is a need for educational institutions to facilitate educations for more knowledge and competence in public welfare services regarding digital competence, technology, and innovation to be able to help develop the service in the future.

Keywords: Innovation diffusion theory · Public benefit organization decision making · Digital work practices · Use of technology

1 Introduction

1.1 A Subsection Sample

This paper is based on perspectives from new work practices by educated social workers in public welfare services and use of technology [1, 2, 27], and analyzes of these work practices related to Everett Rogers' theory of diffusion of innovation [18–20]. This research is based on a study by Zhu and Andersen [27] at two public welfare service offices in Norway. The following issue is examined: *How do* newly *graduated workers experience that technology affects their work practices, and how can new work practices promote innovation in the welfare service?*

Developing new knowledge, new skills and general competence that is incorporated in all education, is the basis for a goal of lifelong learning for a society in constant change. This requires new perspectives that promote innovation in new forms of interdisciplinary education. In this regard is innovation a very important factor, that should contribute to value creation and/or societal benefit. In the new Norwegian national guidelines for health and social sciences educations [28], innovation is included as part of the learning outcome descriptions. The student organization [29], claim that innovation in the education should involve continuous professional development and new thinking

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 278–284, 2022.
https://doi.org/10.1007/978-3-031-15273-3_31

about solutions. Furthermore, they claim that the educations must promote the students' own development of innovation competence, which is characterized by the ability to apply theory, skills and competence, to develop and improve conditions around them.

2 Theory

2.1 Diffusion of Innovation

The term innovation covers all activity that creates something new, "new combinations of knowledge and resources that lead to a desired effect" [2, p. 66], or new idea, new goods, new services, new work practices, new processes and new forms of organization [4, 20, 22, 25]. Dissemination of innovations is called diffusion [9, 13, 16], and is defined by Rogers [19] as «*Diffusion is the process by which an innovation is communicated through certain channels over time among the members of a social system. It is a special type of communication, in that the messages are concerned with new ideas*»(p. 259). Rogers [19] describes four specific elements that affect the spread of innovation in the public sector:

- innovation and its characteristics,
- communication,
- time,
- the social system.

2.2 Characteristic of Innovation

According to Rogers [20], an innovation has specific characteristics:

1. Relative advantage indicates how favorable the new idea or innovation is to key actors assessed on the basis of their interests and objectives [18]. If someone claims that new solutions and technologies do not fit their goals, this may be a sign of inertia and resistance to change.
2. Observability indicates the extent to which the result of an innovation is visible to oneself and to others [18]. Visible innovations will spread faster than innovations that are difficult to observe.
3. Compatibility is about how a new measure fits into the existing structure and culture [18]. An innovation is likely to spread faster than if the innovation is difficult to reconcile with previous experiences and existing attitudes. It also becomes more uncertain whether users will end up using the innovation at all. In public organizations, there is often a hierarchical organization, and it can be difficult to make room for new solutions.
4. Complexity addresses how difficult it is to understand and apply innovation [18]. Innovations that are perceived as difficult to understand and difficult to use will spread more slowly than innovations that are simple and user-friendly.

5. Testability is about the extent to which an innovation can be tested on a small scale or to a limited extent [18]. Testing an innovation gives people a better understanding of an innovation and the opportunity to find out how it works under their conditions. The possibility of a large degree of testability will lead to the innovation being implemented more quickly and reduce the risk of adoption.

3 Methodology

The study follows the hermeneutic and qualitative tradition in pedagogical and social work research [15, 26]. Qualitative method is well suited when one is interested in each individual's experience and interpretation of a phenomenon. Qualitative method uses various forms of systematic collection, processing and analysis of material from participatory observations, focus group interviews and semi-structured interviews [8, 23, 24].

This survey covers two public welfare offices in Norway in the period 2017–2019. 35 newly graduated workers at these offices participated in the survey, 20 women and 15 men between the ages of 27 and 65. All informants were bachelor educated professional social workers. They had all digital competence so they could relate to and use digital tools and media in a safe, critical and creative way. Digital competence is about knowledge, skills and attitudes. It is about being able to perform practical tasks, communicate, obtain or process information [30]. However, they all had to learn to use new systems and solutions at their workplace, and learn about communicate in new ways.

The interview questions dealt with the informants' perception, understanding and practical experiences of the various digital solutions. The individual interviews ranged from 20 to 60 min, with questions about the newly graduated worker's work practices and use of technology. All interviews were recorded and transcribed. All informants are newly graduated worker's and also described as employees in the rest of the article. In the treatment of the empirical data, different work practices and different technologies were considered and identified what all the informants said about precisely these topics. This approach made it possible to compare what all the informants said on the same topic, and made it possible to analyze how similarities and differences between the feedback could be understood. Qualitative method is well suited when one is interested in each individual's experience and interpretation of a phenomenon. It was important that the informants contributed to the survey to the best of their ability and in that way could provide relevant empirical data.

4 Analysis

The findings are analyzed in relation to Rogers' [18] five characteristics for innovation: relative advantages, observability, compatibility, complexity and testability. All informants say that user participation is a fundamental goal in public services. Furthermore, all the informants state that extensive use of laptops and smartphones with access to various systems means that the employees can be more accessible and flexible. The introduction of new technology solutions has made it possible for more frequent communication between employees and users of welare serices. An informant said: «... *I* *can write a short message to the user, and we can discuss it at the next personal meeting. In this way, he can become more involved in his own process.»*

The empiri shows that the challenge is to organize this so that both users and employees experience this as good solutions. This is similar to Rogers' [18] description of relative advantage, in that the new way of working is perceived as something new and innovative for employees, since the new work practices also ensure their interests and objectives. Observability is when employees describe various new ways of communicating, and to what extent the result of such innovation is visible to the employee him/herself and to the users. An informant said:

> *«You need to communicate with young people and understand how they use various social media, snaps and text messages with a mix of symbols, characters and GIFs. I have used Snapchat and Instagram to communicate with a group of young people who are job seekers. I often post new vacancies along with photos or snaps of the workplaces to give them a more visual and visible understanding of what it looks like if they work there.»*

According to Rogers [19], compatibility means fitting in with something. Here it means to what extent the innovation is perceived to be in accordance with existing values, previous experiences and the needs of potential users. Furthermore, an innovation is likely to spread more quickly if the innovation can easily be reconciled with previous experiences and existing attitudes. An informant said: *«I think some people miss seeing a face when communicating. When using a screen, I can not predict the user's reaction. He can read the message long after it was sent, and I can not help in relation to his feeling or reaction.»* The analysis shows that standardization allows for quality assurance of information. An informant said:

> *«I am against standardization. Because it may seem that we who work here are concerned with satisfying a system all the time. I enter a lot of data instead of going out to meet the users. We have the requirements for how much we should do in a week or month. In this way, we work continuously to satisfy the system.»*

Public welfare organizations are often hierarchical. The introduction of new technologies and system solutions in large welfare organizations must be adapted to the organizations at all levels. The use of technologies that may be difficult to use effectively may end up not being used as intended. Rogers [18] describes this as compatibility, as it is about how a new tool fits into the existing structure and culture.

Innovations that are perceived as difficult to understand and difficult to use will spread more slowly than innovations that are simple and user-friendly. One informant said: «I need to log in to the IT system consistently within a day to check if I have overlooked something important coming from my clients.» The quote can be understood so that the informant describes regular logins in IT systems every day. The analysis shows that several task requests in different information systems in public welfare services overlap due to errors in the integration and synchronization of systems.

The introduction of innovation as a new process, new work practices, new systems and solutions that are difficult to understand and apply, is perceived as complex and not very user-friendly [18]. This can lead to innovation being perceived as inappropriate.

Testability and observability means the extent to which an innovation can be tested on a small scale or to a limited extent. The possibility of a large degree of testability will lead to the innovation being implemented more quickly and reduce the risk of adoption. All the informants in this survey describe the technology that has been used (adopted) as a top-down process, since the decision has been made by the public welfare organization entrally.

5 Discussion

The informants in the survey describe that they experience the new technological solutions as good tools in their work practices. Use of technology requires digital competence [12, 14, 17]. There is a need for knowledge related to the advantages and disadvantages of digital welfare services as well as identifying necessary knowledge and resources in the work of supporting digital inclusion [11, 17].

Challenges with complex technologies and system solutions can prevent the acceptance and spread of innovations [20]. Interaction can not be described independently of an offline dimension [4, 6]. The study shows that the technology solutions in public welfare services have led to a standardization of work practices in that case processing takes place by following predefined systematic steps in the information systems [3, 14, 21]. Several informants state that they experience that digital case processing contributes to quality control. Many informants are concerned about all the welfare services that are being standardized. Some of the informants state that they want to give the individual job-seeker individual follow-up and guidance, but that this is sometimes difficult because the system solutions are standardized and do not allow for what is different. Complexity problems are a reason for spending a lot of time on demanding system tasks that take away the attention you want to have on users. The majority of informants stated that they spend more than half of their working time on digital documentation, registration of new information, filling in forms and reporting of meetings.

Almost all the informants want a combination of the various computer systems in public welfare services into a common user-friendly system for data information search and registration. This will simplify employees' digital work practices related to documentation and help to avoid endless duplication of information. A study of similar work practices shows that the result can also provide high-quality information and better service [7, 10]. Findings suggest the need for more training in the use of technology and discussion of new ethical assessments of digital work practices. The majority of the informants stated that they thought previous technology training during education was not interactive and useful enough to help them understand the functionalities and possibilities of the various solutions. Studies in welfare work, point out that new education must focus both on ways of tackling specific system tasks, data registration, and also address challenges and opportunities when using technology [5, 12]. Increased awareness when using digital solutions leads to a need for increased awareness related to the collection, sharing and administration of users' personal information, must take place in an ethically sound manner [7, 11]. More use of digital solutions in the welfare services leads to a need for increased awareness related to the collection, sharing and administration of users' personal information. Other studies indicate that this must be done in an ethically sound manner [10, 12]. The findings show that employees can help users understand how their data can be used, and what is included in privacy statements, terms and conditions. The informants expect that the various digital solutions will be improved and updated so that they can be used with different user groups, among other things so that this is offered as more personal conversations through text-based messages.

6 Concluding Remarks

The survey shows that employees in public welfare services experience those new technological solutions help to simplify the way they now work, the new work practices and that this provides a better overview of the procedure. Further, the survey shows that there is a need for more knowledge and competence in public welfare services regarding digital competence, technology, and innovation. And innovation but also need for further evaluation of change processes related to the introduction of digital solutions.

There is a need for more knowledge and competence to promote the understanding of new work practices through the use of technology. The technology solutions provide the opportunity for active participation for users of the welfare services who have relevant resources and expertise in the use of technology, but that there are also challenges related to communication with the users that must be improved. The survey represents only a small number of employees, and there is therefore a need for further studies with a larger number of respondents to get a more accurate overall picture. In addition to assessing the characteristics of innovation, it will be interesting to study other influencing factors such as communication channels, organizational context and user-centered processes. Educational institutions must facilitate the education of social workers for today's society by implementing and develop new pedagogy and new learning tools so that innovation is better integrated in professional study courses in order to be able to help develop the service in the future.

References

1. Andersen, S.T.: Bruk av sosiale medier åpner for handlingsrom ved barnevernfaglig arbeid. In: Schönfelder, I.W., Andersen, S.T., Kane, A.A. (Red.) Handlingsrom i Barnevernet: Muligheter og begrensninger for profesjonsutøveren, pp. 65–83. Fagbokforlaget, Bergen (2018)
2. Andersen, S.T., Jansen, A.J.: Innovation in ICT-based health care provision. Int. J. Healthcare Inf. Syst. Inform. **6**(2), 14–27 (2011). https://doi.org/10.4018/jhisi.2011040102
3. Andreassen, T.A.: Measures of accountability and delegated discretion in activation work: lessons from the Norwegian Labour and Welfare Service. Eur. J. Soc. Work. **22**, 664–675 (2018). https://doi.org/10.1080/13691457.2018.1423548
4. Antonio, E.M., José, M.J.-P., Chaime, M.S.: e-Social work in practice: a case study. Eur. J. Soc. Work **21**(6), 930–941 (2018). https://doi.org/10.1080/13691457.2018.1423552
5. Peláez, A., García, R., Massó, M.ªV.A.-T.: e-Social work: building a new field of specialization in social work? Eur. J. Soc. Work **21**(6), 804–823 (2018). https://doi.org/10.1080/13691457.2017.1399256
6. Baker, S., Warburton, J., Hodgkin, S., Pascal, J.: Reimagining the relationship between social work and information communication technology in the network society. Aust. Soc. Work. **67**(4), 467–478 (2014)

7. Berzin, S.C., Coulton, C.J.: Harness technology for social good. In: Fong, R., Lubben, E.J., Barth, R.P. (eds.) Grand Challenges for Social Work and Society. Oxford University Press, New York (2017)
8. Creswell, J.W.: Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, 4th edn. SAGE, Los Angeles (2014)
9. Dingfelder, H.E., Mandell, D.S.: Bridging the research-to-practice gap in autism intervention: an application of diffusion of innovation theory. J. Autism Dev. Disord. **41**(5), 597–609 (2011)
10. Fitch, D.: Using data to improve client services. In: Goldkind, L., Wolf, L., Freddolino, P.P. (eds.) Digital Social Work: Tools for Practice with Individuals, Organizations, and Communities. Oxford University Press, USA (2019)
11. Goldkind, L., Wolf, L., Freddolino, P.P.: Digital Social Work: Tools for Practice with Individuals, Organizations, and Communities. Oxford University Press, Oxford (2018)
12. Goldkind, L., Wolf, L., Jones, J.: Late adapters? How social workers acquire knowledge and skills about technology tools. J. Technol. Hum. Serv. **34**(4), 338–358 (2016). https://doi.org/10.1080/15228835.2016.1250027
13. Greenhalgh, T., Robert, G., Macfarlane, F., Bate, P., Kyriakidou, O.: Diffusion of innovations in service organizations: systematic review and recommendations. Milbank Q. **82**(4), 581–629 (2004). https://doi.org/10.1111/j.0887-378X.2004.00325.x
14. Hansen, H.T., Lundberg, K., Syltevik, L.J.: Digitalization, street-level bureaucracy and welfare users' experiences. Soc. Policy Adm. **52**(1), 67–90 (2018). https://doi.org/10.1111/spol.12283
15. Johannessen, A., Tufte, P.A., Kristoffersen, L.: Introduksjon til samfunnsvitenskapelig 1 metode. Abstrakt forlag, Oslo (2004)
16. Knudsen, H.K., Roman, P.M.: Innovation attributes and adoption decisions: perspectives from leaders of a national sample of addiction treatment organizations. J. Subst. Abuse Treat. **49**, 1–7 (2015). https://doi.org/10.1016/j.jsat.2014.08.003
17. Olsson, T., Samuelsson, U., Viscovi, D.: At risk of exclusion? Degrees of ICT access and literacy among senior citizens. Inf. Commun. Soc. **22**(1), 55–72 (2019)
18. Rogers, E.M.: Diffusion of Innovation, 4th edn. Simon & Schuster Inc., New York (1995)
19. Rogers, E.M.: Diffusion of Innovations, 5th edn. Free Press, New York (2003)
20. Rogers, E.M.: Diffusion of Innovations. Free Press, New York (2010)
21. Røhnebæk, M.: Standardized flexibility: the choreography of ICT in standardization of service work. Cult. Unbound **4**(4), 679–698 (2013). https://doi.org/10.3384/cu.2000.1525.124679
22. Schumpeter, J.A.: Teorien om økonomisk utvikling: En undersøkelse av overskudd, kapital, kreditt, renter og konjunktursyklusen, vol. 55. Transaksjonsutgivere, London (1934)
23. Stewart, D.W., Shamdasani, P.N.: Focus Groups: Theory and Practice, vol. 20. Sage publications, London (2014)
24. Thagaard, T.: Systematikk og innlevelse: En innføring i kvalitativ metode, 4 utg. Fagbokforlaget, Bergen (2013)
25. Traube, D., Begun, S., Okpych, N., Choy-Brown, M.: Catalyzing innovation in social work practice. Res. Soc. Work Pract. **27**(2), 134–138 (2016). https://doi.org/10.1177/1049731516659140
26. Walsham, G.: Doing interpretive research. Eur. J. Inf. Syst. **15**(3), 320–330 (2006)
27. Zhu, H., Andersen, S.: User-driven innovation and technology-use in public health and social care: a systematic review of existing evidence. J. Innov. Manag. **6**(2), 138–169 (2018). https://doi.org/10.24840/2183-0606_006.002_0008
28. National guidelines for health and social work education (RETHOS), regjeringen.no
29. Hjem (student.no)
30. www.regjeringen.no/no/dokumenter/nou-2019-2/id2627309/?ch=4

Academics' Perspectives on the Strengths and Limitations of Blackboard Ally

Funmi Adebesin(✉) and Komla Pillay

Department of Informatics, University of Pretoria, Pretoria, South Africa
{funmi.adebesin,komla.pillay}@up.ac.za

Abstract. The number of people living with one or other forms of disability across the globe stands at over one billion. Consequently, the population of students with disability in higher education institutions (HEIs) is also increasing. One of the sustainable development goals of the United Nations is the provision of an inclusive learning environment for all, including people with disabilities. The provision of accessible learning content on Learning Management Systems (LMSs) is one of the ways that differently-abled students can be accommodated by HEIs. This paper presents the perspectives of two academics on the strengths and limitations of Blackboard Ally, an accessibility tool that is integrated into the Blackboard LMS. Based on our experience of use, we analyzed two aspects of the Blackboard Ally accessibility tool, namely (i) the provision of alternative accessible versions of course content to students, and (ii) the provision of guidance to instructors on how to improve the accessibility of course content. We found that the main strength of Blackboard Ally lies in the wide range of alternative formats of course content that the tool supports. We found apparent discrepancies in the accessibility scores that Blackboard Ally assigns to different formats of the same course content. In addition, Blackboard Ally has limitations in its ability to detect missing document headings in course content. Despite the limitations that we found, Blackboard Ally contributes immensely to the goal of inclusive education in the contemporary digital world.

Keywords: Accessible educational content · Alternative content formats · Blackboard Ally · Inclusive higher education

1 Introduction and Background

According to the World Health Organisation (WHO), more than one billion people are living with one or other form of disability across the globe. The body predicts that almost every living person is likely to experience some form of disability, either temporary or permanent, at some point in their life [1]. There are different forms of disability, including inability to move body parts or manipulate objects (physical impairments); partial or complete loss of sight and inability to perceive colour (visual impairments); partial or complete loss of hearing (hearing impairments) [2], as well as cognitive and learning disabilities [3]. People with disabilities face different types of barriers, ranging from inability to access information, education, and healthcare [4].

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 285–295, 2022.
https://doi.org/10.1007/978-3-031-15273-3_32

Advances in Information and Communication Technologies (ICTs) in general, and web 2.0 technologies in particular, have the potential to remove many of the challenges that are faced by people living with disabilities [5]. However, the predominant reliance on visual perception creates accessibility barriers that can impede people with disabilities from taking full advantage of these opportunities.

Accessibility can be described as the extent to which any product or service can be used by people with one or other form of disability [6]. Accessibility used to be of concern for practitioners in the built environment field, where legislation required cuts into street curbs and the building of ramps in public buildings to facilitate easy access to people in wheelchairs. This narrow view of accessibility has given way to a more comprehensive view due to the exponential growth in the use of internet and web technologies. Nowadays, accessibility involves ensuring equal access to digital content like educational materials by everyone, including people with disabilities [7]. Although the primary goal of accessibility is to ensure that digital content is usable by people with disabilities, accessibility is also beneficial to those without disabilities who may be confronted with situational limitations, i.e., situations where the context of use imposes limitations on how people use digital content [8]. For example, text-based feedback will be more appropriate for a student (with no auditory disability) who is completing a formative quiz on a mobile device in a library where noise is prohibited, rather than an audio feedback.

Although many higher education institutions (HEIs), especially those from developed countries, have adopted the use of ICTs for educational purposes [9], the global disruptions wrought at the height of the Covid-19 pandemic saw many more embracing digital technologies to ensure the continuity of teaching and learning [10]. For example, many HEIs have adopted Learning Management Systems (LMSs) like Blackboard [10]. Blackboard enables HEIs to create and deploy digital learning content over the internet. The software also supports course administration, communications between educators and students, synchronous online teaching via Blackboard Collaborate, as well as online assessments [11].

A consequence of the high number of people living with disabilities globally is the growth in the number of students with disabilities in HEIs [12]. As a result, decision-makers in HEIs are under immense pressure to ensure inclusive access to educational content by everyone, including students with disabilities [9]. A narrow view of inclusive education relates to the special education system for students with disabilities, whereas a broader definition encompasses all students, including those with disabilities and students from marginalized groups (i.e. different backgrounds, cultures, and ethnicity) [13]. Given the increasing number of students with disabilities in HEIs, the design of e-learning applications and LMSs must incorporate accessible design principles to ensure access by students with special needs. In its quest to support the accessibility of content on its platform, Blackboard, which owned 20% of LMS market share in American and Canadian HEIs [14], launched Blackboard Ally in 2017 [15]. Blackboard Ally facilitates the accessibility of digital course content by [16]:

- Automatically checking course contents for compliance with the Web Content Accessibility Guideline (WCAG) 2.1 standards,
- Providing alternative accessible versions of course content to students, and

- Guiding instructors on how to improve the accessibility of course content.

The context of this paper is the University of Pretoria (UP), a HEI in South Africa. UP implemented the Blackboard LMS, called ClickUP in 2007 [17], and by 2020 the use of ClickUP has permeated the institution, with more than 40 000 logins per day by students and academics [18]. In 2021, UP piloted Blackboard Ally on ClickUP and rolled out the tool fully in 2022. The specific course that we teach is a first-level information systems analysis and design course. Blackboard Ally was automatically integrated into the course ClickUP page at the beginning of the first semester in 2022. The purpose of this paper is to report on our experience of the strengths and limitations of Blackboard Ally from the perspectives of two of the three stated ways that Blackboard Ally supports the accessibility of digital course content for students.

The remaining sections of the paper are structured as follows: In Sect. 2, we discuss the extant literature that is relevant to the current study. This includes an overview of what accessibility entails and the disabilities that could affect the use of digital content. The section also discusses the importance of accessibility in educational platforms. The research method is presented in Sect. 3. Detailed discussions of our perspectives on the strengths and limitations of Blackboard Ally are presented in Sect. 4. Section 5 concludes the paper.

2 Literature Review

2.1 What is Accessibility?

Accessibility is concerned with ensuring that digital content is usable by as many people as possible. Accessibility is primarily associated with creating an enabling environment for people with disabilities, but the benefits reach a wider group of the population, such as users of mobile platforms, or those with slow internet connectivity. Accessibility aims to include as many users as possible by affording them the same opportunity, irrespective of their ability and situation. As it is wrong to exclude someone based on their physical impairment, it is equally wrong to exclude physically impaired individuals from accessing digital content, including digital educational content. Accessible digital content benefit everyone. Accessibility enables people with disabilities to "perceive, understand, navigate, and interact with electronic information" [6], thus empowering them to be active participants in the contemporary digital world.

Technologies used to improve accessibility also improve Search Engine Optimization. The inclusion of vulnerable segments of the population demonstrates good ethics and values, which builds the corporate brand of an organization. Some countries, especially those from developed nations, have laws that govern accessibility, thereby ensuring global companies prioritize accessibility. Digital content designers need to be aware of the vast array of differently-abled people so that they create an inclusive design. Digital content designers also need to be aware of assistive technologies, which are special tools used to access web-based content. The following paragraphs provide brief overviews of the different impairments that could limit the ability of people with these disabilities from accessing digital content.

- Visual impairments: These include blindness, low vision, and colour blindness. The WHO estimates that nearly 2.2 billion of the world population have visual impairments, with almost half of this population group having visual impairments that could have been prevented [19]. Screen magnifiers, either through physical magnifiers or software with zoom capabilities can assist people with low vision. However, those with complete blindness require special software, called screen readers, which read digital text aloud to access digital content.
- Auditory impairments: Deaf and hard-of-hearing people have various levels of hearing loss, ranging from mild to severe. The WHO projects that almost 2.5 billion of the world population will have one or other form of auditory impairment by 2050 [20]. To accommodate people with auditory impairments, textual alternatives should be provided for audio-based digital content. Video contents should also have captioning to enable access by people with auditory impairments.
- Physical (mobility) impairments: This involves inability to move one or other part(s) of the body due to loss of limb, paralysis, or neurological disorders, leading to weakness or loss of control in limbs. Some of the challenges that are experienced by people with physical impairments include inability to use a mouse with the required precision or total inability to use the limb with the consequence that a head pointer is the only means of interacting with computer systems [21].
- Cognitive impairment: This refers to a range of conditions that affect an individual's ability to think, remember or recall information. Cognitive impairment could occur due to birth defects, the consequence of injuries or the effect of ageing. Cognitive impairments also include mental illnesses like depression and schizophrenia. It also covers people with learning disabilities, like dyslexia and attention deficit hyperactivity disorder (ADHD). Cognitively-impaired individuals have difficulty in understanding content, remembering how to complete tasks, and are easily confused with inconsistent web page layouts [3].

2.2 The Importance of Accessibility on Educational Digital Platforms

Education features prominently in the 2030 Agenda for Sustainable Development. The Sustainable Development Goal 4 (SDG4) aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all [22]. One of the measures of SDG4 is equity, which is the explicit statement to "eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous people and children in vulnerable situations" by the year 2030 [22:17].

In an educational environment, accessibility requires all stakeholders to have equitable access to the entire learning experience. This means that the content and teaching process must be attuned to students' needs and disabilities. Although people with disabilities have the same educational needs as other learners, they face more difficulties to graduate from educational institutions and therefore find it more challenging to find employment [23].

The accessibility of educational content can be achieved through the adoption of accessibility standards. The Web Accessibility Initiative (WAI) of the World Wide Web Consortium (W3C) is an internationally-recognized standards development body that develops guidelines to enable the accessibility of web-based content. One of the most widely adopted web accessibility guidelines is the Web Content Accessibility Guideline (WCAG). The current version of the guideline, WCAG 2.1, is based on four attributes (perceivable, operable, understandable, and robust). These attributes provide the necessary foundations for the accessibility of digital content [24].

3 Method

This paper presents our perspectives on the strengths and limitations of Blackboard Ally to support the accessibility of course content by students on our course. The main research question that we answer in the paper is "*What are the strengths and limitations of Blackboard Ally in facilitating accessible course contents by students?*" To answer the research question, we "analyzed" the alternative accessible versions of course content that are provided to students through Blackboard Ally and the extent to which the tool provides actionable guidance to instructors on how to improve the accessibility of their course contents (see Sect. 1). Analyzing the extent to which Blackboard Ally can automate the compliance of our course contents with WCAG 2.1 would require the use of alternative web accessibility testing tool(s) and comparing the results with that of Blackboard Ally. This is an extensive process and is therefore outside the scope of this paper. We discuss our perspectives on the strengths and limitations of Blackboard Ally for the two other stated approaches to the facilitation of accessibility of digital content in Sect. 4.

4 Perspectives on the Strengths and Limitations of Blackboard Ally

4.1 Provision of Alternative Accessible Versions of Course Contents to Students

Blackboard Ally has a built-in file transformer that converts course content to different formats, such as HTML or ePub (see Fig. 1(a)), to personalize the learning experience for students. The alternative formats are available in the same location as the original file content. A student can access the different alternative formats available for a course content by selecting the "Alternative formats" icon (see Fig. 1(b)).

The contemporary learning environment requires differently-abled students to complete the same tasks as other students. Supporting alternative formats make it possible for students to navigate and access course content in their preferred format. For example, a student with visual impairment can take advantage of audio and Electronic Braille alternatives to text-based content. Alternative formats of course content is not only beneficial for students with disabilities. Those with no apparent disability also benefit. The following paragraphs provide discussions of the different alternative formats that are supported by Blackboard Ally and the key benefits of each alternative file format.

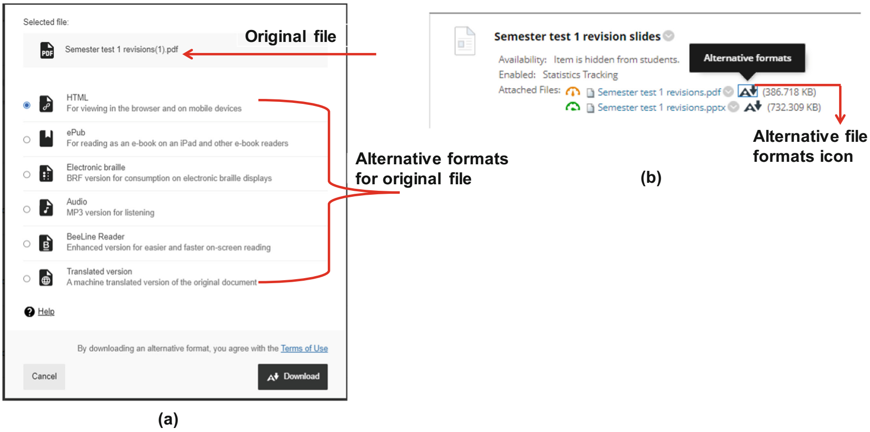


Fig. 1. (a) Alternative file formats; (b) alternative file formats icon

- Tagged PDF: The Tagged PDF file format allows Microsoft Word, PowerPoint and OpenOffice/LibreOffice files to be opened without having the corresponding software installed on a device. A tag can be described as an invisible label that provides valuable information about the structure and layout of a document. The main benefit of tagging PDF documents is that it allows screen readers to identify the different components of a document (for example, the headings, sections, paragraphs, and tables) and read the document to a visually impaired user in the correct order [25].
- Audio: This alternative converts the text component of course content into an MP3 file so that it can be read out to a student [26]. This allows students with visual challenges to access course content that may otherwise not be accessible to them. Blackboard Ally can detect the language in which the text-based course content is written and converts the texts to an audio file in a language that matches the original file. Blackboard Ally currently supports more than 20 languages, including Arabic, Chinese, English, and French [26].
- HTML: A hypertext markup language (HTML) alternative supports mobile platform-friendly adaptation for easier reading on a browser. HTML uses tags, paragraphs, and headings to add meaning to a page. HTML is used in web browsers and can adjust to suit the device that is being used to view or read the course content. HTML alternative format is appropriate when the structure of course content is complex. It also makes it easier for students to change the font size and background colour of course content [26].
- Electronic Braille: Another alternative file format that is specifically aimed at visually impaired students is Electronic Braille [26]. This is achieved by creating a Braille Ready Format (BRF) that a visually impaired student can read on a Refreshable Braille Display (RBD) or other Braille enabled devices. Electronic Braille is beneficial for visually impaired students that are familiar with braille, who prefer to read, and who want to read and listen to the course content at the same time [26].

- ePub: This alternative enables annotation and easy reading of e-books on tablets and other mobile book readers. ePub is beneficial in that it allows a student to make notes, highlight content, and adjust text [26].
- BeeLine Reader: The BeeLine Reader alternative facilitates a quick and more directed onscreen reading. This alternative is suitable for students with learning disabilities, such as dyslexia and ADHD. In addition, students with low vision can also use this alternative format [26].
- Translated Version: This alternative format provides a machine-translated version of the primary course content in 50 different languages. It supports PDF, Word, PowerPoint and HTML documents. Translated Version alternative format is suitable for students where the course content is not in their home language [26].

Despite the various benefits highlighted in the preceding paragraphs, the alternative formats for course content that are supported by Blackboard Ally also have some limitations. The audio alternative file format is limited in terms of the length of characters from the original course content that can be converted to an MP3 file. For example, course content that contains more than 100 000 characters cannot be translated into audio alternatives [26]. This limitation may frustrate learners who depend on audio alternatives but are unable to download this alternative format for large course content.

Although Blackboard Ally supports a large number of languages for the audio and Translated Version alternatives, the accuracy of the translation is dependent on the type of language used in the original document and the technicality of the content [26]. For example, if a large portion of course content uses technical language or has complex sentence composition, translation can create a disparity between the meaning of the original content and the translated versions.

4.2 Guiding Instructors to Improve the Accessibility of Course Content

The guidance provided to instructors on how to improve the accessibility of course content is intricately linked to the accessibility score that Blackboard Ally assigns to a course content. Blackboard Ally automatically checks the extent to which course content is compliant with accessibility guidelines. The tool utilizes a visual colour-coded gauge to represent accessibility compliance. The meaning assigned to a gauge score ranges from low to perfect, where low scores indicate severe accessibility issues. Figure 2 illustrates the meaning of each colour-coded gauge used in Blackboard Ally.

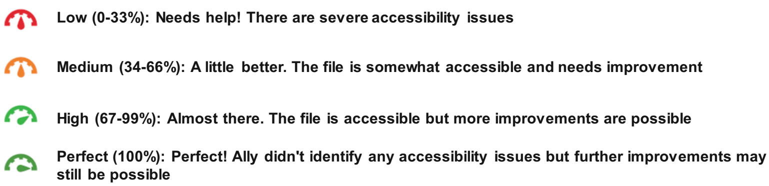


Fig. 2. Interpretation of Blackboard Ally color-coded gauge (adapted from [27])

As illustrated in Fig. 3(a), Blackboard Ally places the accessibility score gauge on the left-hand side of course content that are uploaded unto ClickUP. To improve the accessibility score of course content, the instructor is required to click the accessibility gauge to open a corresponding page that lists the accessibility issues identified by Blackboard Ally. Due to page number restrictions, we have limited our discussions on the strengths and limitations of Blackboard Ally in the provision of guidance on how to improve the accessibility of course content to only one course content, namely the “Semester test 1 revisions” course content. It should be noted that our experience as reported in this paper is the same across all the modules that we teach.

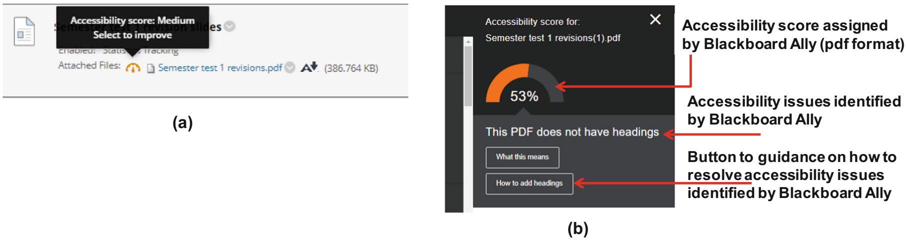


Fig. 3. (a) Placement of accessibility gauge on LMS; (b) accessibility score and issues identified for the PDF format of the “Semester test 1 revisions” course content

As illustrated in Fig. 3(b), the accessibility score of the course content, a PDF version of the course content, is 53%. The only accessibility issue identified in the course content was that the document did not have headings. Document headings are important, especially for the screen readers used by students with visual impairments to navigate through the course content. Based on the accessibility score and the corresponding textual narratives of the score for the course content shown in Fig. 3(a) and Fig. 3(b), students with visual impairments who rely on screen readers will not be able to use the course content.

As educators who wanted to improve the accessibility of course content for our students we attempted to follow the guidelines provided by Blackboard Ally on how to “set headings” in the original PowerPoint format of the course content. Although Blackboard Ally provides guidelines that could help us to accomplish our goal, following the lengthy instructions provided by Blackboard Ally did not resolve the “absent document headings” accessibility issues that was identified. Hence, we decided to upload the original PowerPoint format of the course content as suggested by Blackboard Ally. The accessibility gauges for the two formats of the course content is shown in Fig. 4(a). As illustrated in Fig. 4(b), the accessibility score of the PowerPoint format of the course content was 100%. This meant that Blackboard Ally did not detect any “absent document headings” that were identified in the PDF version of the same course content.

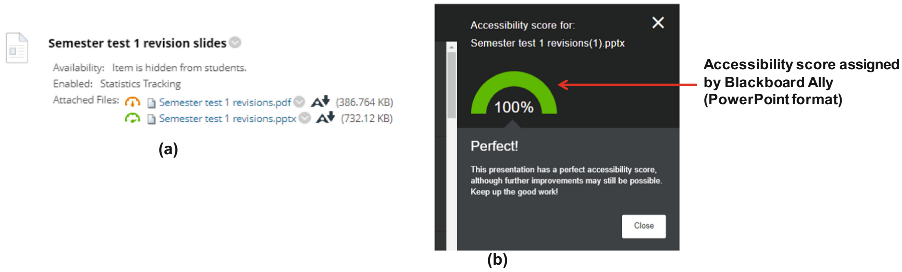


Fig. 4. (a) Accessibility gauges for two formats of the same course content; (b) accessibility score of the PowerPoint format of the "Semester test 1 revisions" course content

Despite the potential shortcomings of Blackboard Ally in providing actionable guidance to us on how to improve the accessibility of the course content, we found the accessibility score gauges to be beneficial in that they provide a visually compelling, call-to-action when a course content receives a low or medium accessibility score, while motivating and inspiring us when content receives a high or perfect accessibility score. We also found the guidance on how to add descriptive texts, called alternative text (alt-text), to the images or figures that often form part of course content useful. Unlike the guidelines on how to "set headings" for PowerPoint files, the steps required to add alt-text to images was straightforward, and following the steps yielded the desired result.

5 Conclusion

This paper reports on the authors' perspectives on two aspects of Blackboard Ally accessibility tool, an important addition to the range of features that have been integrated into the LMS. Based on our experience in the use of Blackboard Ally in our course, the main strengths of the accessibility tool are evident in the wide range of alternative formats that it provides for course content. These alternative formats can improve the quality of the learning experience for students with different disabilities. Students that do not have any apparent disability can also benefit from the alternative formats, which could be more aligned to their preferred way of learning, to access course content. To some extent, we also found the guidance provided to instructors on how to improve the accessibility of course contents to be beneficial. For example, guidelines on how to add descriptive texts to images were straightforward and effective in achieving this specific goal.

Based on our experience of use, there are apparent discrepancies in the accessibility scores assigned to different formats of the same course content. We found that Blackboard Ally is somewhat limited in its ability to detect missing document headings in course content. As discussed in Sect. 4.2, although the PDF format of the course content was flagged as not having document headings, this was not the case for the original version of the course content that was created using Microsoft PowerPoint. This limitation could be because Blackboard Ally based its guidance on the 2016 version of Microsoft Office Suite while the course content was created using the 2019 Microsoft PowerPoint. From the perspective of the alternative formats that are provided for course content, the limit on the size of characters that can be converted into audio format is a drawback of the accessibility tool. In addition, Blackboard Ally has limitations in its ability to accurately translate highly technical course content to different languages.

Overall, the integration of Ally into the Blackboard LMS contributes immensely to the goal of inclusive education in the contemporary digital world. The accessibility tool also contributes to the provision of a personalized learning environment for students.

This perspective paper has implications for HEIs in general and the designers of Blackboard Ally, and other developers of LMSs, in particular. Given the high number of people living with disabilities across the globe, it is inevitable that the population of students enrolled in HEIs who have special needs will continue to increase. It is therefore imperative that accessibility tools that are integrated into LMSs empower educators to create course content that can support the special needs of students.

References

1. WHO: Disability and Health (2021). https://www.who.int/news-room/fact-sheets/detail/disability-and-health. Accessed 31 Mar 2022
2. Laabidi, M., Jemni, M., Ayed, L.J.B., Brahim, H.B., Jemaa, A.B.: Learning technologies for people with disabilities. J. King Saud Univ.-Comput. Inf. Sci. **26**(1), 29–45 (2014). https://doi.org/10.1016/j.jksuci.2013.10.005
3. Friedman, M.G., Bryen, D.N.: Web accessibility design recommendations for people with cognitive disabilities. Technol. Disabil. **19**(4), 205–212 (2007). https://doi.org/10.3233/TAD-2007-19406
4. UNESCO: Opening New Avenues for Empowerment ICTs to Access Information and Knowledge for Persons with Disabilities (2013). https://unesdoc.unesco.org/ark:/48223/pf0000219767. Accessed 31 Mar 2022
5. Kulkarni, M.: Digital accessibility: challenges and opportunities. IIMB Manag. Rev. **31**(1), 91–98 (2019). https://doi.org/10.1016/j.iimb.2018.05.009
6. Henry, S.L.: Understanding Web Accessibility. Web Accessibility: Web Standards and Regulatory Compliance. Apress, New York (2006)
7. Inal, Y., Guribye, F., Rajanen, D., Rajanen, M., Rost, M.: Perspectives and practices of digital accessibility: a survey of user experience professionals in Nordic countries. In: Proceedings of the 11th Nordic Conference on Human-Computer Interaction: Shaping Experiences, Shaping Society, pp. 1–11 (2020)
8. Moreno, L., Martínez, P., Ruiz-Mezcua, B.: A bridge to web accessibility from the usability heuristics. In: Holzinger, A., Miesenberger, K. (eds.) USAB 2009. LNCS, vol. 5889, pp. 290–300. Springer, Heidelberg (2009). https://doi.org/10.1007/978-3-642-10308-7_20
9. Bong, W.K., Chen, W.: Increasing faculty's competence in digital accessibility for inclusive education: a systematic literature review. Int. J. Inclusive Educ. 1–17 (2021). https://doi.org/10.1080/13603116.2021.1937344
10. Adebesin, F., Mennega, N., Botha, A.: Leveraging the use of pre-recorded demonstration videos to support teaching and learning during Covid-19 lockdown. In: Proceedings of the 2021 AIS SIGED International Conference on Information Systems Education and Research (2021)
11. Tonsmann, G.: A study of the effectiveness of blackboard collaborate for conducting synchronous courses at multiple locations. InSight: J. Scholarly Teach. **9**, 54–63 (2014)
12. Moriña, A.: Inclusive education in higher education: challenges and opportunities. Eur. J. Spec. Needs Educ. **32**(1), 3–17 (2017). https://doi.org/10.1080/08856257.2016.1254964
13. Haug, P.: Understanding inclusive education: ideals and reality. Scand. J. Disabil. Res. **19**(3), 206–217 (2017). https://doi.org/10.1080/15017419.2016.1224778

14. Hill, P.: State of Higher Ed LMS Market for US and Canada: Year-End 2021 Edition (2022). https://philonedtech.com/state-of-higher-ed-lms-market-for-us-and-canada-year-end-2021-edition/. Accessed 19 Apr 2022
15. Matthijs, N.: Blackboard Ally: Our Journey of Improving Digital Course Content Accessibility (2018). https://blog.blackboard.com/blackboard-ally-our-journey-of-improving-digital-course-content-accessibility/. Accessed 19 Apr 2022
16. Blackboard: Ally for Learning Management Systems (LMS) (2021). https://help.blackboard.com/Ally/Ally_for_LMS. Accessed 19 Apr 2022
17. Department for Education Innovation: Department for Education Innovation Annual Report (2007). https://tinyurl.com/3r7berda. Accessed 19 Apr 2022
18. Department for Education Innovation: Teach & Learn the UP Way (2020). https://tinyurl.com/4kkuf89b. Accessed 19 Apr 2022
19. WHO: Blindness and Vision Impairment (2021). https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment. Accessed 10 May 2022
20. WHO: Deafness and Hearing Loss (2021). https://www.who.int/news-room/fact-sheets/detail/deafness-and-hearing-loss#:~:text=Hearing%20loss%20and%20deafness,moderate%2C%20severe%2C%20or%20profound. Accessed 10 May 2022
21. MDN: What is Accessibility? (2022). https://developer.mozilla.org/en-US/docs/Learn/Accessibility/What_is_accessibility. Accessed 14 Apr 2022
22. United Nations: Transforming our world: the 2030 Agenda for Sustainable Development (2015). https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E. Accessed 21 Apr 2022
23. WHO and World Bank: World Report on Disability 2011 (2011). chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/ https://www.refworld.org/pdfid/50854a322.pdf. Accessed 20 Apr 2022
24. W3C: Web Content Accessibility Guidelines (WCAG) 2.1 (2018). https://www.w3.org/TR/WCAG21/
25. Adobe: PDF Accessibility Overview (2022). https://www.adobe.com/accessibility/pdf/pdf-accessibility-overview.html. Accessed 11 May 2022
26. Blackboard: Alternative Formats (2021). https://help.blackboard.com/Ally/Ally_for_LMS/Student/Alternative_Formats. Accessed 11 May 2022
27. Blackboard: Accessibility Scores (2021). https://help.blackboard.com/Ally/Ally_for_LMS/Instructor/Accessibility_Scores. Accessed 19 Apr 2011

The Effectiveness of Project-Based Learning in Learning

Chih-Huang Lin(✉) and Forrence Hsinhung Chen

Feng Chia University, Taichung City 407, Taiwan
linchihh@fcu.edu.tw

Abstract. Advanced business management courses in higher education mostly aim to develop integrated and high-level competency. Innovative teaching methods are developed to reduce the gap between knowledge and practice in recent years. Project-Based Learning (PBL) can reduce education-job mismatch and more suitable for transferring learned knowledge to real world practice. This study adopted quasi-experiment and introduced PBL in university business courses. Results from both quantitative and qualitative data indicated: 1) Practical training in PBL provided an opportunity to develop soft skills needed in the workplace. 2) PBL can reduce education-job mismatch and improve alignment with the needs of the workplace. 3) students learned more about their own strengths and developed self-confidence in PBL coursed. Limitations and suggestions for future researches are also discussed.

Keywords: Project-Based Learning (PBL) · Quasi experiment · Innovative teaching methods

1 Introduction

Advanced business management courses mostly aim to develop integrated and high-level competency. However, the traditional learning method may not be able to ensure that students acquire knowledge and skills which are directly transferable to workplace settings [4]. Instead, project-based learning (PBL) is a more appropriate tool to reduce education-job mismatch. Studies note that while the traditional method may be suitable for acquiring structural knowledge, PBL is ideal for gaining procedural knowledge. PBL develops students' ability to apply their knowledge and skills holistically via classroom/field projects. Thomas, Mergendoller and Michaelson (1999) [22] indicated that PBL encompasses a set of complex tasks that are suitably challenging depending on the levels of students. Through activities such as investigation and research, process design, problem-solving, and planning and decision making, students can learn autonomously while completing the project. Thus, PBL is a method that centers around students, and requires a combination of theory and practice; this can help address the issue of transferability of the knowledge taught in advanced business management classes [1].

Currently, under the 2019 Curriculum Guidelines issued by Taiwan's Ministry of Education, the focus is on cultivating students' abilities which are useful to them or are

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 296–305, 2022.
https://doi.org/10.1007/978-3-031-15273-3_33

core competencies in the workplace (core competency). That is, students are expected to adapt to life and face the challenges in a dynamic environment. In line with this goal, while teaching students in a higher education institution, this study aimed to develop students' core competencies required by future workplace settings by re-designing instruction accordingly. We also considered some of the issues encountered by us in own previous class experiences, and the nature and objectives of the course. To parse the effect of PBL over traditional learning methodologies, this study leveraged this teaching opportunity as a quasi-experiment as we taught a one-semester course to two classes for two consecutive years. The major difference in the two classes lied only in the final report: one class had to submit a business proposal as a project instead of the typical course requirement. Importantly, the course design was adjusted to accommodate the following objectives.

1. While teaching structured textbook content in the classroom, PBL should be introduced as supplementary activities for enhancing students' procedural knowledge in settings where the knowledge can be applied and verified.
2. Through these PBL activities, the project should allow students to consolidate knowledge from multiple disciplines vertically and align them to future workplace needs, thereby reducing education-job mismatch and improving the transferability of knowledge.
3. During the course, students' performance in acquiring the advanced level of leadership knowledge and skills should be assessed through the triangulation technique using multiple methods and data sources, including relevant self-assessment and other assessment scales, observations by teachers, teaching assistants, and outside experts, and students' own evaluations and peer evaluations.

2 Literature Review

2.1 Types and Levels of Knowledge

The educational community has mainly adopted Bloom's proposal that cognitive learning focuses on reasoning, knowledge, and problem-solving skills. Bloom's taxonomy of cognitive learning has six levels: knowledge, comprehension, application, analysis, synthesis, and evaluation [15]. Importantly, for any given teaching objective, teachers should ensure that their teaching activities and evaluation methods are aligned with the objective. That is, different teaching models should correspond to different learning levels of students [13]. In current management education, practical knowledge in a broad sense includes knowledge, information, solutions, and abilities, where abilities refer to the capabilities to use knowledge and information creatively, and to learn or create knowledge and skills from doing [6]. The latter corresponds to the concept referred to in metacognitive knowledge. However, in a narrow sense, knowledge can be divided into structural and procedural knowledge. The latter demonstrates itself in the process of achieving specific goals, encompassing the understanding of required knowledge and skills for relevant actions to be performed, and the aspects of analysis and diagnosis at the mental level.

Knowledge at the traditional academic level is mostly structural. To upgrade it into procedural knowledge may require deliberate design for the classroom. Seetoo (2015) [8] indicated that one may learn procedural knowledge through standardized documents and close observation of experienced people; however, given the complexity of real-world and workplace conditions, to develop procedural knowledge that can be applied in practice, one must operate in the field in real-world settings and accumulate it through trial and error, reflection, and attempts at solving problems from multiple dimensions. For example, cracking the secrets behind outstanding works of artists or designers may not be possible through the standardization of knowledge or personal observation. This is also true for mastering leadership that is equally artistic. Rather, learners need to conceive how to simulate real situations for accumulating procedural knowledge in the learning process. For classroom settings, PBL may be an appropriate tool for simulating these situations.

2.2 Project-Based Learning, PBL

The theoretical background of PBL can be justified in terms of John Dewey's pragmatism, cognitive constructivism and situated learning [6]. Dewey highlighted the importance of "learning by doing". For school education, this means that what students learn should be highly relevant to their lives. Otherwise, education may not be as useful. Specifically, students need to participate in real-world circumstances to gain personal experiences, thereby enhancing the connection between their learning and life experiences, and assigning personal significance to the learning. In this sense, course materials are tools to help students solve problems. Teaching in general involves planning and designing environments and conditions for problems, combined with common experiences of teachers and students, so that students can obtain solutions and conceive strategies for the problems.

Previous studies note that PBL is a goal-oriented and student-centered learning model that requires teamwork [16, 20]. Under their teachers' guidance, students can integrate the professional knowledge and skills they have gained in learning settings that motivate learning and self-exploration. Therefore, PBL is more suitable for advanced courses. The PBL instructional design, in principle, needs to address the following six processes, which need not necessarily follow the same order as presented below. Nevertheless, they need to be repeated until specific learning objectives are achieved: (1) defining course objectives and developing related concepts, (2) developing introductory questions, (3) developing foundational knowledge and skills during the process, (4) developing research and investigation activities, (5) time management, and (6) developing appropriate and diverse assessment models [14].

PBL is a learning model built on different learning activities with careful planning as its core feature [20]. It is dynamic, autonomous, and purposeful. Learners can gain more expertise outside of the classroom, and teaching is more flexible with diverse assessment methods [13]. In short, it is an effective learning and teaching strategy. Studies have shown that PBL is beneficial to students' learning performance, including improved skills in motivation, problem-solving, and thinking [18, 19]; teamwork [23], information gathering [1], and application skills; and social interaction [11, 13].

3 Method

3.1 Research Design: Action Research

This study was constructed as an action research by linking action and research together [3]. Specifically, the researchers (here, the authors who serve as teachers) conduct research for problems raised in the specific and actual research setting (here, classroom in real teaching settings) [5]. Next, the directions, methods, and strategies for dealing with the problems are selected and implemented. Then, through evaluation, assessment, feedback, and correction, actions will be taken again to fix the problems. Therefore, action research is an ideal tool for capturing complex teaching phenomena and exploring concepts that can only be vaguely defined at the moment [7, 9].

Here, the research data were collected through secondary data collection, interviews, participant observation, and the authors' own research and action. By accumulating data across different levels, perspectives, and time points, our aim was to achieve theoretical saturation via repeated validation and cross-checking from multiple perspectives [7].

3.2 Procedure: Quasi-Experiment

The authors taught the same course to two different classes in the same semester in two academic years (2020 and 2021). Hence, we were able to implement a quasi-experimental research design simultaneously for two consecutive years to identify the outcomes of PBL. The only difference was that one class used a traditional learning method (selecting a company on their own, running diagnosis, and finally, proposing management suggestions). The other class used a project relevant to an actual company (a lecture at the beginning of the semester, then identifying a problem to be solved in the actual company, seeking instructions from the authors and a company expert during the semester, and finally, producing a solution report with an actual business proposal at the end of the semester).

3.3 Data Collection

Both quantitative and qualitative data were collected in this research. The quantitative data reflected objective evaluations conducted by the university at the end of the semester on teaching performance to show the effectiveness of PBL (The teaching satisfaction survey). For the qualitative data, longitudinal data were collected and processed for process analysis, and different data collection stages and sources were set for the classroom. The data were compiled and analyzed based on the designed method depending on classroom circumstances. Then, the focus was revised and reviewed continuously to inform data collection in the next stage until theoretical saturation was reached.

For example, after interviewing the students randomly, the teaching assistants would assign a code to each student and compile verbatim records. Then, they discussed the appropriateness and accuracy of interview questions with the researchers to decide how the next round of interviews would be carried out. The authors could also obtain observations as an independent third party by talking with the teaching assistants [9].

In sum, the qualitative data comprised four textual feedbacks per semester from students on the online course (once every four weeks), one-on-one interviews between the teachers and teaching assistants during and at the end of the semester, and supplemented by the teachers' own diary for instruction and feedback from teaching assistants. We cross-checked the multiple data to obtain more comprehensive evidence. The relevant interview questions were designed based on the teaching content of the week. For example, after a case study, students were required to answer the following questions: "In your opinion, whether this instructional model is helpful to your learning? How helpful is it? Can you give a few specific examples?" Or, after a group activity and discussion, the questions could be: "Do you know what the purposes of today's activity arranged by the teachers are? Can you explain exactly how to apply the knowledge?".

4 Result

4.1 Quantitative Analysis: The Teaching Satisfaction Survey

The quantitative is from the result of the teaching satisfaction survey conducted by the university at the end of every semester. The objective of quantitative analysis is the same course offered by the authors in two consecutive academic years, covering the classes, the number of students who took the course, and the number of respondents, as well as the final evaluation scores of each course in both years. The scores were obtained with a Likert Scale, five-point agreement scale offering options from strongly disagree to strongly agree for each statement. Classes A and C prepared their final reports in the traditional way, while Classes B and D proceeded with their final reports with the PBL method. For the 2020 (2021) academic year, the traditional and PBL methods received 4.08 and 4.50 (4.17 and 4.56), respectively.

The mean scores of the two academic years were further analyzed to determine if the teaching evaluation scores significantly differed. First, for both years, the mean of the teaching evaluation scores were 4.13 (SD = 064) and 4.53 (SD = 0.03) for the traditional and PBL methods, respectively, and differed significantly (Table 1).

Table 1. Summary of teaching satisfaction survey

Year	2020		2021	
Class	A (Traditional)	B (PBL)	C (Traditional)	D (PBL)
Number of all students	60	49	74	48
Number of respondents	52	44	45	34
Ave. score	4.08	4.50	4.17	4.56

Second, Table 2 presents the results for three items that are more relevant to students' learning performance in the teaching satisfaction survey: "The teachers' teaching methods are flexible, which helps improve learning performance"; "The teachers give feedback to students on the results of assignments and papers to help them learn"; and

"In general, I have gained a lot from the course". The table also shows the evaluation scores and standard deviation for each course in each academic year. The overall scores of the three items for 2020 (traditional, mean = 3.98, $SD = 0.05$; PBL, mean = 4.51, $SD = 0.07$, $t = -10.46$) significantly differed; specifically, the PBL method's evaluation score in these three items was significantly higher than that of the traditional method. A similar result was observed for 2021 (traditional, mean = 4.25, $SD = 0.08$; PBL, mean = 4.61, $SD = 0.03$). Thus, in both years, the PBL method's evaluation score was significantly higher than that for the traditional method.

Table 2. Item score and standard deviation relevant to learning effectiveness and performance

Year	2020		2021	
Class	A	B	C	D
1. The teachers' teaching methods are flexible, which helps improve learning performance	4.02 (0.85)	4.46 (0.70)	4.16 (0.80)	4.65 (0.60)
2. The teachers give feedback to students on the results of assignments and papers to help them learn	3.92 (0.86)	4.59 (0.58)	4.29 (0.82)	4.59 (0.56)
3. In general, I have gained a lot from the course (Knowledge, skills, attitudes or value)	4.00 (0.86)	4.48 (0.70)	4.29 (0.73)	4.59 (0.66)
4. Average Score	3.98	4.51	4.25	4.61

4.2 Qualitative Analysis

The qualitative data collected from student feedback, interviews, teaching assistants' recordings, and teachers' instruction diary were summarized as followed. Three points of conclusion from qualitative data were presented in the followings.

First, practical training provided an opportunity to develop soft skills needed in the workplace. Students' feedback revealed that although the traditional method was helpful, PBL course activities had the additional benefit of creating realistic training settings for students to develop the soft skills needed in the workplace. For example:

At the end of the final report, after hearing the comments from the teachers and outside expert, Manager Wu, I came to realize that the way of practical operation is completely different from the way of theoretical operation you learn in school. Although the school report is also very difficult, but the teachers will give you a direction for you to follow while doing research. In the company, the practice is completely different. There will not be a direction and will only have problems, and you need to use all that you have learned or query data to find ways to solve the problems. Sometimes you even need to find out the problems yourself, so it is really different! (Student feedback, Student 2020B01).

The team that won the award was not successful because of the number of team members. Instead, a team's final performance depends on the whole team's cohesiveness and the division of labor. The fact reminds me that a viable company's survival is not determined by the number of people but by whether the people fit the atmosphere of the company, and whether they have the same goal and relevant abilities, suggesting that the HR department plays a very important role (Student feedback, Student 2020B22).

Second, PBL can reduce education-job mismatch and improve alignment with the needs of the workplace. The biggest focus of PBL was on the final report targeting a real company; hence, students had to learn to contact and obtain relevant information from their company contact, and produce the content expected by the company at each design checkpoint.

At the end of the semester, the company expert participated in the classroom, and gave authentic and direct comments and feedback to the students from the company's perspective. Thus, the students actually learned from understanding the company's different perspectives. Furthermore, as the project aimed to address actual problems faced by the company, at different checkpoints, students had to figure out how to implement their ideas. This exercise was very helpful for students to improve their abilities in applying their knowledge (Student feedback, Student 2020B19).

Through the final report, we heard a lot about the recruitment, selection, and training of digital talents. It was more like an exchange of ideas in the whole class. We learned at once how not only LG, Samsung, and HITACHI but also many other companies operate in talent management. In addition, inviting people from the industry to participate in our proposal was also a great help to us. We could find that people from the industry value the cost, benefit, and feasibility of the proposal, and the rest of the BMA is secondary to the industry. In addition, a proposal cannot contain too much advice. Otherwise, it will lead to the proposal being out of focus. It is necessary to strengthen a few and explain them in detail (Student feedback, Student 2020B22).

What I gained most from the final report was that it was the first time I received such professional advice and judgment in a classroom report. The teachers and Manager Wu were very attentive and careful in guiding each group. This allowed us to learn a lot. From a proposal, we could really appreciate what the industry executives' needs are. The experience is an outpost before I enter into the workplace in the future so that I will not do the same mistakes in the future (Student feedback, Student 2021D22).

I learned a lot more beyond just textbook knowledge in the class, and it was also my favorite class this semester. Defying a standard lecture style, the teachers always used a mixture of discussion and lecture to carry out the class. I can still remember the content of the teacher's lecture even now. In addition, sometimes we also had lectures delivered by outside experts, so that the class was not only a class but could be more diversified and livelier, among which I was most impressed by Manager Fan's speech. Manager Fan gave a lot of examples of himself, making me aware of the consequences of making mistakes. Through one correction after another, I could still perform very well in the end. The lectures of outside experts made me aware of the hard work required by every industry. There are actually many efforts and sorrows behind the seemingly glamorous appearance. We also had the opportunity to work together with students from different departments. Although there was some friction in the process of creating the report, fortunately, everyone finished it successfully in the end (Student feedback, Student 2021D38).

Third, students learned more about their own strengths and developed self-confidence. From the students' feedback and interviews, we found that they understood their own abilities and weaknesses better, discovered their own position, and developed self-confidence from the course. These benefits were derived from the fact that PBL activities were designed by teachers for random groups of students, who were required to act, discuss, and present together. Students could gradually find their own strengths through interaction with others. Meanwhile, feedback from outside experts, although not all positive, provided substantial affirmation and recognition of students' performance, which boosted their self-confidence.

If I had not come to this class, I would not have known that I am good at analysis but unable to propose concrete solutions. I may be suited as a consultant for people, but asking myself to plan a training course and actually suggest practical advice is something that I would try hard but in vain. It is challenging for me (Student interview, Student 2020B03).

I went from being a person who did not know SWOT, competitors, five forces analysis, etc., to learning various analyses from group members and other people's reports and then understanding how to write a business report and what the company wants from the comments of the teachers and Manager Wu. I felt that this group report made me grow fast (Student interview, Student 2021D16).

After a semester of HR course, I learned the most besides the classes in my own department from the many homework assignments that needed to be discussed to the reports that were done, and I recognized many new proper nouns. Perhaps it was because each college had a very different way of conducting classes. I thought HR management was the most difficult class I have ever taken. I was scared to discuss with the group members I did not know well and to do things with the younger students, but I was happy to help each other during the discussion of the report, to give my opinions, and to communicate without people who insisted on their own opinions (Student interview, Student 2021D29).

5 Conclusion and Discussion

This research shows that the application of the PBL approach to curriculum design can indeed enhance students' soft skills required in the workplace, reduce education-job mismatch, and enable students to better understand their strengths and bolster their self-confidence. Quantitative data from learning satisfaction survey reveals significant differences in the mean scores for an academic year and in the performance on different items between students who learned under the PBL versus traditional teaching methods. Therefore, this study provides valuable insights to instructors for designing their courses. Note that for the course offered to the two classes simultaneously, we controlled for the teaching materials, schedule, and design elements to ensure that they were identical as much as possible. Only the design of the final report varied. Therefore, the results of this study should be applicable to future studies, and helpful for teaching institutions and instructors in planning and designing their courses.

However, although the data obtained here can verify the effectiveness of PBL in teaching and learning, by design, it aimed to compare the two classes that adopted different final reports with specific teaching elements. While the number of students is comparable and the teachers are the same, the motivation and subjective assessments may differ because the students are different as this research is limited to quasi-experiment. Therefore, the follow-up studies in the future may consider comparing different teaching methods adopted separately at the beginning and end of a semester, or comparing the teaching methods applied to the same students in different semesters. The study design may provide better evidence.

References

1. Breivik, P.S., Senn, J.A.: Information Literacy: Educating Children for the 21st Century: ERIC (1994)
2. Barrows, H.S., Tamblyn, R.B.: Problem-Based Learning: An Approach to Medical Education. Springer, New York (1980)
3. Borg, W.R., Gall, M.: Educational Research an Introduction, 3rd edn. Longman Publishing Group, New York (1979)
4. Chen, F.H.H.: A synergy analysis of the design of the theory-practice-social implementation curriculum. Bull. Res. Elementary Educ. **43**, 29–61 (2021)
5. Denzin, N.K., Lincoln, Y.S.: Introduction: the discipline and practice of qualitative research (2008)
6. Dewey, J.: Democracy and Education: An Introduction to the Philosophy of Education. The McMillan Company, New York (1922). http://www.books.google.com
7. Clark, J.S., Porath, S., Thiele, J., Jobe, M.: Action Research. New Prairie Press (2020)
8. Seetoo, D.H.: D.H. Seetoo's Case Teaching. CWGV Publishing, Taipei (2015)
9. Eisenhardt, K.M.: Building theories from case study research. Acad. Manag. Rev. **14**, 532–550 (1989)
10. Glaser, B., Strauss, A.: Grounded Theory: The Discovery of Grounded Theory. Aldine Publishing Company, Chicago (1967)
11. Horan, C., Lavaroni, C., Beldon, P.: Observation for the tinker tech program students for critical thinking and social participation behaviors. Buck Institute for Education, Novato (1996)
12. Hsiao, H.C.: The improvement of creativity and productivity of technical workers through partnership between university and industry. In: The International Conference on Creativity Development in Technical Education and Teaching, Taipei, Taiwan (1997)
13. Huang, G.Q., Shen, B., Mak, K.L.: Participatory and collaborative learning with TELD courseware engine. J. Prof. Issues Eng. Educ. Pract. **128**(1), 36–43 (2002)
14. Krajcik, J.S., Czerniak, C., Berger, C.: Teaching Children Science: A Project-Based Approach. McGraw-Hill College, Boston (1999)
15. Krathwohl, D.R.: A revision of Bloom's taxonomy: an overview. Theory Pract. **41**(4), 212–219 (2002)
16. Loto, K.: Learn to learn: training on new technology. J. Object-Oriented Program. **10**(1), 24–27 (1997)
17. Moursund, D.: Project-Based Learning Using Information Technology. ISTE Publication, Oregon (1999)
18. Ormell, C.P.: Blooms taxonomy and objectives of education. Educ. Res. **17**, 3–18 (1974)
19. Perkins, D.: Smart Schools: Better Thinking and Learning for Every Child. Free Press, New York (1992)
20. Polman, J., Fishman, B.: Electronic communication tools in the classroom: student and environment characteristics as predictors of adoption. Paper Presented at the Annual Meeting of the American Educational Research Association, San Francisco, CA (1995)

21. Thomas, J.W.: A Review of Research on Project-Based Learning. Autodesk, San Rafael (2000)
22. Thomas, J.W., Mergendoller, J.R., Michaelson, A.: Project-Based Learning. The Buck Institute for Education, Novato (1999)
23. Wiburg, K., Carter, B.: Thinking with computers, Part II. Computing. Teacher **22**(2), 6–9 (1994)

Enhancing Students' Higher Order Thinking Skills with Problem-Based Learning in a Regression Analysis Course

Minh-Trang Vo Nguyen[1] and Jane Lu Hsu[2](✉)

[1] Department of Applied Economics, National Chung Hsing University, Taichung 402202, Taiwan
jennietrangvo@smail.nchu.edu.tw
[2] Department of Marketing, National Chung Hsing University, Taichung 402202, Taiwan
jlu@dragon.nchu.edu.tw

Abstract. The concept of Higher-Order Thinking Skills (HOTS) is one of the highlighted aspects in producing human capital of high quality. However, how to enhance students' HOTS is a challenge. Meanwhile, abilities in data analyzing have become an advantage qualification to employers. Therefore, the main focus in this study is to investigate the potential role of using problem-based learning in a regression analysis course to increase students' level of HOTS. Data collected from this study is through an assessment giving to students before (pre) and after (post) them taking the regression analysis course. Results from this study conclude that students' HOTS including looking for data from open sources, using a statistical software, analyzing data, and offering solutions could be enhanced from using problem-based learning. Moreover, there is a statistically difference between pre and post in students' data analysis level, confidence in applying statistics in practice and the meaningfulness of statistics in life.

Keywords: Higher order thinking skill · Problem-based learning · Regression analysis

1 Introduction

Abilities in analyzing, critical thinking and problems-solving have become important and must-have skills for students. In education, those above abilities are referred as higher order thinking skills (HOTS). Meanwhile, in the world where data are integrated with almost everything, from marketing (for example: consumer shopping behavior), financial forecasting to weather forecasting, etc., the ability to understand and interpreting data or data analyzing literacy is essential to youngsters not only in getting advantage in their career but also in making better life decision [1, 2]. In addition, if youngsters are able to interpret data from crucial issues such as pollution or climate change, there is a higher chance that they would try to involve more in the process of how to solve those issues, and eventually to make the world a more sustainable and better place for all [3]. Hence, it is important for educators to continuously looking for a way to improve their

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 306–312, 2022.
https://doi.org/10.1007/978-3-031-15273-3_34

education strategies in improve students' HOTS with data analyzing skills in order to prepare the students to become more rounded and competitive employees as well as to produce more human capital of high quality to the society.

1.1 Higher Order Thinking Skills

Higher order thinking skills (HOTS) is referred to the ability to think in higher level including analyzing and evaluating problems as well as offering critically and logically [4, 5].

1.2 Project-Based Learning

Project based learning (PBL) is a type of inquiry-based learning in which questions and problems from the real world are brought up to students [6]. As PBL provides students opportunities to get engaged with learning through real world challenges, students can take an active role as a problem solver from making judgements and interpretations information. Thus, students will gain deeper knowledge and develop adaptive skills through PBL [7].

2 Research Objective

The objective of this study is evaluating the effect of PBL on students' HOTS in a regression analysis course. The regression analysis course used for analyzing in this study was from Department of Marketing at National Chung Hsing University, and the course was taught in 2021. There were a total 15 undergraduate students taking the course and given the pre and post short assessment survey. After the process of data management, 13 valid samples were used in data analyzing.

3 Research Methodology

This course was designed to introduce students the concepts and techniques of regression analysis, and basic statistical theory, as well as to train students to use basic regression analysis programs to interpret the meaning of the analysis results. Before each class, students were provided with actual cases in the school's online system (called i-Learning) for pre-class reading. Students were also required to conduct self-study in small groups during lectures and report their learning results during class. During the reporting and discussion process, different groups had the opportunity to learn from each other.

This course was divided into three stages to develop students' ability to run regression analysis programs and interpret the implied meaning of the analysis results. The first stage (week 1 to week 8) was teaching of basic statistical theory and analysis operations. In this stage, the was taught basic statistical theory of regression analysis in the classroom, and basic analysis skills. The second stage (week 9 to week 15) was practical learning of analytical skills and how to use SAS analysis software to increase students' ability in reading and interpreting analytic results. The third stage (weeks 16 to 18) provided students real problems from the society, then asked students to search for open data on the Internet and to use SAS, Excel, etc. to perform regression analysis and learns how to identify and solve problems by analyzing data. Among 13 students, 10 were female and 3 were male. Data from the surveys was analyzed by pair sample t-test.

Table 1 explains the topics and software students were introduced and trained in the course and Table 2 covers the criteria that were used assess students' evaluation.

Table 1. Topics and software students have learned in the regression analysis course

Topics covered in class	Software used in class
Case Study	SPSS SAS Excel Python
Introduction to Regression Analysis	
Simple Linear Regression	
Multiple Regression Models	
Principles of Model Building	
Case Study	
Variable Screening Methods	
Some Regression Pitfalls	
Residual Analysis	
Special Topics in Regression	
Introduction to Time Series Modeling and Forecasting	
Case study (EMI session)	

Table 2. Students' self-assessment criteria before and after taking the regression analysis course.

Area	Criteria
Statistical analyzing literacy	Current data analysis level
	Confidence in solving statistical problems
	Confidence in understanding statistical problems
	Confidence in applying statistics in practice
Importance of statistical analytic skills in career developments	Analytical skills in the workplace
	Product development capability
Importance of statistical analytic skills in personal developments	Make life more meaningful

4 Results

Results from students' evaluation survey from before and taking the course indicates that after taking the regression analysis course using PBL, students felt more confident in their data analytical skills including using data from open source, running the software, analyzing data and explaining results. In addition, students show an increasing in believing that the course has polished their qualifications in terms of career developments as well as personal development. Table 3 illustrates details of comparison in mean of students' assessment before (pre) and after (post) taking the regression analysis course which was integrated with PBL in teaching method. From pair sample t-test (Table 3), there was a statistically significant different in students' data analysis level (p value = 0.046), confidence in applying statistics in practice (p value = 0.039) and the meaningfulness of statistics in life (p value = 0.026) between pre and post taking the regression analysis course. Figure 1, 2 and 3 illustrates student's online individual and group report after being introduced the topic and case study.

These results suggest that using PBL in a regression course not only can improve students' analytical skills but also soft skills such as problem solving, creativity, and the ability to look for open-source data. In another word, students' HOTS can be enhanced by using PBL in a statistical course.

Table 3. Results from t-test of students' self-assessment criteria before and after taking the regression analysis

		Pre (Mean)	Post (Mean)	t Stat	p_value
Statistical analyzing literacy	Current data analysis level	5.83	7.00	2.24	0.046*
	Confidence in solving statistical problems	7.33	7.58	0.64	0.536
	Confidence in understanding statistical problems	7.50	7.67	0.39	0.701
	Confidence in applying statistics in practice	6.50	7.50	2.35	0.039*
Importance of statistical analytic skills in career developments	Analytical skills in the workplace	9.08	9.17	0.36	0.723
	Communication skills	7.75	8.08	1.48	0.166
	Product development capability	5.58	6.00	1.45	0.175
Usefulness of statistical analytic skills in personal developments	Make life more meaningful	7.5	8.00	2.57	0.026*

Note: * indicates significance at 5% significant level

Fig. 1. Screenshot of the online oral report of students at the end of the regression analysis.

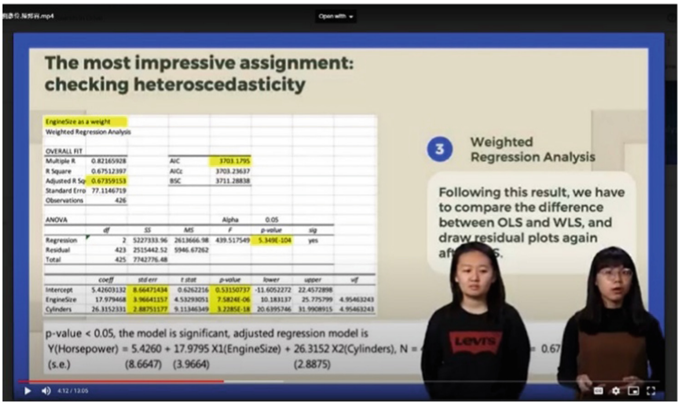


Fig. 2. Screenshot of students presenting group assignment using heterogeneity analysis.

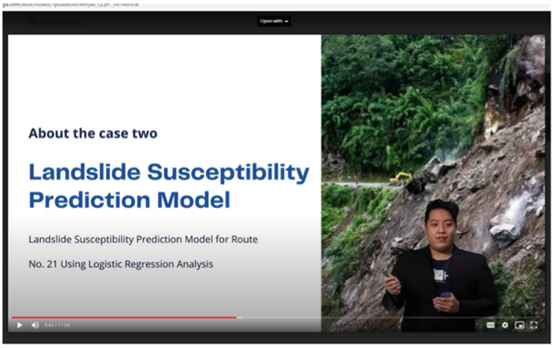


Fig. 3. Screenshot of student presenting analysis of soil and rock flow prediction model. Using logistic regression model

5 Conclusions

Abilities to evaluate and analyze problems critically as well as provide solutions logically and creatively are important to university students. As those skills are included in higher order thinking skills (HOTS), it is important for educators. Results from this study has implied that problem-based learning (PBL) is an effective to enhance students' HOTS. Data literacy courses could consider applying PBL in order to increase students' HOTS including climate change literacy or climate change mitigation. In this study, data was used from regression analysis course. Future research can consider applying PBL into other courses such as languages, mathematics, etc. to evaluate the effectiveness of PBL in education.

Funding Information. This study is supported by Ministry of Education in Taiwan (#PBM1101163).

References

1. Avella, J.T., Kebritchi, M., Nunn, S.G., Kanai, T.: Learning analytics methods, benefits, and challenges in higher education: a systematic literature review. Online Learn. **20**(2), 13–29 (2016)
2. Sin, K., Muthu, L.: Application of big data in education data mining and learning analytics–a literature review. ICTACT J. Soft Comput. **5**(4) (2015)
3. Alismaiel, O.A.: Adaptation of Big Data: an empirical investigation for sustainability of education. Entrepreneurship Sustain. Issues **9**(1), 590 (2021)
4. Anderson, L.W., et al.: A Taxonomy for Learning, Teaching and Assessing: A Revision of Bloom's Taxonomy of Educational Outcomes: Complete edition. Longman, New York (2001)
5. Aisyah, A., Salehuddin, K., Aman, I., Yasin, R.M., Mimiko, N.: Eliciting elements of higher order thinking skills in the higher secondary examination question structure in Japan and Malaysia. In: Mohamad Noor, M.Y., Ahmad, B.E., Ismail, M.R., Hashim, H., Abdullah Baharum, M.A. (eds.) Proceedings of the Regional Conference on Science, Technology and Social Sciences (RCSTSS 2016), pp. 455–464. Springer, Singapore (2019). https://doi.org/10.1007/978-981-13-0203-9_42
6. Al-Balushi, S.M., Al-Aamri, S.S.: The effect of environmental science projects on students' environmental knowledge and science attitudes. Int. Res. Geogr. Environ. Educ. **23**(3), 213–227 (2014)
7. Harun, Y.: Project-Based Learning Handbook Educating the Millennial Learner. Educational Technology Division Ministry of Education, Kuala Lumpur (2006)

Factors Influencing Internet Users' Attitude and Behaviour Toward Digital Piracy: A Systematic Literature Review Article

Nompilo Fakude(✉) and Elmarie Kritzinger

Science, Engineering and Technology College, School of Computing, University of South Africa (UNISA), PO Box 392, Pretoria 0003, South Africa
42315867@mylife.unisa.ac.za, kritze@unisa.ac.za

Abstract. The unauthorized copying and distribution of digital media content via the internet is known as digital piracy, one of the computer ethical issues. The main objective of this study is to answer this research question: "According to the literature, what factors influence the internet users' attitude towards digital piracy?". To address the research question, the researchers used a systematic literature review methodology to investigate several studies published between 2010 and 2020 on digital piracy. Following the PRISMA approach, the researchers found and reviewed 31 papers related to digital piracy topics out of 123 articles. The initial findings were five (5) factor groupings identified as the primary motivation behind digital piracy. The factor groups were further categorized into three (3) super factor groups, namely, 1) accessibility, 2) awareness and education about digital piracy, and 3) social and cultural factors. According to this paper, these are the core factors influencing internet users toward digital piracy. This study adds to the growing literature on digital media piracy by better equipping those affected by digital piracy (educational, government, business organizations, digital media houses, etc.) with strategies and tools to effectively address digital piracy.

Keywords: Digital piracy · Factors · Factor groups · Super factor groups

1 Introduction

The world is now on the verge of the fourth industrial revolution (4IR). Technological innovations related to the 4th IR provide new capabilities and significantly alter how people work, obtain, and exchange digital content [10]. Unfortunately, several established ICT transformation paths have been jeopardized due to internet users abusing how they manage digital content via the internet. This is referred to as digital piracy, which is defined as the unauthorized copying and transmission of digital media, be it movies, games, eBooks, music, or software files, over the internet using various methods [6]. Governments have joined forces with law enforcers, intellectual property (IP), and multimedia content owners to combat the widespread practice with minimal success rates [2].

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 313–323, 2022.
https://doi.org/10.1007/978-3-031-15273-3_35

According to [16], a factor is "one of the elements contributing to a particular result or situation. In this research, factors are defined as motives that drive internet users to commit digital piracy. Therefore, this paper's key objective is to address its research question by evaluating the literature on the factors influencing internet consumers' behavior and attitude toward digital piracy. It is anticipated that the findings will help those affected by piracy address the phenomenon more effectively.

The layout of this paper is set out as follows: Sect. 2 provides a brief literature review covering the digital piracy topic, and Sect. 3 presents the methodology used in this study. Section 4 covers the results and findings of the study. Lastly, Sect. 5 provides a conclusion to the study.

2 The Systematic Literature Review (SLR)

This article investigates the various factors contributing to digital piracy globally by examining and reviewing literature in the existing body of knowledge. Expectantly, the phenomenon of digital piracy can be understood through the lens of multiple factors or motives driving individuals' pirating behaviors. If digital piracy is uncontrolled, its victims will be left incapable financially, negatively impacting the global economies as a result [6]. This article aims to discover what lies at the heart of the digital piracy problem, thereby identifying potential solutions.

3 Methodology

A systematic literature review identifies, evaluates, and interprets available research relevant to research questions, area of study, or rising phenomenon of interest. According to [22], this approach can provide statistical support for studies of the exact nature. Therefore, this study adopted the systematic literature review methodology to examine past research articles from 2010 to 2020. The period choice was to ensure the currency in the selected papers.

3.1 Scoping Keywords

The database search strategy included the keywords displayed in Table 1.

Based on the results per search, in some instances, keywords were refined. Results were filtered by article title, filtered by reading the abstract, looking at keywords, and by reading the entire article to find relevance in the content.

3.2 Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA)

To ensure the accuracy reporting of the paper, the researchers carried out the analysis following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement approach [17]. The articles were searched from the UNISA research database repository, in Google Scholar, Emerald Insight, ScienceDirect, Springer, and ResearchGate. As reflected in Fig. 1, the PRISMA shows the number of records found, how many were included and excluded.

Table 1. Search keywords

Keywords
Modes of sharing: (File sharing OR DRM OR Digital rights manag* OR digital medi* OR File download* OR peer-to-peer OR usenet OR freenet OR File transfer protocol OR shared directory OR Piracy OR pirat* OR online piracy OR copywrit* OR intellectual property)
AND: Relevant media
(software OR video game OR game OR electronic games OR digital game* OR Music OR iTunes OR Album OR sound record* OR record sales OR DVD sales OR music purchas*)
AND: Behavioral terms
(attitude* OR intention OR habit OR Digital Piracy factors OR digital piracy behavior outcomes)
NOT: Noise inducing keywords
(Medical OR medicine OR medieval OR Navy or naval or maritime)

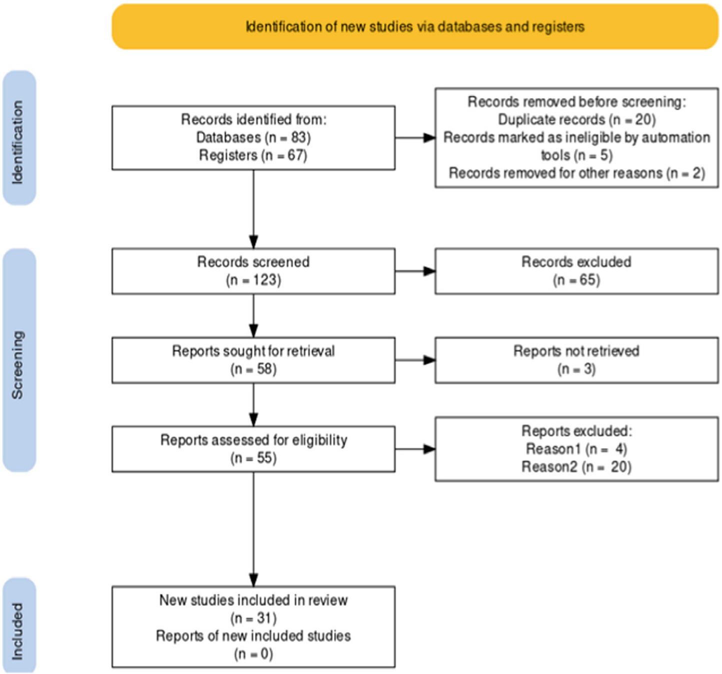


Fig. 1. PRISMA 2020 flow diagram – the flow of information in the systematic review

3.3 Article Categorization

The selected articles were downloaded from the cumulative 31 journals across various disciplines. The researchers analyzed articles to define the dynamics behind the digital piracy problem (Table 2). Furthermore, the authors of the articles reviewed researched digital content, software, movies (videos), and online music piracy. In analysis, the researchers grouped studies on similar topics and, where possible, attempted to highlight commonalities or differences between the study findings.

3.4 Inclusion and Exclusion Criteria

Inclusion Criteria: the publication is in English, and it includes hypothesis testing for the relationship between digital piracy factors or the behaviour itself.

Exclusion Criteria: media files are acquired via a legitimate acquisition channel, and the media files contain illegal material for example, child pornography. Additionally, no novel data is presented, for instance, reviews, opinion pieces, and dual publications.

Table 2. Literature matrix of factors influencing digital piracy

Article	Authors	Factors
1	Meireles and Campos, 2016	Moral obligation, moral factors, and public awareness
2	Cronan and Al-Rafee, 2003	Moral obligation, risk of penalty, and regulation recognition
3	Yoon, 2011(b)	Attitude, morals, justice, relativism, utilitarianism, and deontology
4	Hoang and Ha, 2014	Perceived risk, subjective norms, and technology development
5	Ahmed, 2020	Less moral obligation, ethics, and law respect,
6	Eisend, 2019	Morality and education
7	Karakaya, 2011	Social and cultural factors, high software prices, and the author's remoteness
8	Lowry et al., 2017	Moral disengagement and social learning
9	Yoon, 2011(a)	Justice, utilitarianism, and ethical judgment
10	Wang and McClung, 2012	Norms
11	Cox and Collins, 2014	Awareness of legality and the threat of punishment
12	Sahni and Gupta, 2019	Legal, criminological, psychosocial, cultural, economic, and sociological factors
13	Petrescu, Gironda and Korgaonkar, 2017	Protection of intellectual property rights and the strictness of legal systems

(*continued*)

Table 2. (*continued*)

Article	Authors	Factors
14	Liao et al., 2010	Perceived prosecution risk
15	Vida, Kukar-kinney and Koklič, 2015	Cultural variables
16	Byl and Belle, 2008	Individual attributes and situational Attributes
17	Pham, Dang and Nguyen, 2020	Social and contextual factors
18	Yoon, 2011	Subjective norms, social and cultural factors
19	Morris and Higgins (2010)	Social learning factors
20	Jacobs et al. (2012)	Social environment
21	Park, 2020	Hedonic pleasure, price value
22	Dilmperi et al., 2011	Music preference, music experience, and internet bandwidth
23	Scaria, 2013	Pro-industry and education
24	Wulandari, 2014	Pro-industry and technology and work
25	Bethelhem, 2013	High software prices and affordability
26	Peace, Galletta and Thong, 2003	High cost of software, punishment possibility, and punishment level
27	Yubero, Larrañaga and Villora, 2017	Saving money, negative peer or social influence, and financial costs
28	Nii, Barnor, Afful-dadzie and Patterson., 2020	Economic conditions of the country
29	Stoddart and Sandiford, 2017	Genuine products are too expensive, ability to pay
30	Belle, Macdonald and Wilson, 2007	Access to enabling technology, and awareness of consequences
31	Moon et al., 2010	Opportunity

Table 2 is a Literature Matrix that provides a synopsis of 31 authors covering numerous factors influencing internet users to commit digital piracy. The Literature Matrix aims to bring all the sources into one coherent argument. The researchers' organization in mapping out the literature matrix allows identifying more patterns in the research to make insightful conclusions and communicate the research findings in a polished manner.

4 Findings

4.1 Factors Influencing Digital Piracy

In any problem-solving process, identifying the factors or motives of a problem is the first crucial step towards a working solution. Therefore, the following subsection covers the factors that influence internet users toward digital piracy as identified in Table 2 and categorized into individual factors.

4.2 Basic-Level Categorization or Grouping of Digital Piracy Factors

According to [24], "the basic-level categorization is frequently utilized when labeling objects (e.g., dog, ship)". Categorizing a list of factors based on their qualities and features, as depicted in Table 3, provides the study with a clear and concise hierarchical category structure of the factors influencing digital piracy [25].

Table 3. Grouping of factors that influence digital piracy

Factor groups	No.	Factors
1. Ethics, norms, and morality	1.1	Moral factors
	1.2	Moral obligation, justice, relativism, utilitarianism, deontology
	1.3	Respect for ethics and law
	1.4	Ethics on attitude to commit digital piracy
	1.5	Moral intensity
	1.6	Moral disengagement
2. Lack of Public Awareness and or Education	2.1	Knowledge of intellectual property regulations
	2.2	Digital piracy education or awareness
	2.3	Awareness of consequences
3. Lack of Law Enforcement and Perceived Punishment	3.1	Respect for ethics and law
	3.2	Level of intellectual property rights protection
	3.3	The strictness of legal systems
	3.4	Punishment possibility and level
	3.5	Regulation recognition
	3.6	Legal or law enforcement

(*continued*)

Table 3. (*continued*)

Factor groups	No.	Factors
	3.7	Criminological factors
	3.8	Risk of penalty
	3.9	Punishment certainty, celerity, and severity
4. Economic	4.1	Affordability
	4.2	State of the Economy
	4.3	Expensive or Costly Digital Piracy Products
5. Ease of Access or Opportunity	5.1	Access to enabling technology
	5.2	Frequency of computer use
	5.3	Product not available at local retailers or author's
	5.4	Remoteness and time delay
	5.5	Author's remoteness

The following section will discuss the five (5) factor groups that the researchers identified in Table 3.

Factor Group 1: Ethics, Norms, and Morality
Friends, co-workers, and family are relationships that affect how others' views will be towards any behavior [20]. Some internet users do not consider piracy illegal since it does not require physical products to be lifted from a shop. Consequently, the lack of ethical knowledge, low morale levels, norms, social and cultural association, and inefficiency of existing laws are the commonly identified factors that bolster the act of digital piracy [7].

Factor Group 2: Lack of Public Awareness and Education
The lack of knowledge about copyright laws, policies, standards, rules, and penalties if transgressed [8], has led some internet users to commit digital unknowingly [11]. Therefore, public awareness initiatives need to be investigated to inculcate knowledge in internet users about the risks of digital piracy [4].

Factor Group 3: Lack of Law Enforcement and Perceived Punishment
Users will continue using unlicensed products when there are low to no chances of being apprehended and penalized [15]. Therefore, more stringent laws alongside the certainty of punishment are likely to create a deterrent effect globally for online users [3, 14].

Factor Group 4: Economic Factors
The dominance of digital piracy in developing countries is because such impoverished countries cannot afford expensive digital media products; therefore, piracy is a reachable

alternative [18]. This may sound like a "validated" reason for piracy; however, the results are a sad threat to legitimate digital media businesses and the loss of hundreds of jobs [21].

Factor Group 5: Ease of Access
Access to high-speed internet connections through personal computers, cellphones, tablets, and other devices has made internet users' lives easy [13]. Sadly, as considerable amount internet users obtain digital media content via the internet channels illegally [1]. The accessibility of digitally pirated products through the interweb is among the main factors contributing to the worldwide escalating piracy rates [9].

4.3 Superordinate-Level Categorization or Grouping of Digital Piracy Group Factors

The researchers applied a more specific breakdown of the factor groups within a basic-level category through the superordinate-level approach [13] as observed in Table 4.

Table 4. Digital piracy super factor groups

Super factor groups	No.	Factors
1. Accessibility	1.1	Affordability
	1.2	State of the Economy
	1.3	Expensive or Costly Digital Media Products
	1.4	Access to enabling technology
	1.5	Frequency of computer use
	1.6	Product not available at local retailers
	1.7	Remoteness and time delay
2. Awareness and education about digital piracy	2.1	Knowledge of intellectual property regulations
	2.2	Digital piracy education or awareness
	2.3	Knowledge about penalty certainty, celerity, and severity
	2.4	Awareness of consequences
3. Social and Cultural Factors	3.1	Social interactions, culture, politics, norms, industrial factors, and organizational culture
	3.2	Sociological factors
	3.3	Moral disengagement
	3.4	Moral obligation, justice, relativism, utilitarianism, deontology

(*continued*)

Table 4. (*continued*)

Super factor groups	No.	Factors
	3.5	Social learning
	3.6	Collectivistic or individualistic factors
	3.7	Psychosocial factors

In Table 4, the factor groups were categorized following their characteristics and features to afford the study with a simple hierarchical category structure and readability and enable readers to quickly identify how the part of the factor groups are similar. Additionally, the categorization of factor groups aided the researchers in collectively defining the related factor groups and their related factors. The super factor groups are, therefore, summarized as follows:

Super Factor Group 1: Accessibility
The accessibility super factor group has various factors associated with it, such as the availability of free illegal internet sites and underprivileged online users justifying their digital piracy behaviors [23]. Additionally, delay in publicizing the digital content already available at some locations will tempt online users who cannot wait to obtain such content illegally [5]. Technology advancement and a sense of anonymity for internet users have made it fast and easy for computer users to access pirated digital media without fear of being caught [9].

Super Factor Group 2: Awareness and Education about Digital Piracy
Individuals in technology and education deprived regions may not have enough awareness about copyright laws, digital content infringement, and consequences thereto. As such, they proceed to pirate, unknowing of the repercussions and financial damages they are causing to the digital media copyright owners [19].

Super Factor Group 3: Social and Cultural Factors
Social factors play a role in the decision to pirate digital media. If the members of a culture feel a social distance from authority figures, they may be more likely to engage in digital piracy behavior [12].

5 Conclusion

This systematic literature review article's fundamental goal was to identify the factors that contribute to the internet users to commit digital piracy. Accordingly, this paper's results confirmed the three (3) super-factor groups as the core digital piracy factors, namely, 1) accessibility, 2) awareness and knowledge about digital piracy, and 3) social and cultural factors. The study will help fill the identified gaps in the existing literature base. Its findings will offer better awareness of the prevalence of this epidemic, help develop new strategies, and ultimately reduce piracy. Furthermore, the study will help those affected by digital privacy such as the policymakers, government sectors such as the Department of Education, law enforcement, education institutions, educators, broadcasters (TV and radio), and general communities address the digital piracy problem more effectively based on its known core factors.

Acknowledgments. The researchers declare no conflict of interest. Professor Elmarie Kritzinger supervised the master's full dissertation, from which this paper was developed. Both authors contributed towards all sections of the paper and had approved its final version.

References

1. Ahmed, M.: The relevance of online piracy in the new decade - an empirical study of video content piracy. Thesis - Bachelor of Science in Economics and Business Administration. Aalto University, Mikkeli Campus (2020)
2. Andrés, A.R., Asongu, S.A.: Fighting software piracy: which governance tools matter in Africa? J. Bus. Ethics **118**(3), 667–682 (2013). https://doi.org/10.1007/s10551-013-1620-7
3. Arias, J.J., Ellis, C.: The decreasing excludability of digital music: implications for copyright law. Am. Econ. **58**(2), 124–133 (2013). https://doi.org/10.1177/056943451305800205
4. Arli, D., Tjiptono, F., Porto, R.: The impact of moral equity, relativism and attitude on individuals' digital piracy behavior in a developing country. Mark. Intell. Plann. **33**(3) (2015). https://doi.org/10.1108/MIP-09-2013-0149
5. Asongu, S.A.: Software piracy, inequality and the poor: evidence from Africa. SSRN Electron. J. **41**(4), 526–553 (2012). https://doi.org/10.2139/ssrn.2493273
6. Athey, S., Stern, S.: The nature and incidence of software piracy: evidence from windows. Natl. Bur. Econ. Res. **19755**, 443–477 (2013). https://doi.org/10.7208/Chicago/9780226206981.003.0015
7. Balestrino, A.: It is a theft but not a crime. SSRN Electron. J. **24**(2), 455–469 (2021). https://doi.org/10.2139/ssrn.998767
8. Bethelhem, T.: Motivations Behind Software Piracy: From the Viewpoint of Computer Ethics Theories. University of Oulu, Oulun Yliopisto (2013)
9. van der Byl, K., van Belle, J.P.: Factors influencing South African attitudes toward digital piracy. Commun. IBIMA **1**, 140–149 (2008)
10. Cilliers, L.: Evaluation of information ethical issues among undergraduate students: an exploratory study. SA J. Inf. Manag. **19**(1), 1–6 (2017). https://doi.org/10.4102/sajim.v19i1.767
11. Eisend, M.: Explaining digital piracy: a meta-analysis explaining digital piracy. Inst. Oper. Res. Manage. Sci. (INFORMS) **30**(2), 636–664 (2019). https://doi.org/10.1287/isre.2018.0821
12. Gerhards, J., et al.: WP5/06 search working paper cultural diversity and national performance cultural diversity and national performance. Econ. J. **20**(1) (2016)
13. González, R., Brown, R.: Generalization of a positive attitude as a function of subgroup and superordinate group identifications in intergroup contact. Eur. J. Soc. Psychol. **33**(2) (2003). https://doi.org/10.1002/ejsp.140
14. Larsson, S.: Copy me happy: the metaphoric expansion of copyright in a digital society. Int. J. Semiot Law **26**(3), 615–634 (2013). https://doi.org/10.1007/s11196-012-9297-2
15. Meireles, R., Campos, P.: Digital piracy: factors that influence the intention to pirate - a structural equation model approach. FEP Working Pap. **35**(1), 1–15 (2016). https://doi.org/10.1080/10447318.2018.1507783

16. Merriam Webster: Merriam-Webster Online Dictionary (2022). https://www.merriam-webster.com. Accessed 8 Jan 2022
17. Moher, D., et al.: Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement (Reprinted from annals of internal medicine). Phys. Ther. **89**(9), 873–880 (2009). https://doi.org/10.1371/journal.pmed.1000097
18. Nii, J., et al.: A systematic literature review of digital piracy research in information systems journals (2010–2020): preliminary insights. In: Moines, D. (ed.) Proceedings of the Fifteenth Midwest Association for Information Systems Conference, vol. 1, no. 1, pp. 1–7 (2020)
19. Petrescu, M., Gironda, J.G., Korgaonkar, P.: Online piracy versus policy and cultural influencers. Int. J. Mark. Soc. Policy **1**(1), 3–14 (2017). https://doi.org/10.17501/23621044.2017.1102
20. Phau, I., et al.: Engaging in digital piracy of movies: a theory of planned behavior approach. Internet Res. **24**(2) (2014). https://doi.org/10.1108/IntR-11-2012-0243
21. Sahni, S.P., Gupta, I.: Piracy in the Digital Era. Springer, Singapore (2019). https://doi.org/10.1007/978-981-13-7173-8
22. Senyo, P.K., Addae, E., Boateng, R.: Cloud computing research: a review of research themes, frameworks, methods, and future research directions. Int. J. Inf. Manag. **38**(1), 128–139 (2018). https://doi.org/10.1016/j.ijinfomgt.2017.07.007
23. Stoddart, B., Sandiford, K.A.P.: Media piracy in emerging economies: South Africa. In: Lloyd, N.P. (ed.) Social Science Research Council, Cape Town, pp. 99–147 (2017). https://doi.org/10.7765/MSI/9781526123824.04
24. Tarassov, E.B.: Gregory murphy versus Eleanor Rosch: are categorization theories comparable? Shagi/Steps **5**(1) (2019). https://doi.org/10.22394/2412-9410-2019-5-1-128-135
25. Wales, R., Colman, M., Pattison, P.: How a thing is called - a study of mothers' and children's naming. J. Exp. Child Psychol. **36**(1) (1983). https://doi.org/10.1016/0022-0965(83)90053-X

Engineering Design Thinking in LEGO Robot Projects: An Experimental Study

Pao-Nan Chou(✉) and Ru-Chu Shih

Graduate Institute of Technological and Vocational Education, National Pingtung University of Science and Technology, Neipu, Taiwan
pnchou@g4e.npust.edu.tw

Abstract. Pedagogy issues regarding the LEGO Spike kit remains unknown. The study aimed to investigate students' engineering design thinking in robot projects. A quasi-experimental posttest with control group was used to answer the research purpose. Participants were two groups of students who participated in the Maker Program at different semesters (experimental: 2021 Fall; control: 2021 Spring). Students were 30 s graders from a public elementary school in Taiwan. The same teacher delivered 8-week program instruction for those students. In the experimental group, some well-performing students were encouraged to orally demonstrate their robot projects whereas students in the control group only focused on creating their projects without a need for a peer demonstration. Upon completion of the experiment, all students received programming and electrical engineering tests. Students' weekly engineering design behaviors were cumulated to define engineering design performances. The findings indicated that all students achieved a medium-high level on the content knowledge of programming and electrical engineering. In addition, students immersing in peer oral presentation increased engineering design thinking behaviors morn than their counterparts in class.

Keywords: Educational robotics · Engineering design thinking · Programming · LEGO kits · Electrical engineering · Sustainable development education

1 Introduction

LEGO Robot kits have been incorporated in various types of instructional activities to support students in learning content knowledge or developing specific thinking skills. At an entry level of educational training, the LEGO WeDo kit is regarded as a useful tool to introduce basic programming knowledge for young kids. For example, Mayerove and Veselovska [1] developed eight LEGO WeDo learning units, and suggested that elementary school students might obtain an understanding of introductory programming through those robotic projects. Polishuk and Verner [2] integrated the LEGO WeDo to a museum workshop and evaluated participants' (elementary students) learning performance. They found that learning by doing through robot education greatly improved students' progress in the systems thinking skills. Veselovska and Mayerova [3] developed several LEGO WeDo learning rubrics, and suggested the instructor might adopt

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 324–333, 2022.
https://doi.org/10.1007/978-3-031-15273-3_36

the assessments to observe students' learning behaviors. However, of those past studies, none have analyzed students' engineering design thinking.

Compared to the LEGO WeDo kit, because of advanced electronic sensors, the LEGO Mindstorm kit is widely used for a medium-high level of robotic training for students. For instance, Williams et al. [4] investigated the effect of the LEGO Mindstorm robot on middle-school students' learning performances and scientific inquiry skills. The findings indicated a significant growth on students' content knowledge but not on scientific inquiry skills. Barker and Ansorge [5] evaluated how the LEGO Mindstorm robot influenced students' learning outcomes at the after-school program, and identified that students' achievement test scores were significantly increased. In Hussain et al.' [6] study, students with good math skills might excel in LEGO robot activities. However, past research tended to focus on middle school students.

The LEGO Spike kit is a new robotic tool, which combines the basic programming platform in the LEGO WeDo with technological features in the LEGO Mindstorm. In other words, young kids might use simplified block-based programming language to control advanced electronic sensors. Because of being as a new learning tool in the education market, the LEGO Spike kit is only adopted for robot construction projects [7]. Pedagogy issues regarding the LEGO Spike kit remains unknown.

Based on the background information abovementioned, the purpose of the study was to investigate students' engineering design thinking in robot projects. Participants were two groups of second-grade students at an after-school maker program, where the LEGO Spike kit was a major learning tool for building varied types of educational robots. Specifically, research questions were threefold:

1. What were students' engineering design thinking patterns in robot projects?
2. Did different types of learning strategies influence students' engineering design thinking?
3. What was a relationship between students' engineering design thinking and learning performances?

2 Engineering Design Thinking Models

Our previous study developed two engineering design thinking models for different ages of elementary students. The first model [8] is a three-stage instructional framework, consisting of pre-design, in-design, and post-design stages. This model fits in the cognitive development of upper elementary students. In the pre-design stage, students experiment the learning material created by the instructor. In the in-design stage, students begin to engage in engineering design process from their own ideas. In the final stage, students evaluate their works by sharing ideas.

Another model [9] is also a three-stage instructional framework but with simplified learning elements: copy, tinker, and create stages. This model is cognitively suitable for lower elementary students. In the copy stage, young children directly copy the instructor's ideas. In the tinker stage, students begin to modify examples in the learning material; In the create stage, students attempt to create a whole new project. Table 1 summarizes the differences between two engineering design models.

Table 1. Differences between two engineering design models.

Types	Model 1	Model 2
Framework	Pre-design, In-design, and Post-design	Copy, Tinker, and Create
Instructional elements	1. Pre-design: copy ideas and try out 2. In-design: imagine, re-design, and build, and test 3. Post-design: review and self-reflect	1. Copy: directly copy ideas 2. Tinker: modify ideas 3. Create: develop a whole new idea
Suitable for learners	Upper elementary students	Lower elementary students

3 Research Method

3.1 Research Design

A quasi-experimental posttest with control group was used to answer the research questions. Two groups of students participated in the Maker Program at different semesters (experimental: 2021 Fall; control: 2021 Spring). The same teacher delivered 8-week program instruction for those students. A major difference for two groups was the student presentation in class. In the experimental group, some well-performing students took turn to demonstrate their robot projects. Table 2 shows the research design of the study. Prior to the program, all students had no experiences of doing programming and building robots. Upon completion of the experiment, all students received programming and electrical engineering tests. In addition, students' weekly engineering design behaviors were cumulated to define engineering design performances.

Table 2. The research design of the study.

Group	Intervention	Post-test
Experimental (2021 Fall)	X	O_1, O_3
Control (2021 Spring)		O_2, O_4

O_1, O_2: Total Engineering Design Performances
O_3, O_4: Content Knowledge on Programming and Electrical Engineering

3.2 Research Participant

30 s graders from a public elementary school in Taiwan voluntarily participated in the study. Two experimental groups had the equal number of students. The male to female ratio is almost 1. Table 3 provides a profile of research participants.

Table 3. Research participant.

Group	n	Male	Female
Experimental (2021 Fall)	15	8	7
Control (2021 Spring)	15	7	8

3.3 Technology Tool

Student participants in the study learned to code by using LEGO Spike App in the tablet computer. The App offers a simplified block-based programming platform (See Fig. 1). The robot kit contains several sensors (e.g., a color sensor) and motors, which allow students to engage in engineering design projects. Once young children completed assignments, Bluetooth connection between the LEGO Spike and the tablet computer enabled students to verify coding results. Figure 2 presents one student building his robot project.

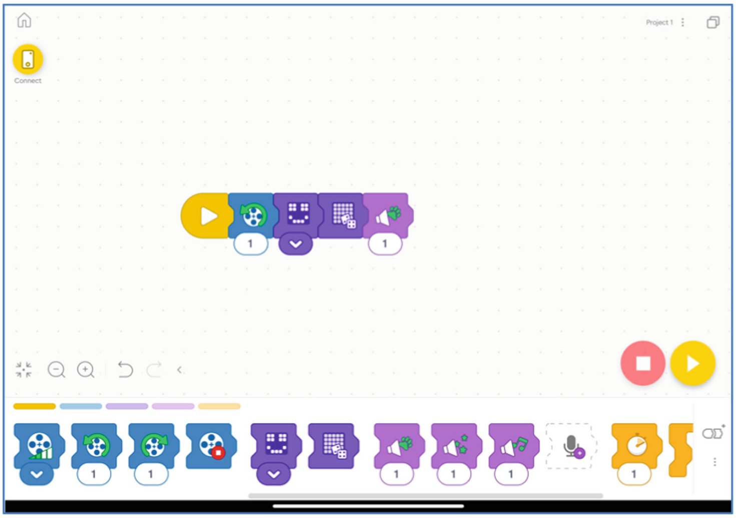


Fig. 1. Programming platform in LEGO Spike App.

Fig. 2. One student building the LEGO robot.

3.4 Assessment Tool

The study adopted a simplified engineering design model [9] to measure students' engineering design thinking. A successful completion of each stage obtains specific points. Scoring 6 points represents a completion of full cycle of engineering design for one robot project (see Table 4). By following this scoring metric, the instructor observed students' performances, and then assigned points for them.

Table 4. Engineering design model.

Score point	Definition
0	Failing to do anything
1	Completing the first stage (copy)
2	Completing the second stage (tinker)
3	Completing the third stage (create)

Chou [10] suggested a video demonstration test might be suitable for assessing young children's programming knowledge. Thus, the study developed 20 multi-choice questions regarding basic programming. Each question item is accompanied by one short video clip. Students needed to choose one answer on a sheet of test paper after observing the test item in the video clip. Two computer teachers were invited to examine the test items to ensure the validity. In addition, KR-21 test was performed to analyze the reliability of the test, yielding a Cronbach alpha coefficient of 0.8.

In addition, an achievement test was developed to measure students' electrical engineering knowledge. The test contained 10 matching items. Several electrical gadgets appeared in the paper. Students needed to choose an appropriate description for the gadget. To ensure the content validity, the test was examined by two elementary science teachers.

3.5 Instructional Strategy

Student oral presentation was used as an instructional intervention in the study.

1. Control group (no presentation): During class instruction, students fully engaged in robot projects. Student oral presentation was not required in the control group.
2. Experimental group (oral presentation): At class, when the instructor identified some students who performed well on project building, the students were invited to demonstrate their works and share their design thinking. (See Fig. 3).

Fig. 3. One well-performing student demonstrating his robot project

3.6 Instructional Content

Educational experiment in the study lasted for 8 weeks. Various themes were presented in weekly 3-h learning session at one science classroom. All instructional contents were identical at two experimental groups. A curriculum design was summarized in Table 5. Figure 4 shows one student testing his sixth-week project (robot bicycle).

Table 5. Curriculum design of the maker program.

Week	Learning unit
1	Introduction to Lego Spike/Programming training
2	Programming training
3	Engineering Project1: Dancing Robot
4	Engineering Project2: Bionic Robot
5	Engineering Project3: Robot Car
6	Engineering Project4: Robot Bicycle
7	Engineering Project5: Robot Hand
8	Engineering Project6: Walking Robot

During project development, the instructional procedure based on copy-tinker-create principle. Initially, students were asked to use the template provided by the instructor to practice what they learned. Subsequently, the instructor encouraged students to modify the template. Finally, students need to create a whole new project.

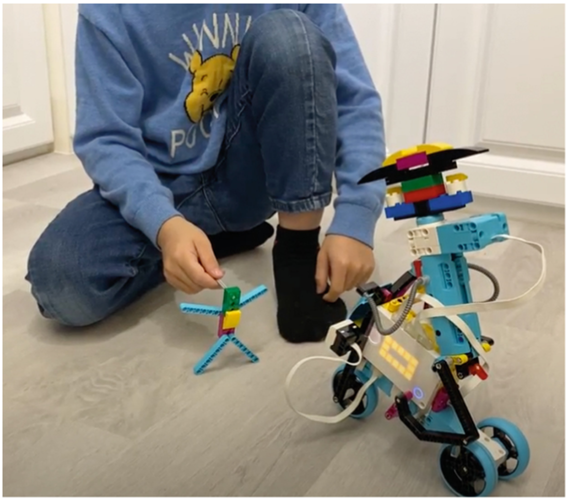


Fig. 4. One student testing his robot bicycle

4 Findings

Table 6 reports the results of descriptive statistics on programming, electrical engineering, and engineering design performances. The findings showed that students in the experimental group outperformed their counterparts on programming and engineering design.

Table 6. Results of descriptive statistics for three posttests.

Item	Control group (M/SD)	Experimental group (M/SD)
Programming	12.47 (2.62)	13.20 (3.23)
Electrical Engineering	7.67 (0.90)	7.00 (1.19)
Engineering Design	22.20 (5.41)	29.60 (3.18)

Note: Programming (0–20), Electrical Engineering (0–10), Engineering Design (0–36)

Frequency of engineering design thinking is summarized in Table 7. The information indicated that all students fulfilled requirements in the copy and tinker stages. However, a major difference between two experimental groups appeared in the create stage.

Table 7. Frequency of engineering design thinking.

Group	Copy	Tinker	Create
Experimental	90	90	21
Control	90	90	58

Note: Copy, Tinker, and Create (0–90)

Tables 8, 9 and 10 summarize the results of one-way ANOVA for three posttests. The findings indicated that no significant difference was found in the programming test ($F = 6.47, p > 0.05$) and the electrical engineering test ($F = 2.98, p > 0.05$) between the control and experimental groups. However, a significant difference ($F = 20.83, p < 0.01$) existed in the engineering design performance between the control and experimental groups.

Table 8. Results of one-way ANOVA for the programming test.

Type	Sum of square	*df*	*Mean square*	F	*p*
Between groups	4.03	1	4.03	6.47	0.5
Within groups	242.13	28	8.65		
Total	246.17	29			

Table 9. Results of one-way ANOVA for the electrical engineering test.

Type	Sum of square	*df*	*Mean square*	F	*p*
Between groups	3.33	1	3.33	2.98	
Within groups	31.33	28	1.12		0.10
Total	34.67	29			

Table 10. Results of one-way ANOVA for the engineering design performance.

Type	Sum of square	*df*	*Mean square*	F	*p*
Between groups	410.7	1	410.7	20.83	
Within groups	552.0	28	10.71		0.00**
Total	962.7	29			

** $p < 0.01$

Table 11 presents the results of Pearson correlation among three posttests. It was found that no significant relationship was identified between engineering design and programming performances (r = 0.13, $p > 0.05$) and between engineering design and electrical engineering performances (r = −3.01, $p > 0.05$).

Table 11. Results of Pearson correlation.

Engineering design	Programming	Engineering
r	0.13	−3.01
sig.	0.49	0.11
n	30	30

5 Conclusion

Through 8-week robotic training, all students achieved a medium-high level on the content knowledge of programming and electrical engineering. In addition, students immersing in peer oral presentation increased engineering design thinking behaviors more than their counterparts did in class. In other words, the project demonstration by well-performing students might stimulate other students' willingness to create a whole new robot project. However, students' engineering design performances did not relate to their achievements on programming and electrical engineering knowledge. Because of the limited sample size, the findings may not be generalized into other learning scenarios. Our ongoing project is to qualitatively examine the effect of the project demonstration on students' engineering design performances.

References

1. Mayerové, K., Veselovská, M.: How to teach with LEGO WeDo at primary school. In: Merdan, M., Lepuschitz, W., Koppensteiner, G., Balogh, R. (eds.) Robotics in Education. AISC, vol. 457, pp. 55–62. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-42975-5_5
2. Polishuk, A., Verner, I.: Student-robot interactions in museum workshops: learning activities and outcomes. In: Merdan, M., Lepuschitz, W., Koppensteiner, G., Balogh, R. (eds.) Robotics in Education. AISC, vol. 457, pp. 233–244. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-42975-5_21
3. Veselovská, M., Mayerová, K.: Assessment of lower secondary school pupils' work at educational robotics classes. In: Alimisis, D., Moro, M., Menegatti, E. (eds.) Edurobotics 2016 2016. AISC, vol. 560, pp. 170–179. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-55553-9_13
4. Williams, D.C., et al.: Acquisition of physics content knowledge and scientific inquiry skills in a robotics summer camp. J. Res. Technol. Educ. **40**(2), 201–216 (2007)
5. Barker, B.S., Ansorge, J.: Robotics as means to increase achievement scores in an informal learning environment. J. Res. Technol. Educ. **39**(3), 229–243 (2007)
6. Hussain, S., et al.: The effect of LEGO training on pupils' school performance in mathematics, problem solving ability and attitude: Swedish data. Educ. Technol. Soc. **9**(3), 182–194 (2006)
7. Gervais, O., Patrosio, T.: Developing an introduction to ROS and Gazebo through the LEGO SPIKE Prime. In: Merdan, M., Lepuschitz, W., Koppensteiner, G., Balogh, R., Obdržálek, D. (eds.) RiE 2021. AISC, vol. 1359, pp. 201–209. Springer, Cham (2022). https://doi.org/10.1007/978-3-030-82544-7_19
8. Chou, P.-N.: Skill development and knowledge acquisition cultivated by maker education: evidence from Arduino-based educational robotics. EURASIA J. Math. Sci. Technol. Educ. **14**(10), em1600 (2018)
9. Chou, P.-N.: Smart technology for sustainable curriculum: using drone to support young students' learning. Sustainability **10**(10), 3819 (2018)
10. Chou, P.-N.: Using ScratchJr to foster young children's computational thinking competence: a case study in a third-grade computer class. J. Educ. Comput. Res. **58**(3), 570–595 (2020)

Moving a Project-Based Information Systems Development (ISD) Capstone Module Online: Lessons Learnt

Lizette Weilbach(✉) and Marie Hattingh

University of Pretoria, Private Bag X20, Hatfield 0028, South Africa
Lizette.weilbach@up.ac.za

Abstract. Project-based capstone modules are challenging in a face-to-face environment and even more so when trying to move them online. In an information systems development (ISD) capstone module at a South African university, students are required to work in teams and engage with their real-life clients whilst consulting with their lecturers and completing several deliverables throughout the year. This paper reports on a case where the teaching of this project-based module was moved online due to the COVID-19 worldwide pandemic. The contribution lies in the lessons learnt and insights derived during this time. Students were still able to continue to deliver high quality work that enabled them to meet the learning outcomes of the module. With the IT industry in the post COVID era moving online, working remotely or in a hybrid fashion, the online PBL experience prepared students for the 'new' work life which makes them 'industry ready'.

Keywords: Capstone module · ISD capstone project · Project-based learning · Face-to-face teaching · Online teaching · Lessons learnt

1 Introduction

A capstone module forms a very important part of a university degree's curriculum. It provides students with a unique opportunity to build an innovative solution for a real-world problem. The scope and scale of the module is usually very challenging and compels students to practically apply their complete undergraduate skill set, which include inter alia creative, critical, and strategic thinking, effective communication, teamwork, and problem solving skills [1].

Project-based learning (PBL) is rooted in inquiry pedagogy and is grounded in three constructivist principles: student learning is context-specific; learners actively take part in the process of learning; and learners accomplish their learning goals through a process of social interaction and knowledge sharing and understanding [2]. For proper PBL to take place, students are expected to solve real-world problems by asking questions, conducting investigations, gathering and analyzing data, interpreting the data, designing solutions, drawing conclusions and reporting on their findings [3].

The PBL approach is therefore suitable to teach an information systems development (ISD) capstone module, where students are required to design and develop an information

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 334–342, 2022.
https://doi.org/10.1007/978-3-031-15273-3_37

system for a real-life client, while working in teams. Each real-life client has a unique business problem usually related to the inefficiency and ineffectiveness of the current business processes, which for small businesses are mostly hand driven. Students are required to complete all activities associated with a typical Systems Development Life Cycle [4], from requirements gathering to implementation, as part of their project.

Capstone modules are challenging in a face-to-face environment and even more so when trying to move them online. This paper reports on a case where the teaching of a project-based capstone ISD module was moved online in 2020 and 2021 due to the COVID-19 worldwide pandemic. Although a number of scholars reported on the implications of education during the COVID-19 pandemic, for example [5], the authors have not noticed any reports on the delivery of Capstone modules during the COVID-19 pandemic. Therefore, the contribution lies in the lessons learnt and insights derived during this time. Students were still able to continue to deliver high quality work that enabled them to meet the learning outcomes of the module. With the IT industry in the post COVID era moving online, working remotely or in a hybrid fashion, we argue that the online PBL experience prepared our students for the 'new' work life which makes them 'industry ready'.

The paper is structured as follows. Section 2 details the methodology applied in this study. Section 3 provides a description of the case study, both in the pre-COVID setting and how it was adapted during the COVID period. Section 4 discusses the reflection and observations of both the lecturers and the survey results of the students. Section 5 offers the lessons learnt from the case described. The paper concludes in Sect. 6.

2 Methodology

The study utilizes a case study research approach. This approach is appropriate when considering phenomena in its natural setting to get and in depth understanding of an instance [6]. In [7] it distinguishes between different types of case studies: exploratory case studies are used to define questions or hypotheses; descriptive case studies provide rich descriptions and in-depth analysis of cases; and explanatory case studies extend descriptive case studies by providing further understanding and explanations by comparing the results to literature.

This study makes use of a descriptive case study and reports on the lessons learnt and insights gained after moving an ISD capstone project online. Feedback from students on the online course was gathered through a voluntary mainly open-ended Google Form survey which was distributed online. 29 students responded to the survey. However, as students worked in Teams, it was not expected that all the students respond, but rather one response per Team. The responses also indicated that saturation was reached. Section 4 reports on the feedback gained from both the students and the lecturing team.

A descriptive case approach in PBL has been used before in the instruction of middle school chemistry [8] and ninth grade intertidal biodiversity instruction [9].

3 Case Description

Final year ISD students must complete a fully-fledged information system for a real-life client. Cohort numbers range from 150 to 180 students. Students need to complete the project in teams of five members. Each team completes 11 deliverables throughout the year. These include inter alia a project proposal, functional and technical specifications, a prototype and a final coded information system with a user and a training manual. They learn to work with a real-life client who must sign-off on each deliverable.

The following two sections provide the context in which the PBL took place. Section 3.1 describes the initial setting of the PBL (face-to-face), while the online learning environment (after COVID) is described in Sect. 3.2.

3.1 Face to Face Environment

In completing the 11 deliverables, student teams seek advice from the two lecturers assigned to the module, by booking face-to-face consultation sessions (consultative meetings to discuss areas where the students struggle with design or development elements) via Google Calendar.

Two assistant lecturers (ALs) (postgraduate students who completed the module the previous year) act as student mentors. A collaboration lab is available on campus where teams can book cubicles to work together, but they are allowed to work in any space they find convenient. Two lecturers mark the completed deliverables during face-to-face team presentation sessions. Students are required to hand in a printed copy of their work on the morning of the deliverable due date and are then allocated an hour-long session to present it. Some deliverable hand-ins are grouped together and there are five face-to-face presentation sessions throughout the year. For each session, the students must dress formally, and present and argue their work. During these sessions, both lecturers mark their printed document by discussing their work and providing hand-written feedback on the respective models in the printed document.

3.2 Adapted Online Learning Environment

This section explains how the capstone module's work environment was adjusted to cater for online teaching and learning during the COVID-19 pandemic.

Online Working and Consultation. Students were allowed to make their own decisions on how they would continue to communicate with each other. They also had to find their own solutions to share their work online. Furthermore, they needed to consult with their clients to find a way to communicate which would be acceptable to both parties.

Lecturers continued to make consultation times available through Google Calendar's appointment slot functionality, but students were now also invited to an online Google Meet session for the scheduled consultation times. Students had to email the documents containing their questions in advance, but were also able to share these documents online during a meeting.

Online Submissions. To replace the printed documents that were submitted previously, each team was assigned a folder on Google Drive. Only the lecturers and the students of the specific team were given 'content manager rights' to their team's folder. Students were instructed via an announcement on the University's Blackboard learning system to split the large document they prepared for hand in, into smaller pdf files (one for each section of the document e.g., use cases and narratives, data flow diagrams (DFDs), entity-relationship diagram (ERD), hardware and software specifications, etc.). This was done to ease up the marking process, as the two lecturers had to mark different models/sections of the document instantaneously and the functional and technical specification documents were voluminous. Once the hand-in time expired, the ALs changed the teams' folder rights to prevent them from editing anything in their folder and to ensure equal completion time allowed for all groups.

Online Evaluation and Marking Sessions. Online marking sessions were scheduled using Google Calendar. An hour-long session was scheduled per team using Google Meet, and the team, lecturers and ALs were invited to join this session. To make the assigning of timeslots fair, an online randomizer was used. During the marking sessions, both lecturers marked the students' deliverables but focused on different parts of it. They downloaded the submitted files into team folders on their tablet devices and were able to use their digital pens to 'write' their feedback on the pdf documents and to 'show' students where their modelling or narratives went wrong, through sharing their tablet screens during the Google Meet session. All meeting participants were asked to switch off their videos to streamline the sessions. Marks were captured in a Google Sheet Workbook shared between the lecturers and ALs in a dedicated folder on Google Drive. After each marking session, the lecturers and ALs joined their own Zoom meeting to discuss issues relating to the marking session and to consolidate the team's marks. The ALs created a 'Feedback' folder within each team's Google Drive folder, into which they posted the final mark sheets of the team. Marking sessions were also recorded using Google Meet's recording functionality and all students invited to the Google Meet session received an automatic email with a link to the recording directly after their session. The lecturers also uploaded the pdf documents with their feedback into every team's Google Drive 'Feedback' folder.

4 Discussion

After transforming from a face-to-face environment to an online learning environment, the lecturing team reflected on the implementation of the changes. Students were also prompted for their feedback on the online consultations and marking sessions, through a voluntary Google Form which was distributed online. The following feedback, with regards to the different aspects of the course, came from the lecturers' and students' perspectives.

4.1 Feedback on Online Working and Consultations

From the Lecturers' Perspective. Lecturers found the online consultations to work quite well as students were able to join the meetings and successfully carry on with their projects. Connectivity issues in some cases led to long sessions as lecturers had to frequently repeat what they said due to sound problems and a lagging Internet connection. Lecturers also found it difficult to explain systems modelling without having a way in which they could physically draw the model and indicate the notation while explaining the concepts. There was also a need to write on the documents submitted for the consultation to point out the errors or the required changes. This was solved when they found the Notability App (both lecturers used iPads, however similar annotating applications are available for Android) that allowed them to do this using an electronic pen on a tablet.

Students were more eager to make online appointments and while they found it beneficial, this resulted in much longer working hours for the lecturers as students would 'expect' them to be more 'instantly' available and lecturers correspondingly wanted to compensate for the fact that students might feel lost and more helpless during the lockdown. Students would for instance email their lecturers at odd times during a weekend to request an online consultation should the lecturer's timetable show no more available slots for the week. Students also booked slots weeks in advance, as they wanted to ensure that they had a spot should they need it. This resulted in some unneeded slots being cancelled at the last minute, while other teams struggled to find an available time to consult. Lecturers consequently had to open more slots.

From the Students' Perspective. Students had to collaborate online within their team members, their lecturers, and their clients.

Online Collaboration with Team Members. Students indicated that they used various technologies to support their online teamwork. They used Google Drive and Microsoft OneDrive to backup and share their documents. They also reported that not all group members always had enough data to upload and download these documents. The University's zero-rated data portal (students could access the learning management system and predefined websites using no data) seemed to be very slow at times. Asana (a project work management platform) was used to manage their workload and it assisted them to assign project tasks and to control and plan their projects. One group indicated that they used WhatsApp to remind group members about "important dates" in their project plan, as: "Asana wasn't as easy to have discussions on since nobody noticed when a message was sent." Asana was also used to measure the individual progress of tasks assigned to team members. Interestingly, the main intra-team communication application seemed to be Discord. Students indicated that it was easier to use than Zoom as they did not have to 'schedule' a meeting, and there was no time limit to their meetings. The ability to share multiple screens at the same time was also useful. WhatsApp was additionally used for team and client communication. The main advantage of WhatsApp for intra-team communication is that it is less data intensive - students could send the Google Meet videos over WhatsApp to save data, and it allowed team members to communicate instantly about an issue. Interestingly, one group reported that they experienced the use of WhatsApp as negative as they "had a lot of arguments over WhatsApp because sincere sentences easily sounded sarcastic, causing anger". Students used GitHub (a code hosting platform for version control and collaboration) to share their code and to manage the version control of their code. Microsoft Office Online was found to be a better option than Google Docs for sharing analysis and design documents, as it has more formatting possibilities.

Online Consultation with Lecturers. Students found the online consultations with their lecturers convenient as they spent less time on travelling to the University. One student reported that s/he had never consulted in person (before COVID) but was brave enough to consult online (during COVID) as it was less intimidating. Most students reported that they enjoyed the ability to listen to recorded consultation sessions in preparation for their subsequent deliverables. However, some students had connection issues due to limited data or the lack of electricity. They overcame this by sharing the session recordings with their team members over WhatsApp. The main challenge they had with the online consultations was that they struggled to 'explain' their problems. They now had to verbalize more, and they felt that this wasted valuable time and made them more anxious. Students complained that there were not enough consultation slots (although both lecturers exceeded their required consultation hours) and that the 30-min-long online consultation slots were not long enough.

Online Consultation with their Clients. Students consulted with their clients through Google Meet, email, Microsoft Teams, Skype, phone calls and WhatsApp. It was evident that students who had a more personal relationship with their client, used phone calls or WhatsApp more often. One group used WhatsApp voice notes to "explain" the detail of the document that needed to be signed off by the client that assisted the client to understand what they were signing. Other clients engaged in online meetings to review documents and perform sign offs. Students learnt that sending the documents beforehand reduced their meeting time.

4.2 Feedback on Online Submissions

From the Lecturers' Perspective. The online submissions were done without any difficulties. Some groups did though not adhere to the format of the submitted files. Lecturers used Notability to 'mark' these files with a digital pen, and files in the wrong format had to be converted into pdfs before they could be imported into the folders on their tablets, as importing a MSWord file would for instance blank out the file when viewed in Notability.

From the Students' Perspective. Students experienced the online submission very positively. They did not need to print their documents which not only saved them a lot of time, but also money (especially when printing in color). Furthermore, they were not required to queue very early to hand in their printed work and to choose a suitable presentation slot. Their only concern was that they could possibly lack a quality Internet connectivity when they were required to hand in. However, the online submission process was seen as the most popular aspect to keep when returning to 'normal' after the lockdown.

4.3 Feedback on Online Evaluation and Marking Sessions

From the Lecturers' Perspective. Lecturers felt that the online marking sessions worked well. Out of the 31 scheduled sessions, only one group experienced connectivity issues. Students were mindful of their marking session times and mostly connected on time. Compared to the normal face-to-face sessions, the online marking sessions took 30 min longer, as the marks needed to be captured in the electronic mark sheets, and the mark sheets and the pdf feedback documents had to be uploaded onto the groups' Google Drive folders. One disadvantage of marking online was that students were not required to share their videos throughout the meeting to save on data costs. Lecturers were therefore not able to know whether all students were continuously paying their undivided attention to the session.

From the Students' Perspective. Some students experienced the marking sessions as "more relaxed", with "less pressure". The recordings also provided them with "direct feedback which we might have been missing out on, due to stress and nervousness". However, some students indicated that the lack of being able to see the lecturers' facial expressions and body language made them stress more. Students were also not always completely sure which aspects of their submitted documents lecturers referred to and queried during the sessions. They felt that they would be able to find the sections lecturers asked for more easily in a 'face-to-face' meeting when they could physically page through their document. Some described the online session as "feeling distant" and felt that there sometimes was some miscommunication.

5 Lesson(s) Learnt, and Insights Gained from the Adapted Online Experience

The lessons learnt from the different aspects of the online capstone module is summarized below:

5.1 Online Working and Consultation Lessons Learnt

1. Students are very innovative when it comes to making plans to communicate and share documents online. They use technologies which they find most applicable, easy to use and which saves them effort and money. An example of this is the use of Discord (originally designed for gaming communities to communicate) for intra-team communication. This is in line with the PBL approach where students are actively involved in solving the real-life problem in order to reach their set study goals [2].
2. The 'Appointment' functionality of Google Calendar works well to set up online Google Meet consultation slots, which students can book. This aspect was retained in the face to face setting. Students are now also offered to indicate whether they would like to have the appointment online or face to face which gives them the flexibility. This supports previous research regarding online learning during the COVID pandemic, such as [5] who reported that students' ability to better manage their time, and the flexibility of the online option as positives.
3. When allowing student teams to book an online consultation slot, you need to restrict the number of slots a single team can book. Leaving this unrestricted will cause some teams to book almost all available slots for just in case they might need it. This leads to wasted time due to last minute cancellations.

4. Working online is much more exhausting and leads to many more hours of teaching and advising as the lecturer is 'technically available' at all hours and students seem to have expectations of being helped immediately. To minimize stress, lecturers should set up some rules on how quickly students can expect to receive feedback on their online requests.
5. Request students to prepare well for their online meetings, i.e., to send the documents they want to discuss before the meeting and to decide in advance who would run the meeting and share their screen.
6. Requesting students to switch off their videos during an online consultation session can save them some data costs, but it at the same time decreases the richness of the communication as facial expressions and body language will be lost. Lecturers are also not able to see what students do during the meeting and whether they pay their undivided attention to the online discussion.
7. To assist with explaining concepts during online consultations and online marking sessions, an App such as 'Notability' is very useful as it allows a lecturer to write or draw with an electronic pen, while explaining content. Android applications delivering the same annotative abilities are available.
8. Students found Asana to be a very valuable project management tool to plan their project, to assign work to team members, to keep track of the tasks completed and of those behind schedule.

5.2 Online Submission Lessons Learnt

1. In a developing country, allowing students to hand in their capstone deliverables as an electronic document can save them a lot of traveling time and money due to printing costs. This aspect seems to be one that could also be continued with in the 'normal' face-to-face setting.
2. Being able to view documents online also allowed many students to display their work in color that might for some teams not have been possible if they had to pay for color printing.
3. Creating dedicated team folders on Google Drive for students to submit their documents for evaluation purposes and providing them with detailed instructions as to what to name their documents, where to upload it, and in what format to upload it, could ease up the online evaluation process significantly.
4. The ability to adjust the editing and viewing settings of the folders on Google Drive can assist lecturers to manage student activity in their dedicated hand-in folders (especially after the hand-in time expired).
5. Using an online randomizer to assign student teams their evaluation slots seems to be acceptable and fair.

5.3 Online Evaluation and Marking Session Lessons

1. Compared to previous years' results, the marks students obtained were very similar. This indicates that technology can solve many issues posed by a lockdown, although the similar results could also be attributed to the fact that students had more time to consult with their lecturers.

2. Being able to record what was said during the evaluation session and making the recording available to students after the session can save lecturers ample time spent on student queries. Students also find this very valuable as they could watch and listen to it again.
3. Marking the content of a large document could lead to a lot of frustration. Rather split the document into a number of smaller documents as these speeds up the scrolling through and evaluation process.

6 Conclusion

This paper reported on the technologies and initiatives employed by both the lecturing team and students (enrolled for the project-based capstone ISD module at a South African University) to change the module to an online module. The results indicate that it is possible to successfully present a project-based capstone module online. Although the richness of a face-to-face setting was noticeably absent, the overall experience of the online module was positive. The lecturers were not too prescriptive with how students needed to conduct intra-team and client communication and students posed to be very innovative in this regard. It is however important to manage students' communication and consultation with their lecturers well and to provide clear guidelines on how students need to submit their documentation for evaluation. Combining different technologies, such as annotating a document using the Notability App while explaining a concept during a Google Meet recording, allowed students to receive proper and thorough feedback.

References

1. Lukins S.L.: What is a capstone project? And why is it important? In: Top Universities (2022). https://www.topuniversities.com/student-info/careers-advice-articles/what-capstone-project-why-it-important. Accessed 4 Jul 2022
2. Kokotsaki, D., Menzies, V., Wiggins, A.: Project-based learning : a review of the literature. Improv. Sch. **19**, 267–277 (2016). https://doi.org/10.1177/1365480216659733
3. Blumenfeld, P., Fishman, B.J., Krajcik, J., et al.: Creating usable innovations in systemic reform: Scaling up technology-embedded project-based science in urban schools. Educ. Psychol. **35**, 149–164 (2000). https://doi.org/10.1207/S15326985EP3503_2
4. Bhuvaneswari, T., Prabaharan, S.: A survey on software development life cycle models. Int. J. Comput. Sci. Mob. Comput. **2**, 262–267 (2013)
5. Al-Mawee, W., Kwayu, K.M., Gharaibeh, T.: Student's perspective on distance learning during COVID-19 pandemic: a case study of Western Michigan University, United States. Int J Educ Res Open **2**, 100080 (2021). https://doi.org/10.1016/j.ijedro.2021.100080
6. Oates, B.J.: Researching Information Systems and Computing, 1st edn. SAGE Publications Ltd, London, Thousand Oaks, Calif (2005)
7. Yin, R.K.: Case Study Research Design and Methods. Sage, Thousand Oaks, CA, US (2016)
8. Zhao, Y., Wang, L.: A case study of student development across project-based learning units in middle school chemistry. Disciplinary Interdisc. Sci. Educ. Res. **4**, 5 (2022). https://doi.org/10.1186/s43031-021-00045-8
9. Baumgartner, E., Zabin, C.J.: A case study of project-based instruction in the ninth grade: a semester-long study of intertidal biodiversity. Environ. Educ. Res. **14**, 97–114 (2008). https://doi.org/10.1080/13504620801951640

Motion Balance of Creative Assembly JIMU Robot with a Smartphone Remote Control

Weng Ting-Sheng[1](✉) and Chao I-Ching[2]

[1] National Chiayi University, Chiayi City, Taiwan ROC
politeweng1@gmail.com
[2] Kao Yuan University, Chiayi City, Taiwan ROC

Abstract. Mathematics is a tool often used to solve scientific problems. However, the motion balance of the JIMU (robot building blocks) robot after assembly is affected due to the proportion of the center of gravity of the assembled shape. This study provides students with the components of a JIMU robot, in order that they could assemble, design program codes, control the robot, and experience the mathematical and physical relationship between the robot's balance and action. The students' reflections on the key skills of building the robot, learning the concepts of assembly logic and organizational structure, and understanding the relationship between mathematics and physics could help to improve their abilities of applying mathematics in programming language design and using assembly tools to give the robot balanced movements in the design. Students actually carried out the design and development of the system, considered the problem-solving steps, designed the program code, and practiced robot balance during motion. The case interviews with students were analyzed to understand students' attitudes towards such a learning style.

Keywords: Robots · STEAM · Hands-on · Creative assembly · Mathematics and physics · Motion balance

1 Introduction

Building blocks are creative materials with complex changes [6], which cultivate the hands-on ability, the utility of objects after assembly, and the cognition and training of spatial geometry. They can foster users' ability and concepts to build different structures, help students in their reasoning performance [1], and enhance students' creativity, thus, building blocks are a good learning aid. Assembling building blocks into robots can enhance and inspire the ability of creative ability construction.

2 Motivation

Mathematics is the foundation of physics learning. As mathematics and physics affect the dynamics and actions of objects, mathematics can meet the needs of solving physics

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 343–352, 2022.
https://doi.org/10.1007/978-3-031-15273-3_38

problems. Moreover, as the program code controls the behavior of a robot, the learning of basic design is important [2].

Chen mentioned that mathematics is a thought-provoking subject with a high failure rate, and this high failure rate affects students' willingness to learn [7]. However, as a compulsory basic course, mathematics is needed to prepare for later professional application. Therefore, this study suggests that if the practical cases of mathematics in scientific application situations can be improved, and the use of mathematics in science can be verified and seen visually, the pursuit of this discipline may be increased in the future.

Chiu re-enhanced what was learned in the general physics class through high school experimental classes to deepen learning through practice [15]. Students were assigned software or programs to design animations to gain an in-depth understanding of the characteristics of waves and become familiar with the concepts of the implementation process.

There are many students who feel that their performance in mathematics is inferior to others and do not take the initiative to learn, or give up learning. For these low-achieving students, teaching with emerging technology tools, appropriate methods, and timings can stimulate their learning potential and enable them to make flexible use of mathematics, physics, and programming code in learning. It is expected that multidisciplinary training in the classroom will build students' confidence to face difficult learning situations and solve problems in real-time.

3 Purpose

Learning is a continuous accumulation of knowledge, and one can learn further course content only with a solid foundation. An article of Turner discussed the evolution of American science education with the slope balance experiment as an example, and pointed out that between 1880 and 1920, science teaching in the United States had gradually transformed from lecture and demonstration teaching to a teaching type based on students' hands-on experiments due to increased funding [10]. However, this issues is studied on elementary school in Taiwan [1]. Chiu mentioned that, in most of Taiwan's junior and senior high schools, the teaching mode still focuses on lectures, while demonstration experiments and group experiments are seldom conducted [14].

Therefore, the aim of this study was a pilot study, used interview and case study to discuss a teaching style in which students could have hands-on experiences during the course. Sufficient mathematical and physical background knowledge of basic concepts are needed to assemble JIMU (building block) robots and write programs, in order to ensure the balance of the robot's movements is maintained and the robot will not fall, through experience and reflection, students can achieve seeing, thinking, and doing in person.

4 Literature Review

4.1 Impact of Creative Assembly

Building blocks can be used for toys, teaching aids, mathematics, architectural knowledge concepts and systems, and mathematical knowledge and systems. Building blocks are also helpful for the development of human hand movements, language skills, cognitive skills, social skills, creativity, and sensory support [4]. Fang pointed out that participation in hands-on science learning can enhance kindergarten teachers' knowledge and production skills of science toys, which will make teachers more confident in science teaching, and their lessons will be more vivid, lively, and interesting [3]. Then, science toys can be applied in their teaching of children's science games. The study of Hsieh and Chang found that the integration of creative problem solving into the teaching of science toy making can improve the creativity and precision of the creative projects of students in the gifted education programs of the upper grades of elementary schools [5]. This integration also improved their capacity to discover scientific and creative problem-solving items, and most students had a positive attitude towards the integration of creative problem solving into the teaching of scientific toy making and believed that it helped enhance their creativity.

After teaching, Ye found that the production of technology toys and the theme of technology implementation can effectively enhance learning interest, the importance of practice should be shown during teaching activities, and group competitions can be added after the work is completed, and finally, it was suggested that STEAM education should be promoted in stages starting from elementary schools [12]. The Ministry of Science and Technology in Taiwan also includes the "Scientific Toy Design and Production" project in the "Promotion Plan of Science Education Practice Research Planning", and encourages engagement in scientific toy-related research, which shows that Taiwan attaches great importance to the development of scientific toy-related teaching and research [8].

This study suggests that the introduction of mathematics and physics in the design thinking of programming code is needed for the influence of balance and power, and the application of manipulating building block robots will arouse students' curiosity.

4.2 Importance of Mathematics and Physics for Motion Balance

Mathematics and physics are important for the motion balance of object dynamics, as mathematics affects the physical motion of an object's sense of balance and ability to sustain motion.

As life is the source of people's development and learning of mathematical concepts, when students encounter real and specific problems regarding numbers, quantities, and shapes in their lives, knowledge of mathematics will allow students to understand and solve them [11]. Mathematical ability is a very important basic ability in human intelligence and is related to various quantitative relationships in life, thus, people naturally want to learn or challenge how to use the concept of quantitative relationships to solve the problems they face [9]. Therefore, the concepts of mathematics and physics should be brought into teaching program coding by connecting them with life in many ways, which will enhance students' interest in mathematics learning, and they can learn easily and naturally in an interesting and pleasant environment. Moreover, such knowledge will allow them to truly utilize their cross-domain knowledge and skills, solve problems, and prevent learning difficulties to achieve the best education effect.

5 Teaching Practice and Action Verification

Hu pointed out that it is imperative to cultivate program design in the age of technology. Teaching should consider both process and results, and should pay greater attention to "process"; it is expected that teachers in the future will implement literacy-oriented teaching, and provide students with sufficient time for practicing exercises, applying outputs, and exploring reflections in the process [13]. This study suggests that results are used by teachers to examine the differences and appropriateness of individual students' learning strategies and abilities in the teaching process, in order to understand how to improve the effectiveness of their teaching strategies. The "process" refers to learning methods that can guide students to create and reflect, provide students with increased participation in interaction and practice, help students take responsibility for their own learning, and cooperate with their peers in a scientific context.

This study was designed with AI robots as the course theme. Through the process of developing AI robots, students can actually learn physical knowledge and develop knowledge. This course provided development examples and physics-related data for students' reference, and students were guided to import mathematics into their programming code to control the action and balance posture of the assembled robot, and thus, achieve the practical application of physical knowledge.

Description: First, turn on the robot's switch and the smartphone's Bluetooth connection to complete the connection. After confirming that detection is obtained, as our theme is dynamic balance, the angle parameters of the balance must be adjusted, each part must be selected to adjust separately, and check the operation after the adjustment is completed. After all parts are adjusted separately, a robot that meets the goal of the theme can be constructed (Fig. 1).

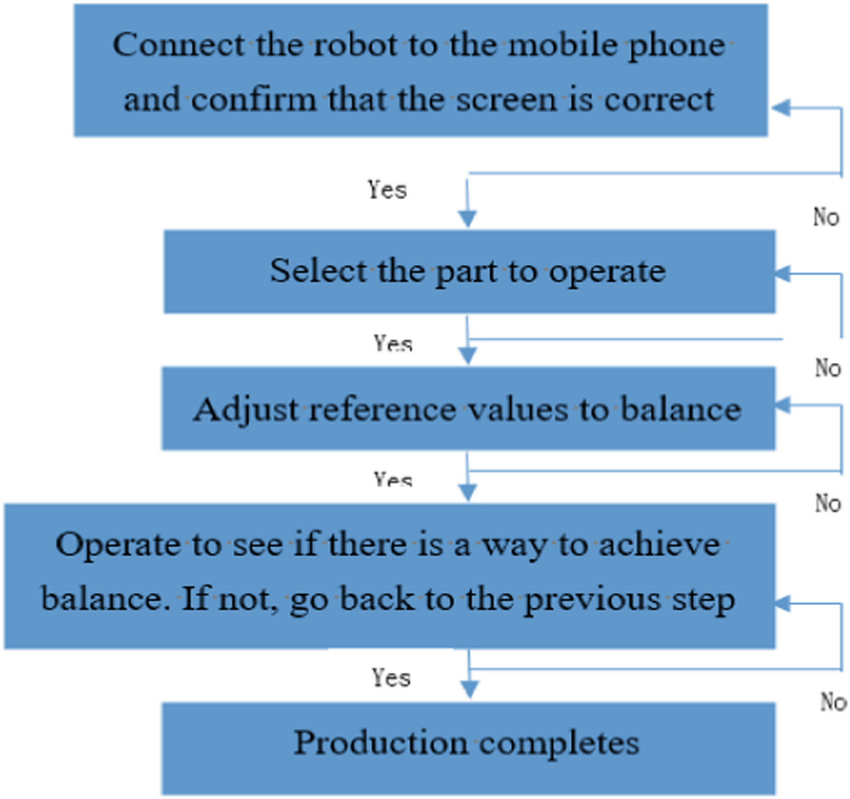


Fig. 1. Process steps.

Each group of three students was provided with a building block set, and after the teacher demonstrated the assembly, the students explored their assembly skills. However, as the students were not very familiar with this new type of assembled robot, they required time to explore the components; for example, students lacking the basic knowledge or ability background in information management spent a lot of time to establish the Bluetooth connection. When the initial movements could not make the robot move in a balanced manner, the students quickly discovered the imbalance of the center of gravity, and immediately reassembled the robot and retested it. After many attempts to replace building blocks, several groups of students still could not make the robot move in balance, thus, the teacher guided them to import the dynamic relationship between mathematics and objects into the program code, or directly use balance as the benchmark to try to change it. Finally, students realized that mathematics and physics had a great influence on the robot's action and motion balance.

5.1 Mathematical Thinking in the Design of Program Code

The JIMU APP integrates the manufacturing, control, and programming of an assembled JIMU robot, thus, users can follow the 3D animation in the smartphone APP to build a JIMU robot and make it move. The mathematical angle is the key to balanced action, thus, through the graphical programming interface, users can learn to program robots, and even see how these graphical interfaces translate to Swift codes.

The angles of the hand servo of the JIMU robot action are shown in Table 1, while Fig. 2 and Fig. 3 show the front and side angles, respectively, when the building block robot action is performed.

Fig. 2. Front view of JIMU robot program during execution

Fig. 3. Side view of JIMU robot program during execution

Table 1. Angle of the hand servo of JIMU robot.

The angle of the hand servo
The angles of the hand servos are 33, 43, 33, and 43°, respectively, and the duration is 400 ms
The angles of the hand servos are −33, −45, −31, and −45°, respectively, and the duration is 400 ms
The angles of the hand servos are −104, 71, −80, and 96°, respectively, and the duration is 400 ms
The angles of the hand servos are −28, −50, −90, and −10°, respectively, and the duration is 400 ms

5.2 Case Interviews

This study interviewed three third-year female students of business and management with experience in learning C language programming during one semester of their freshman year. The students' attitudes towards learning physics knowledge by developing robots are provided, as follows:

Female Student A:

"I have learned how to work as a team, so that the whole process can be smoothly promoted, and complicated things can be simplified so that the students in the team can easily understand them. When designing programs, we've learned the ability to cultivate mathematical logic, so that the assembled robot can continue to operate in a mathematically balanced state".

"There were actually many situations in the process, such as the JIMU program. At first, we thought that some of its actions were limited. We originally thought that there were not many things that could be worked out, but with the efforts of the team members, we designed a lot of novel actions. I think that in addition to learning the theory of knowledge, the other part of this class is practical operation. It has allowed us to operate some machines in practice, know how to think, cooperate, grow, and be familiar with the knowledge and skills that can't be brought to us by books. Then, it will enable us to teach others and turn the knowledge into our own".

Female Student B:

"Sometimes, we had different opinions, so we had to communicate with each other, unify the best idea, show the program code to compare with the building block robot, and learn how to communicate with the team members. I also learned to keep trying hard to assemble components, and constantly trying to change the program code. Don't give up, because in the process of production, we must try to modify various angles so that the robot can reach a balance, and there must be many failures in the process, such as the robot's being unable to stand. But after a few more attempts, we successfully completed our program code".

"By making a JIMU robot, I have entered the world of robots, because I have never had the opportunity to contact robots before, and it was impossible for me to get involved in the program code myself to make the robot perform actions. Only then did I realize that robots already help human beings do so many things, such as being a counter staff in a restaurant or accompanying the elderly. In this course, when I saw that the robot really moved and performed the movements that we designed, I had a sense of achievement, and I felt that I had successfully made the robot move".

Female Student C:

"During this robot-making process, I learned that many robots are not like the previous ones that only have a single function. Our modern robots, especially the more professional robots, can all be connected to a smartphone to become robots with different functions or themes. This is what I think the most special this time".

"Robots are in a field that I am rarely exposed to in my daily life, so I can say that I don't know anything about this part. If I hadn't relied on teamwork, I'm afraid I would not have been able to participate in this work. I feel that this work experience is quite special. It's not just a job on the computer. I think it symbolizes the coming of a new era, because technology is advancing day by day, and robots already occupy a certain part of our lives. Therefore, human beings cannot regress, and they can only progress. Otherwise, human beings may be easily replaced in the future. This is what I have realized this time".

5.3 Discussion

During the practical test, when a group of students tried to connect their robot, there was a problem, and the Bluetooth failed to connect, thus, they asked the researcher (teacher) for help, but the researcher found no problem with the Bluetooth connection. After a few more tries, the connection became successful.

In the process of designing the program code, there were also cases where the designed robot was not able to balance during the movement, or it immediately fell when moving forward. Therefore, some groups of students had repeatedly tried to improve the program code from various angles to adjust and improve the design until there was a way for the robot to achieve balance and execute the program code. Some groups of students observed the balance pattern of the robot and discussed how to adjust the mathematical angle with mathematical thinking, in order that the robot could be balanced during operation.

The implementation process allowed users (students) to understand that the modular robot could make different actions according to different angles, such as running movements could be made with servo ID-1: $-28°$, servo ID-2: $-50°$, servo ID-3: $-90°$, and servo ID-4: $-10°$. Students also found that changing the program code to design different angles might also cause the robot to fail for being unbalanced when moving quickly, thus, no game tasks were designed for users.

Students felt that the creative part of the designed robot was that it can challenge its own limits when balanced by mathematics and physics, such as manipulating the robot's hands and feet to maintain balance and complete more difficult movements without falling down. Such balance manipulations not only helped the robot to move, they also pushed it to the limit of trying some difficult moves under mathematical balance.

Some student groups initially designed simple movements, but after observing the designed movements of other groups, they searched the internet and found that building block robots can complete difficult movements. By discussing and experimenting with their teammates, the students adjusted the mathematical angle of the hand servo to change its movement, which enabled the students to challenge themselves to apply mathematical angles to complete other difficult movements in a rhythmic manner. Under such designed mathematical balance, the students changed the original simple program design to achieve their intended movement.

In fact, there are many problems and challenges in STEAM education, such as the lack of qualified STEAM teachers, as well as the lack and uneven distribution of resources. How should we deal with such issues? In this course, some students felt that, as college students, they should actively study, instead of waiting passively for someone else to teach them. Independent thinking and self-directed learning are useful in the process of learning by oneself.

Regarding programming languages, students believe that more and more people are learning programming languages in recent years, and it is also included in school curriculums. However, it has been observed that when taking a course that involves hands-on learning, some students will encounter frustrations, which often leads to no further in-depth study, whereas others want to overcome these frustrations. If students are studying by themselves, they are advised to use simple introductory courses through apps to make it easier to start improving their abilities.

Regarding everyday life and technology literacy, in contemporary times, technology is combined with life, and the two cannot be separated. When students feel that they can bring their knowledge to life, the subject matter becomes relatable to daily life, thus, applying solutions to life through technology can help users to grow and learn new things.

6 Conclusion and Suggestions

6.1 Conclusion

During the practical operation experiment of this study, students were encouraged to think independently, then, solve problems together in the learning process, and establish personal connections. The multi-dimensional participation and inquiry-based learning style of this course allowed the students to demonstrate mathematics learning and building processes. In terms of learning results, students' inquiry-based learning allowed them to form robots by assembling building blocks, and then, control the robot's balanced movements via mathematics and physics combined with program coding, and thus, achieve a multi-dimensional understanding of the course content explanations, interpret and apply the knowledge, and develop empathy by considering the viewpoints of others through teamwork.

However, programming is a difficult subject for some students. The difficulty for beginners to learn programming is that they can neither understand the process of program execution nor the description methods allowed by the computer. If the presentation of the concepts can be changed via actual visualization when teaching programming, it will help students learn programming. The programming platform of the JIMU robot is a set of technologically innovative building blocks that can apply graphical programming in teaching. After students' exposure is increased, they will have a general understanding of how the program operates the robot, and feel that the JIMU robot is more interesting than simply using computer simulation to learn programming. And at the same time, such exposure will reduce the obstacles and fears of beginners in learning programming.

6.2 Conclusion

This study only conducted one class of experimental teaching at the university. It was determined that the robot programming course in the shape of ninja turtles could arouse the interest of university students to learn programming and improve their attitude towards learning. Therefore, it is suggested that gender should be taken as a dependent variable to study the impact of robotic programming courses on high school students' willingness to learn programming. The students gained a lot of practical experience and reflection in the process of this study. It is recommended that future research can use an experimental group and control group to conduct action experimental teaching, and increase the implementation time of the course, in order to analyze and verify the effect of the creative design of building block robots with smartphone remote control on programming teaching.

Acknowledgments. The authors appreciate the comments of the review committee.

References

1. Chen, Y.Z., Yang, K.L., Lin, F.L.: Fifth and sixth graders' reasoning performance with orthogonal views of cubic blocks. Taiwan J. Math. Educ. **5**(1), 1–34 (2020)
2. Chevalier, M., Giang, C., Piatti, A., Mondada, F.: Fostering computational thinking through educational robotics: a model for creative computational problem solving. Int. J. STEM Educ. **7**(1), 1–18 (2020). https://doi.org/10.1186/s40594-020-00238-z
3. Fang, C.H.: Hands-on designs of playing science with creative plastic straw piping for young children and application to creative teaching with scientific games. STUST J. Humanit. Soc. Sci. **3**, 1–24 (2010)
4. Guo, C.T.: The study of the elements of toys designing based on the viewpoint of physical and mental development of infant children. J. Appl. Arts Des. **1**, 53–62 (2006)
5. Hsieh, Y.S., Chang, S.H.: Creative problem solving integrated into scientific toys making instruction on creativity and scientific creative problem solving for elementary gifted students. Spec. Educ. Forum **20**, 20–35 (2016)
6. Lee, C.W., Huang, S.H., Huang, J.K.: Experience decomposition and learning of form design with building blocks – a link between real image and mental image. J. Des. Environ. **19**, 1–21 (2018)
7. Chen, M.H.: The stimulation of learning potential: an exploration of the effects of short term supplemental instruction on mathematics learning. J. Humanit. Soc. Sci. **10**(2), 1–9 (2014)
8. Ministry of Science and Technology: Science Education Practice - Planning of 2022 Key Research Projects for the Research Project Discipline (2021)
9. Du, S.C., Juan, S.Y., Lin, P.Y.: Kindergarteners' mathematics abilities between disadvantaged and advantaged families. J. Early Child. Educ. **22**, 21–42 (2011)
10. Turner, S.C.: Changing images of the inclined plane: a case study of a revolution in American science education. Sci. Educ. **21**(2), 245–270 (2012). https://doi.org/10.1007/s11191-010-9322-3
11. Tsao, Y.L.: The importance of mathematics education to the development of preschool children. New Trends Cult. Educ. **9**(3), 5–9 (2004)
12. Ye, B.W.: Designed of STEAM-based technology implementation activities in elementary school: rubber band car. Technol. Hum. Resour. Q. **4**(1), 63–75 (2017)
13. Hu, Y.B.: Literacy-oriented teaching: designing perspectives of the S.M drake curriculum. Taiwan Educ. Rev. Mon. **8**(10), 19–26 (2019)
14. Chiu, Y.J.: The mathematical level of science and engineering students. Sci. Mon. **45**(9), 714–717 (2014)
15. Chiu, Y.J.: From seeing to doing: reinforcing core competencies and improving the efficiency of studying on the unit of wave motion. Chin. Phys. Educ. **20**(2), 37–47 (2019)

Application and Design of Innovative Learning

The Effectiveness of Cross-Disciplinary in Problem-Based Learning: An Innovative Implementation of Students' Bakery Performances in the Context of Challenge for STEM Education

King-Dow Su[1,2](✉) and Hsih-Yueh Chen[1]

[1] Hungkuo Delin University of Technology, New Taipei City, Taiwan
su-87168@mail.hdut.edu.tw

[2] Chung Yuan Christian University, Taoyuan CIty, Taiwan

Abstract. This study looked at how interdisciplinary learning concepts were established and whether Problem-Based Learning for STEM teaching materials improved students' learning effectiveness in a novel implementation of new baking performances. All students from Taiwan's University of Technology participated in this study. Through STEM instrument development, five experts contributed to the content, surface, construct validity, and reliability of 35 learning effectiveness test items. The quantitative evaluations of the pretest and posttest revealed that most students improved their STEM cognitive skills of PBL and demonstrated their logical reasoning and activation capacity in the classroom. They might mix theory and practice in systematic thinking with hands-on, machine implementation, and processing of key ingredients to open interactive conversations. Students displayed favorable thinking traits for integrating interdisciplinary PBL and STEM into inventive knowledge, according to the descriptive statistical study of STEM learning efficiency. These findings had ramifications for STEM cognitions in a PBL educational environment in order to improve their baking class vocational competency. Their learning passion and interest in the environment, according to pedagogical proposals, demands long-term development in order to create substantial new vision and value in the future.

Keywords: Cognitive skills · Learning effectiveness · Problem-based learning · STEM

1 Introduction

In the United States, interdisciplinary STEM education emerged by combining Science, Technology, Engineering, and Mathematics (STEM) into a unified learning paradigm in multi-curriculum learning. Students could experience creating links between digital learning and the real world as a result of the STEM challenge. The importance of problem-based learning (PBL) in STEM to develop innovative thinking abilities in students' domain knowledge has already been emphasized by researchers [1, 2]. PBL was

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 355–363, 2022.
https://doi.org/10.1007/978-3-031-15273-3_39

identified as a student-centered teaching style by scholars [3, 4]. They have more control over what they learn when they use PBL and STEM (PBL-STEM) [5, 6].

Through engineering-based thinking, PBL-STEM education could enhance students' communicative expression, teamwork spirit, skill practice, and independent thinking abilities [7]. It would improve their critical reasoning skills, learning interests, and effectiveness [8]. As a result, they needed to participate in a hands-on PBL-STEM discussion in order to create actual opportunities by thinking and acting like engineers and scientists [9]. By relying on domain knowledge from other disciplines, PBL-STEM education could help students find answers to complicated and real-world challenges [10]. Researchers discovered that meta-analyses of PBL-STEM education have verified the impact on their conceptual knowledge and higher-order abilities [11].

As a result, this research uses a complete integration of the PBL-STEM to examine students' learning efficiency in inter-disciplinary baking learning. They hoped that by using this integrated method, they would be able to improve their thinking specifically for the PBL-STEM inter-discipline process through teamwork. In this study, it's possible that creating a PBL-STEM module with a learning objective can aid students in gaining innovative domain knowledge and higher-order thinking skills about scientific solutions.

2 Research Purposes and Questions

This study looked at whether inter-disciplinary PBL-STEM teaching materials benefited students' learning effectiveness in an innovative baking performance implementation. This study intends to answer the following four questions in particular:

1. What is the context of the interdisciplinary PBL-STEM baked creative implementation teaching material?
2. What is the validity and reliability of the evidence of PBL-STEM learning effectiveness assessment tools?
3. How do their learning differences affect the implementation of an interdisciplinary PBL-STEM baking project?
4. How does their one-way ANOVA reveal regard the effectiveness of PBL-STEM learning in relation to students' gender, age, and disposition toward the PBL-STEM pastry bakery course?

3 Literature Review

3.1 STEM Characteristics

The history of current educational research reveals that directing students to STEM achievement has gotten extraordinary local and international attention [12]. Seven essential qualities of STEM education, according to scholars [8, 13], provided different proliferated educational benefits in an interdisciplinary curriculum. Interdisciplinary, interesting, experiential, situational, cooperation, design, evidence, and technological advancement were among the fundamental features. STEM qualities will motivate students to execute some tasks including integrated knowledge, experiences, and problem-solving in a real-world setting. As a result, the core qualities will promote their subject knowledge engagement, cooperation, and motivation [14].

3.2 PBL-STEM Education

PBL was a student-centered instructional method that focused on increasing participants' curriculum comprehension and problem-solving abilities. Students, on the other hand, did not have a single accurate solution in real-world and ill-structured situations [15]. As a result, PBL-STEM integration refers to a wide range of science, technology, engineering, and mathematics (STEM) education that is used as a teaching strategy in PBL [16]. Students benefited from the student-centered approaches in terms of meaningful collaboration and offering a comprehensive during the STEM scaffolding experience task [17]. The purpose was to offer pupils fundamental humanistic literacy as well as information about the subject.

PBL-STEM education blends teamwork, learning, and engagement in the classroom with an environment that encourages innovative advanced thinking [18]. In addition, students handle real-world challenges and complicated social contexts via hands-on, brainstorming thinking, discussion of practical participation, and experience [10]. In this study, the interdisciplinary PBL-STEM education used a combination of machine implementation and processed pertinent elements to determine their learning efficacy.

4 Method

4.1 Participants

A PBL-STEM learning platform was implemented for 115 students and five experts at a university of science and technology in northern Taiwan as part of this study. In terms of students, the pilot test guided 44 first-year students who had prior knowledge to participate in the PBL-STEM learning efficacy developments. The research sample consisted of 71 students with higher-order thinking skills who participated in the PBL-STEM strategy. All ethical considerations were taken into account when the experimental techniques in this study were approved. The students had all done PBL before, but none of them had any STEM experience. One scientist, two scientific and technological academics, one educator, and one media designer were among the five specialists who participated in this study. They logically edited and examined the intelligibility of the PBL-STEM learning questionnaire draft.

4.2 Research Design and Development of Instrument

This study designed a learning effective questionnaire to assess students' curiosity, comprehension capacity, problem-solving ability, self-efficacy, and teamwork in STEM. The questionnaire had two parts: a basic background information section and a structured learning effective questionnaire with alternatives such as strongly agree, agree, neutral, disagree, and strongly disagree on a five-point Likert scale [19]. We obtained quantitative and qualitative data and examined their learning efficacy in PBL-STEM education through the construction of questionnaires and data collection.

In this study, their background information, such as gender, age, and temperament, served as independent factors. In addition, five aspects of the STEM questionnaire were used as dependent variables because of their composition. Patrick [20] and Su's [21] questionnaires were used to create the first draft test items. All five experts contributed to the questionnaire's content and face validity by reviewing, revising, and removing test items. 44 first-year students who studied the pastry bakery course and performed following the mid-term assessment between November and December 2021 participated in a pilot test.

The Cronbach's α average reliability value was greater than .900 in the reliability test, and it received a positive and formal questionnaire [22]. Q1, learning interest towards STEM situational problem-based learning (PBL-STEM) course; Q2, understanding ability towards PBL-STEM course; Q3, problem-solving skill towards PBL-STEM course; Q4, self-efficacy towards PBL-STEM course; and Q5, teamwork towards PBL-STEM course were all included in the STEM learning effectiveness questionnaire. In this study, the final questionnaire, PBL-STEMQ, comprised 35 test items, which were summarized as follows: STEM content (item 1) is precisely the type of learning that I enjoy.

4.3 Data Acquisition

Pre-test and post-test questions were used to assess students' STEM learning efficacy. The PBL-STEMQ has five elements, and the regulations were scored on a five-point Likert-type scale with a range of one to five. At the end of the research, students' learning effectiveness was assessed once more. The acquired data would be analyzed using computer code and Arabic numerals during the pretest and posttest management of PBL-STEM teaching. Cronbach's α internal consistency of the PBL-STEMQ, descriptive statistical analysis, and one-way ANOVA were among the statistical procedures used. All statistical methods for the analysis of their PBL-STEM learning efficacy were done utilizing the SPSS for MS Windows 25.0 application. Data collection and analysis were done with the students' permission. This research was conducted with the help of all students who volunteered and actively engaged. Students agreed to participate in this study.

5 Results and Discussion

5.1 The PBL-STEM Baked Creative Implementation Teaching Material

This research successfully designed an experience PBL-STEM context of the scientific content in the life technology of pastry bakery, as shown in Fig. 1. Based on Miller's [23] learning objectives framework of knowledge and action fifth-level and Ausubel's [24] constructive learning theory, this research successfully designed an experience PBL-STEM context of the scientific content in the life technology of pastry bakery, as seen in Fig. 1. Figure 2 illustrates a PBL-STEM multivariate learning environment and conversation to develop students' broader basic knowledge and cross-disciplinary to guide PBL-STEM multivariate learning environment and discussion. In science, the finished product is baked in an acceptable shape after fermentation, using flour as the major raw material, adding water, yeast, salt, and auxiliary raw materials oil, sugar, eggs, milk, or other raw materials, and adding legal improvers or additives. In the hands-on of pastry, what is the fermentation process? Fermentation is a biological reaction that involves the usage of organisms such as bacteria, plant cells, and yeast to breakdown organic waste. Winemaking and bean fermented foods both employ the same fermentation method. Fermentation reaction:

$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2\ \triangle H = 118\ \text{kJ/mol}$

To summarize, fermentation can be defined in a broad sense as the change of organic matter caused by enzymes. In the field of technology, a mixer is used to: (1) Select the proper mixer for the product, and the maximum mixing volume should not exceed 2/3 of the mixing tank. (2) When first starting off, keep your hands and utensils out of the mixing tank. (3) When you open the door, check to see if the transmission remains in the correct speed position. When altering the stirring speed, switch the machine off first, then change the speed from low to medium to high. Always switch off the electricity before adjusting the speed. (4) When stirring granular ingredients, start slowly and gradually increase the speed, as this will cause the powder to fly. However, as technology has advanced, the oven has progressed from a kiln constructed of bricks or stones in the early days to a bunker-style oven, and finally to an oven heated by electricity or gas. It can be classified as an electric oven, a gas oven, a steam oven, a diesel oven (which is less common), and so on, depending on the source of energy.

Choosing a good and suitable work surface in engineering processes will make the snack maker more convenient in the operation process, as well as achieve the effect of hygiene and safety. According to ergonomics, the work surface should be exactly the same height as the operator's waist (typically around 90 to 120 cm), so that the operator does not become weary or sore in the back after a long period of activity. The most widely used worktops are stainless steel counters. Marble countertops are often made of granite or man-made stone. Finally, weighing, stirring raise temperature calculation, applicable to water temperature calculation, and calculation of specific gravity of batter, among other things, are all covered in mathematics.

STEM education, according to Vasquez et al. [25], encouraged pupils to know learning goals of knowledge and action using multidisciplinary approaches. Scholars [26–28] have found that the PBL-STEM baked innovative implementation teaching materials activities have a favorable impact on students' achievement in life technology.

5.2 The Validity and Reliability of the Assessment Tools

The five experts' agreement score in the validity and reliability of the PBL-STEM learning effectiveness evaluation tools is .95, which is a respectable average agreement rate. According to Polit et al. [29], the Content Verification Index value should be at least .78. The average Cronbach's value, mean value, and standard deviation for the PBL-STEM learning effectiveness evaluation instruments are .967, 3.9, and .7, respectively, according to a descriptive statistical study. Researchers [22, 30] considered the values for their dynamic statistic discoveries arrived at a positive satisfactory level.

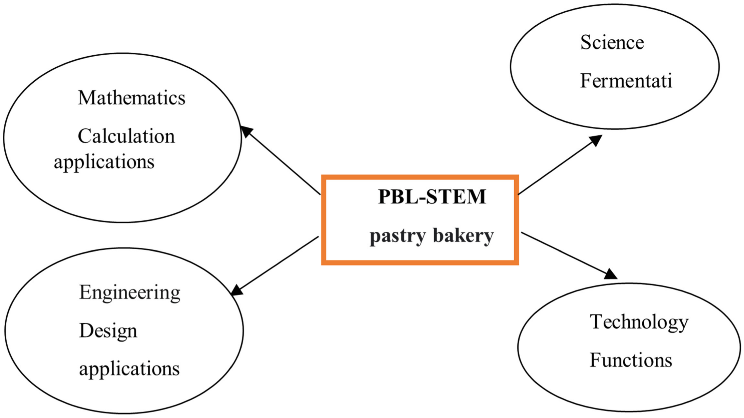


Fig. 1. Students' experience PBL-STEM teaching materials in the life technology of pastry bakery.

Fig. 2. Students' hands-on experience PBL-STEM group learning in the pastry bakery course.

5.3 Students' Learning Differences

T-tests were used to see how the learning differences between the pretest and posttest affected the implementation of an interdisciplinary PBL-STEM baking project. The results demonstrated that the efficiency of PBL-STEM learning among subscales was significant ($p < .05$) and superior to pretest for Q1, Q3, Q4, and Q5. For professional learning interest, problem-solving skill, self-efficacy, and teamwork skills, the statistical findings revealed that four dependent variables were significant. The learning differences between the pretest and posttest were not significant in comprehending abilities toward PBL-STEM course. Learning interest, problem-solving, self-efficacy, and collaborative abilities were found to be major elements determining learning differences in PBL-STEM courses by researchers [20, 31-33].

5.4 One-Way ANOVA

How does their one-way ANOVA reveal regard the effectiveness of PBL-STEM learning in relation to students' gender, age, and disposition toward the PBL-STEM pastry bakery course? ANOVA statistical tests were used to scrutinize their learning differences in gender, age, and disposition about the PBL-STEM pastry bakery course. The outcomes revealed that gender differences in learning throughout five subscales were not significant, and their effect sizes were below medium [34]. That really is, there were hardly any learning differences between male and female students in the course.

Learning differences of the PBL-STEM pastry bakery course among five subscales were significantly different and had large impact sizes ($f > .4$), Q1($F = 12.13, p < .001, f = .74$), Q2($F = 6.90, p < .001, f = .56$), Q3($F = 5.21, p = .003, f = .49$), Q4($F = 6.99, p < .001, f = .56$), Q5($F = 3.88, p = .013, f = .42$) as students age. Additionally, Scheffé's post-hoc analysis revealed significant differences within all subscales from Q1 to Q5. There were two probable justifications for the variations. Freshmen, on the one hand, are more curious and interested than seniors, and on the other hand, freshmen are more engaged in group discussions than seniors.

All five dependent variables in the STEM pastry bakery course are significantly different, and the effect sizes ($f > .4$) are all larger than substantial [34]. Then, through Scheffé's post-hoc comparison, they may see that their independent variables have significant differences. In this study, "extremely positive" was preferred over "positive" and "neutral" by all five dependents. That is, in PBL-STEM education, students' dispositions will play vital roles in learning effectiveness.

The quantitative findings showed that including STEM education into PBL teaching improved students' learning effectiveness, helped them understand the goal of problem-solving and allowed them to interact more meaningfully in these settings [35, 36]. The PBL technique was also shown to have a lot of potential in helping real-world problem solving in the STEM pastry baking course [37]. As previously stated, the PBL group cooperative learning demonstrated a collaborative environment that was favorable to right thinking guidance and training [19, 38].

6 Conclusions

Considering the aforementioned findings and perspectives, cross-disciplinary PBL-STEM education produced numerous favorable interactive learning environments through innovative implementation of students' performances. However, most students benefited from the hands-on practice contact and direction in the pastry bakery, which helped them expand their cognition knowledge, problem-solving abilities, and learning levels.

All of the cross-disciplinary results emphasized students' logical reasoning and critical thinking abilities, which might give them confidence overall problem-solving abilities in STEM education by implementing innovative pastry bakery performances.

Acknowledgements. The author wishes to express his appreciation to the Ministry of Science and Technology in Taiwan for their support (under Grant No. MOST 110-2511-H-237-001). This research could not have been accomplished in its current form without their assistance and financial support.

References

1. Mizell, S., Brown, S.: The current status of STEM education research 2013–2015. J. STEM Educ. **17**(4), 52–56 (2016)
2. Siew, N.M., Chong, C.L., Lee, B.N.: Fostering fifth graders' scientific creativity through problem-based learning. J. Balt. Sci. Educ. **14**(5), 655–669 (2015)
3. Lapuz, A.M., Fulgencio, M.N.: Improving the critical thinking skills of secondary school students using problem-based learning. Int. J. Acad. Multidiscip. Res. **4**(1), 1–7 (2020)
4. Torp, L., Sage, S.: Problems as Possibilities: Problem-Based Learning for K-16 Education, 2nd edn. Association for Supervision and Curriculum Development (2002)
5. Loi, N.V.: Promoting learner autonomy: Lesson from using project work as a supplement in English skills courses. Can Tho Univ. J. Sci. **7**, 118–125 (2017)
6. Yuliani, Y., Sri Lengkanawati, N.: Project-based learning in promoting learner autonomy in an EFL classroom. Indones. J. Appl. Linguist. **7**(2), 285–293 (2017)
7. Honey, M., Pearson, G., Schweingruber, H.: STEM integration in K-12 education: status, prospects, and an agenda for research, Washington, DC (2014)
8. Moore, T.J., Tank, K.M., Glancy, A.W., Kersten, J.A.: NGSS and the landscape of engineering in K-12 state science standards. J. Res. Sci. Teach. **52**(3), 296–318 (2015)
9. Williams, J.P.: STEM education: proceed with caution. Des. Technol. Educ. Int. J. **16**, 26–35 (2011)
10. English, L.D., King, K., Smeed, J.: Advancing integrated STEM learning through engineering design: sixth-grade students' design and construction of earthquake resistant buildings. J. Educ. Res. **110**(3), 255–271 (2017)
11. Kim, N.J., Belland, B.R., Walker, A.E.: Effectiveness of computer-based scaffolding in the context of problem-based learning for STEM education: Bayesian meta-analysis. Educ. Psychol. Rev. **30**, 397–429 (2018). https://doi.org/10.1007/s10648-017-9419-1
12. Han, S., Rosli, R., Capraro, M.M., Capraro, R.M.: The effect of science, technology, engineering and mathematics (STEM) project-based learning (PBL) on students' achievement in four mathematics topics. J. Turk. Sci. Educ. **13**, 3–29 (2016)
13. Tsai, L.-T., Chang, C.-C., Cheng, H.-T.: Effect of a stem-oriented course on students' marine science motivation, interest, and achievements. J. Balt. Sci. Educ. **20**(1), 134–145 (2021)
14. Shahin, A., Top, N.: STEM students on the stage (SOS): promoting student voice and choice in STEM education through an interdisciplinary, standards-focused, project-based learning approach. J. STEM Educ. **16**, 24–33 (2015)
15. Thistlethwaite, J.E., et al.: The effectiveness of case-based learning in health professional education. A BEME systematic review: BEME Guide No. 23. Med. Teach. **34**, e421–e444 (2012)
16. Wallace, M.F.G., Webb, A.W.: In the midst of a shift: undergraduate STEM education and "PBL" enactment. J. Coll. Sci. Teach. **46**, 47–55 (2016)
17. Belland, B.R., Walker, A.E., Kim, N.J., Lefler, M.: Synthesizing results from empirical research on computer-based scaffolding in STEM education: a meta-analysis. Rev. Educ. Res. **87**(2), 309–344 (2017)
18. Cencelj, Z., Aberšek, M.K., Aberšek, B., Flogie, A.: Role and meaning of functional science, technological and engineering literacy in problem-based learning. J. Balt. Sci. Educ. **18**(1), 132–146 (2019)
19. Su, K.D.: Implementation of innovative artificial intelligence cognitions with problem-based learning guided tasks to enhance students' performance in science. J. Balt. Sci. Educ. **21**(2), 245–257 (2022)
20. Patrick, L.B., James, P.C., Donna, M., Christopher, W.D., Alicia, B.: An examination of middle school students STEM self-efficacy with relation to interest and perceptions of STEM. J. STEM Educ. **17**(3), 27–37 (2016)

21. Su, K.D.: Strengthening strategic applications of problem-solving skills for Taiwan students' chemistry understanding. J. Balt. Sci. Educ. **15**(6), 662–679 (2016)
22. Salta, K., Tzougraki, C.: Attitudes toward chemistry among 11th grade students in high schools in Greece. Sci. Educ. **88**(4), 535–547 (2004)
23. Miller, G.E.: The assessment of clinical skills/competence/performance. Acad. Med. **65**(9), S63–S67 (1990)
24. Ausubel, D.P.: The Acquisition and Retention of Knowledge: A Cognitive View. Kluwer Academic Publishers, Dordresht (2000)
25. Vasquez, J.A., Sneider, C., Comer, M.: STEM Lesson Essentials, Grades 3–8: Integrating Science, Technology, Engineering, and Mathematics. Heinemann, London (2013)
26. Ercan, S., Sahin, F.: The usage of engineering practices in science education: effects of design-based science learning on students' academic achievement. Necatibey Fac. Educ. Electron. J. Sci. Math. Educ. **9**(1), 128–164 (2015)
27. Gulhan, F., Şahin, F.: Fen-teknoloji-muhendislik-matematik entegrasyonunun (STEM). sınıf oğrencilerinin kavramsal anlamalarına ve mesleklerle ilgili goruşlerine etkisi, pp. 283–302. Pegem Yayıncılık (2016). The effect of science-technology-engineering-mathematics integration (STEM) on 5th grade students' conceptual understanding and views on professions
28. Wendell, K.B., Rogers, C.: Engineering design-based science, science content performance, and science attitudes in elementary school. J. Eng. Educ. **102**(4), 513–540 (2013)
29. Polit, D.F., Beck, C.T., Owen, S.V.: Is the CVI an acceptable indicator of content validity? Appraisal and recommendations. Res. Nurs. Health **30**(4), 459–467 (2017)
30. Su, K.D.: Enhancing students' corresponding reasoning of cognitive performances by animated concept mapping in electrochemistry. J. Balt. Sci. Educ. **17**(4), 662–673 (2018)
31. Dabney, K.P., et al.: Out-of-school time science activities and their association with career interest in STEM. Int. J. Sci. Educ. Part B **2**(1), 63–79 (2012)
32. Jansson, S., Soderstrom, H., Andersson, P.L., Nording, M.L.: Implementation of problem-based learning in environmental chemistry. J. Chem. Educ. **92**, 2080–2086 (2015)
33. Mohtar, L.E., Halim, L., Rahman, N.A., Maat, S.M., Iksan, Z.H., Osman, K.: A model of interest in STEM careers among secondary school students. J. Balt. Sci. Educ. **18**(3), 404–416 (2019)
34. Cohen, J.: Statistical Power Analysis for the Behavioral Sciences, 2nd edn. Erlbaum, Mahwah (1988)
35. Mayer, K.: Addressing students' misconceptions about gases, mass, and composition. J. Chem. Educ. **88**(1), 111–115 (2011)
36. Mundilarto, H.I.: Effect of problem-based learning on improvement physics achievement and critical thinking of senior high school student. J. Balt. Sci. Educ. **16**(5), 761–780 (2018)
37. Hernández-Ramos, J., Pernaa, J., Cáceres-Jensen, L., Rodríguez-Becerra, J.: The effects of using socio-scientific issues and technology in problem-based learning: a systematic review. Educ. Sci. **11**(10), 640 (2021)
38. Rillero, P., Chen, Y.C.: The use of a digital problem-based learning module in science methods courses. J. Probl. Based Learn. High. Educ. **7**(1), 107–119 (2019)

Application for Digital Affective Learning to Improve the Emotion Regulation of Children with Emotional Handicap

Fu-Rung Yang[1], Jih-Hsin Tang[2(✉)], and Chih-Fen Wei[3]

[1] Center for General Education, National Taipei University of Education, Taipei City, Taiwan
[2] Department of Information Management, National Taipei University of Business, Taipei City, Taiwan
jefftang@ntub.edu.tw
[3] Department of Psychology and Counseling, University of Taipei, Taipei City, Taiwan

Abstract. The number of students exhibiting long-term emotional or behavioral problems has increased. Such students face difficulty in adjusting to school life and might be unhappy, angry, or frustrated. In this study, we developed an application (app) for digital affective learning to improve the emotion regulation of children facing emotional difficulties. A total of 26 children were recruited in this study to participate in an experiment; half of the participants exhibited typical emotional development and the other half had emotional problems. The recruited children were aware of their emotional state and used numerical clicks to select their current emotions when using the developed app. Cognitive behavioral therapy was used to modify the children's attribution and cognitive patterns. The children were also encouraged to develop positive problem-solving strategies. The developed app records information regarding the time, the weather, and a person who gets along with the child. The experimental results indicated that the use of the developed affective learning app resulted in improvements in the emotional state of the typically developing children and the children with emotional problems. The developed app enhanced the positive emotion of the two groups, and no significant difference was noted in the enhancement in positive emotion between the two groups.

Keywords: Digital affective learning · Emotion regulation · Children with emotional handicap · Positive emotion

1 Introduction

Long-term emotional or behavioral difficulties considerably affect the adjustment of children to school life. Emotional problems include extroverted behaviors, such as aggression and disobedience, and introverted behaviors, such as anxiety and depression [1]. The inappropriate behaviors and emotions of children with emotional problems affect their interpersonal relationships with teachers and peers, and such children tend to exhibit unhappy, frustrated, and angry emotions in school. Eisenhower et al. indicated

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 364–371, 2022.
https://doi.org/10.1007/978-3-031-15273-3_40

that teachers feel considerable pressure when handling disruptive behavior from children with emotional problems [2]. Such children can improve their social adjustment by learning emotion regulation.

2 Literature Review

2.1 Emotion Regulation

Emotions involve loosely coupled changes in the domains of subjective experience, behavior, and peripheral physiology [3]. Emotion-related behaviors include changes in facial expression; posture; and situation-specific instrumental behaviors, such as withdrawing or striking. Individuals can apply emotion regulation by, for example, focusing on their breathing, reading a book, or thinking about a situation differently. According to the process model of emotion regulation (Fig. 1), different emotion regulation strategies have distinct consequences for how a person feels, thinks, and acts immediately and over a long-term period [3]. Situation selection refers to taking actions that make it more (or less) likely that one would elicit desirable (or undesirable) emotions. Situation modification refers to taking actions that directly modify the situation to alter its emotional impact. Attentional deployment involves directing one's attention to influence one's emotional responses. Cognitive change refers to modifying one's assessment of a situation to alter its emotional impact. Response modulation refers to the modification of experiential, behavioral, or physiological components that directly influence emotional responses following emotional development [3].

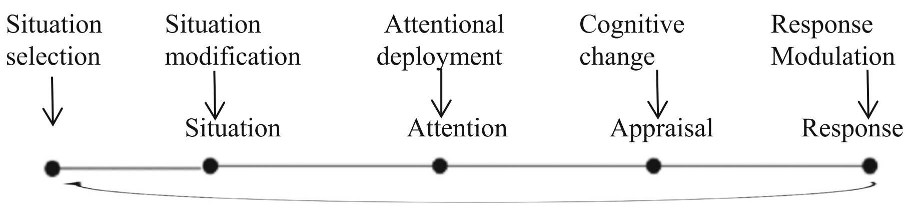


Fig. 1. Process model of emotion regulation.

Emotion regulation is similar to coping, but it refers specifically to attempts to influence the emotions that one experiences, when one experiences these emotions, and how one experiences or expresses these emotions [4]. People use many methods to control or regulate their emotions.

2.2 Emotion Regulation in Children with Emotional Problems

Children with autism or attention deficit hyperactivity disorder face difficulty in emotional regulation and exhibit introverted behavior. Difficulties in emotional regulation and introverted behavior can prompt disruptive and extroverted behaviors [5]. The inappropriate behaviors and emotions of children with emotional problems affect their relationships with teachers and peers.

Children with emotional problems exhibit deficits in their emotion regulation. Emotion regulation is crucial for controlling negative emotions and negative behaviors. It includes the abilities to listen, follow directions, and work independently; inhibitory control; and cognitive regulation skills [6]. Emotion regulation can help a person effectively improve their problematic behaviors and improve their relationships with others [7].

2.3 Digital Affective Learning

Digital affective learning has the advantages of convenience and time flexibility. Children can engage in digital learning as per their own schedules. Hsu et al. designed a digital self-discovery game for regulating teenagers' emotions [8]. Their results indicated that adolescents exhibit significant improvements in self-identity, courage, empathy, values, and emotion regulation after playing digital self-exploration games. On the basis of cognitive behavioral theory, Yang et al. developed a digital emotion regulation application (app), which was found to help children with emotional problems regulate their emotions in a pilot study [9]. The results of the study of Yang et al. indicated that the content of their app can effectively improve children's positive emotions. Thus, digital emotion learning had potential for improving children's positive emotions.

In the present study, we designed a digital affective learning app for emotion regulation that can be easily used by children. This app helps children with emotional handicap to become aware of their emotions and change their attribution of cognitive patterns. In digital affective learning, children might learn to generate positive behaviors for solving problems, improve their positive emotions, and enhance their social adaptation. In the current research, we explored the following questions:

1. What is the positive emotional outcome when children with emotional problems use an app for digital affective learning?
2. Is there difference in improvement in positive emotion between typically developing children and children with emotional problems after the use of an app for digital affective learning?

3 Method

3.1 Participants

A total of 26 elementary school children were recruited in this research, with 13 of them being typically developing children without emotional problems and the remaining 13 being children with emotional problems. A parent or teacher filled out an emotional disturbance assessment scale for each child [10]. The participants with emotional handicap of this study were students from nonconcentrated special education classes, and these students were assessed by special education teachers as having autism, emotional problems, or attention deficit hyperactivity disorder that result in interpersonal interaction challenges. The parents of the participating children provided consent for their participation in the experiment, and all relevant protocols were reviewed by an institutional review board.

3.2 Procedures

We designed an app for digital affective learning. All the participants used this app eight times over 4 weeks, and the changes in their positive emotions after using the app were explored. The developed affective learning app comprises an emotion thermometer, feeling journals, a gaming zone, and a personal area. The emotion thermometer is used with cognitive behavior therapy to help children change their attribution and cognitive patterns. The participants of this study were aware of their emotional state and used numerical clicks to represent their current emotional state. The developed app allows children to examine their physical reactions and thoughts. It encourages children to use relaxation exercises, diversion techniques, and positive cognitive reassessment to calm their emotions. The app also encourages children to consider feasible positive problem-solving methods and helps them detect differences in their emotional state. In feeling journals, children can record information on the time, the weather, and a person who gets along with them. The introductory sentences in these journals teach children how to think about their inner emotions and use words to address their emotions. The game zone contains puzzles and emotion recognition games to help children feel that they have the ability and control through the puzzles, and understand emotional words. After children finish the game, they receive feedback immediately. In the personal area, a chart or table is provided to indicate the emotion progress of a child. Children can review their emotional state in the previous month and maintain an emotion diary (Figs. 2, 3 and 4).

Fig. 2. Emotional state of a child.

Fig. 3. Relaxation training provided to a child.

Fig. 4. Relaxation training provided to a child

The children participating in this study used the developed app to record their emotional states before and after app use. We explored the difference in emotional state between typically developing children and children with emotional problems after app use.

3.3 Data Analysis

We used SPSS 22 for analyzing the descriptive statistics and conducted a paired t test to examine whether the emotion regulation of typically developing children and those with emotional problems improved after affective learning. Furthermore, we conducted an analysis of covariance (ANCOVA) to examine the difference in improvement in emotion regulation between the two groups after app usage.

4 Results

4.1 Descriptive Analysis

Table 1 lists the means and standard deviations of the emotional disturbance scores of the two groups. As presented in Table 1, the typically developing children exhibited a higher emotional disturbance score (M = 4.54, SD = .16) than did the children with emotional problems (M = 3.65, SD = .43). The children with emotional problems exhibited more emotional and behavioral problems than did the typically developing children (Table 2).

Table 1. Mean and standard deviation of the emotional disturbance scores of the typically developing children and children with emotional problems

	N	Mean	SD
Typically developing children	13	4.54	.16
Children with emotional problems	13	3.65	.43

SD: standard deviation

Table 2. Mean and standard deviation of the emotional state of the typically developing children and children with emotional problems

	Typically developing children (N = 13)		Children with emotional problems (N = 13)	
	Mean	SD	Mean	SD
Pretest	4.38	.51	4.69	1.25
Posttest	5.92	1.32	6.38	1.04

SD: standard deviation

4.2 Comparison of the Pretest and Posttest Results Obtained for the Two Groups

The results of the paired t test are presented in Table 3. Significant differences were observed in the pretest and posttest emotional states of the typically developing children ($t = -4.92, p = .000$) and children with emotional problems ($t = -5.16, p = .000$). The positive emotions of both groups significantly improved after using the developed app.

Table 3. Results of the paired t test

	Post–pre mean diff	S.D.	*t*	*p*
Typically developing children	−1.54	1.13	−4.92***	.000
Children with emotional problems	−1.69	1.18	−5.16***	.000

*$p < .05$, **$p < .01$, ***$p < .001$; SD: standard deviation

4.3 Difference Between the Emotional States of the Normal Children and Children with Emotional Handicap After App Usage

The results of the ANCOVA are presented in Table 4. When the pretest emotional state was controlled for, the posttest scores for the emotional state did not differ between the two groups.

Table 4. ANCOVA results

	SS	df	MS	F	*p*
Pretest	6.51	1	6.51	5.44	.029
Children	.55	1	.55	.46	.506
Error	27.49	23	1.20		

*$p < .05$, **$p < .01$

5 Discussion and Conclusion

In this study, we invited 13 children with emotional problems and 13 typically developing children to use an app developed for digital affective learning. These children exhibited significant improvement in their positive emotion expressions after using the developed emotion regulation app. Furthermore, no significant difference was noted in the improvement in positive emotion between the two groups. This result suggests that typically developing children and children with emotional problems might employ similar emotion regulation strategies.

The developed app includes strategies for emotional awareness, observing others, physiological relaxation, attention shifting, and cognitive restructuring, which are used to teach children with emotion problems to regulate emotions in a positive and effective manner. Children can operate the developed app by themselves. They can record their emotional state in the personal area of the app, which can help teachers understand the students' status. Teachers can also observe the influences of weather and temperature changes on the emotion of children with emotional problems from the app and help these children regulate their emotions. The developed app can help mitigate the distress caused by inappropriate emotional expression or extroversion problems among children with emotional problems.

6 Limitations and Directions for Future Research

This study has certain limitations. First, the research sample might be biased because only children whose parents provided consent were able to participate in this study. Parents who provided this consent may be more likely to prioritize their children's emotional education. In the future, we will verify the results of this study by recruiting additional children. Second, in this study, we only explored the change in children's emotion after digital affective learning. Future studies should investigate the effects of digital affective learning on children's changes in social adjustment in school.

References

1. McKenna, J.W., et al.: A systematic review of intervention studies for young children with emotional and behavioral disorders: identifying the research base. J. Res. Spec. Educ. Needs **21**(2), 120–145 (2021). https://doi.org/10.1111/1471-3802.12505
2. Eisenhower, A., Blacher, J., Hurst Bush, H.: Longitudinal associations between externalizing problems and student–teacher relationship quality for young children with ASD. Res. Autism Spectr. Disord. **9**(1), 163–173 (2015). https://doi.org/10.1016/j.rasd.2014.09.007
3. Gross, J.J.: Emotion regulation: current status and future prospects. Psychol. Inq. **26**, 1–26 (2015). https://doi.org/10.1080/1047840X.2014.940781
4. Gross, J.J.: The emerging field of emotion regulation: an integrative review. Rev. Gen. Psychol. **2**, 271–299 (1998)
5. Pruijssers, A.C., van Meijel, B., Maaskant, M., Nijssen, W., van Achterberg, T.: The relationship between challenging behaviour and anxiety in adults with intellectual disabilities: a literature review'. J. Intell. Disabil. Res. **58**(2), 162–171 (2014). https://doi.org/10.1111/jir.12012
6. Blair, C., Raver, C.C., Berry, D.J., Family Life Project Investigators: Two approaches to estimating the effect of parenting on the development of executive function in early childhood. Dev Psychol. **50**(2), 554–565 (2014). https://doi.org/10.1037/a0033647
7. Nucifora, A., Walker, S.: The importance of self-regulation: a mediator of early socio-emotional difficulties on later socio-emotional and relational outcomes. J. Res. Spec. Educ. Needs **21**(1), 3–18 (2021). https://doi.org/10.1111/1471-3802.12495
8. Hsu, Y.J., Wen, Y.Y., Yang, M.C., Hwang, G.J.: Exploring the development of teenagers' emotion regulation in the digital self-discovery game. Int. J. Digit. Learn. Technol. **10**(3), 103–132 (2018). https://doi.org/10.3966/2071260X2018071003005
9. Yang F.R., Tang, J.H., Wei, C.F.: Empower Yourself- Digital Emotional Regulation App for Children with Emotional Handicap. 2021 Application of the Artificial Intelligence and Mobile Interactive Technologies in Business and Management Education (2021)
10. Cheng, L.Y.: Scale for Assessing Emotional Disturbance. Psychological Publishing, Taipei (2001)

Enhancement of Reading Comprehension Skills in Collaborative Setting: A Preliminary Research on Students' Perception

Olivia de H. Basoeki[1,2] and Ting-Ting Wu[1](✉)

[1] Graduate School of Technological and Vocational Education, National Yunlin University of Science and Technology, Yunlin County, Taiwan
ttwu@yuntech.edu.tw

[2] Kupang State Polytechnic, Kupang, East Nusa Tenggara, Indonesia

Abstract. This preliminary research aimed to examine students' perceptions of the effectiveness of the RT-CL strategy in enhancing students' reading comprehension skills at Kupang State Polytechnic, East Nusa Tenggara-Indonesia. A pre-experimental design with an experimental class took one group of pre-test and post-test survey questionnaires to identify how the RT-CL strategy was perceived to promote students' activeness and stimulate students' motivation. The paired sample *t*-test analysis indicated that the most significant change was motivation, which was 0.859 (2,925 to 3,784), and activeness which was 0.667 (3,255 to 3,922). This study revealed that the RT-CL strategy supports one another to help students enhance reading comprehension skills in less time. The strategy emphasized students participating in text discussion and active work with the subject material, mainly improving reading comprehension skills. In addition, most students felt motivated to read and could engage actively to accomplish English text quickly and accurately, reducing stress and eliminating boredom.

Keywords: Reading comprehension · RT-CL strategy · Students' perception

1 Introduction

Developing students' reading comprehension has always been an objective of many English teachers [1]. Though many students can read fluently, it does not guarantee they understand what they read well. They should interact with what they read to understand the content accurately and quickly [2, 3].

Reading comprehension is one essential skill for students' progress in academic learning and future career development [3]. Therefore, teachers must provide an excellent strategy to assist students with reading comprehension skills [4]. Underscoring this point is crucial to applying effective and efficient techniques, encouraging students to be more engaged and motivated to participate in the classroom actively.

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 372–381, 2022.
https://doi.org/10.1007/978-3-031-15273-3_41

Furthermore, integrating learning components can assist students in learning best and enrich learning outcomes [5]. Therefore, it encourages the researcher to incorporate instructional strategies to develop students' proficiencies and skills in reading comprehension. Consequently, the researcher equips reciprocal teaching (RT) with collaborative learning (CL) as a model breakthrough instructional strategy that creates a vivid classroom atmosphere for reading comprehension at Kupang State Polytechnic (henceforth PNK), East Nusa Tenggara-Indonesia [6].

This preliminary research purposed to determine students' perceptions of the RT-CL strategy's effectiveness in enhancing students' reading comprehension skills at PNK. However, due to the COVID-19 pandemic, Indonesia's 2020 school year has been dominated by online education. Thus, considering that situation, this study was conducted through online learning with a small student sample to minimize connection disruptions and the availability of supporting facilities.

In addition, this preliminary research implicitly introduces how to implement the RT-CL strategy whereby the involved students could later assist others in applying its strategy to the actual research. To this end, the study administered a survey questionnaire as a measurement tool. It focuses on students' perceptions of the effectiveness of using the RT-CL strategy by formulating two goals guided: a) the RT-CL strategy was believed to promote students' activeness; b) the RT-CL strategy was perceived as stimulating students' motivation.

2 Literature Review

2.1 Reading Comprehension and Reciprocal Teaching

One common instructional strategy to assist students in comprehending the text better is reciprocal teaching (RT) [7]. It is designed based on the four techniques for students who experience difficult comprehension. These four techniques are used as a guide where reading comprehension skills are needed [8]. It includes predicting what will happen next in the text, clarifying the confusing words or text sections, generating questions, and summarizing essential information in the students' own words. RT in reading comprehension has positively affected students' reading comprehension. For instance, it was carried out by [9] to examine the effectiveness of RT in promoting adolescents' reading comprehension and guided practice activities on adolescent academic skills [10].

2.2 Reading Comprehension and Collaborative Learning

Reading comprehension focuses on the students' competence to understand and use the information they read, so students must interact with the text to construct a meaning successfully. Hence, one good solution to this reading gap is peer interaction [11]. In the CL activity, peer interaction enables students to share ideas and pool their knowledge and experience among the group members to reach a goal [12]. Further, in groups, students engage actively and effectively in their learning. They quickly handle the tasks with peers in the teaching and learning process [13]. Numerous research has noted the advantages of peer collaboration for literacy instruction [14]. For example, through peer interaction in the CL group, students help each other, and the weak student is supported and assisted in practice with brighter students [15].

3 Methodology

3.1 Research Design and Participants

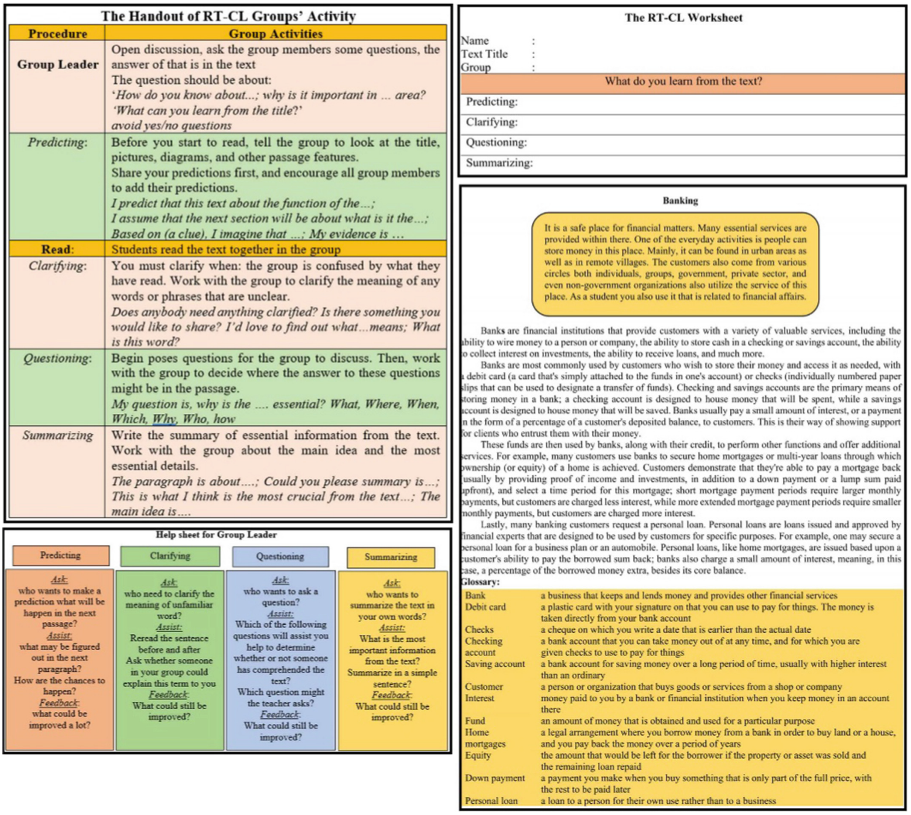
The study used a pre-experimental design with an experimental class that took one group pre-test and post-test survey questionnaires. Since it was conducted through online learning, the participants were limited to avoiding frequent connection problems and other technical issues. Ten students from the Business Administration Department were selected randomly.

3.2 Procedures

Some procedures were used in this study. This design started with a pre-test to examine the students' basic abilities before providing treatment. Next, students were treated with the RT-CL strategy with a pre-test article to gain deep knowledge. After the learning activities were completed, a post-test on additional articles was conducted.

In the treatment, the teacher initially demonstrated each function of the four RT techniques in comprehending the text collaboratively. Then, as students became familiar with the RT-CL strategy, they were divided into two experimental groups of five for easy control. Afterward, they had a chance to participate in text discussion through group interaction with peers to comprehend the text by collaboratively accomplishing the worksheet task on the four target techniques.

Since this study integrates RT with CL as effective practice to enhance students' reading comprehension, some interventions were used in group interaction to optimize CL in its strategy. First, it involved *the preface and glossary* to attract students' curiosity about the text and related to time efficiency. At the same time, *the handout of the RT-CL in groups activity* was employed to keep students active in group discussion and focused on practicing four target techniques in comprehending the text. Besides, *the worksheet task* was provided to determine students' progress in constructing their comprehension of the text. Afterward, *the help sheet of group leaders* assists leaders in leading text discussions collaboratively and directing members' reading activities. Each group member takes turns as the leader. Consequently, text discussion was carried out per paragraph so that each member engaged actively in group interaction by implementing the four target strategies to comprehend the text. Figure 1 below shows the RT-CL intervention.



The Handout of RT-CL Groups' Activity

Procedure	Group Activities
Group Leader	Open discussion, ask the group members some questions, the answer of that is in the text The question should be about: *'How do you know about...; why is it important in ... area?* *'What can you learn from the title?'* *avoid yes/no questions*
Predicting:	Before you start to read, tell the group to look at the title, pictures, diagrams, and other passage features. Share your predictions first, and encourage all group members to add their predictions. *I predict that this text about the function of the ...;* *I assume that the next section will be about what is it the ...;* *Based on (a clue), I imagine that ...; My evidence is ...*
Read:	Students read the text together in the group
Clarifying:	You must clarify when: the group is confused by what they have read. Work with the group to clarify the meaning of any words or phrases that are unclear. *Does anybody need anything clarified? Is there something you would like to share? I'd love to find out what...means; What is this word?*
Questioning:	Begin poses questions for the group to discuss. Then, work with the group to decide where the answer to these questions might be in the passage. *My question is, why is the .... essential? What, Where, When, Which, Why, Who, how*
Summarizing	Write the summary of essential information from the text. Work with the group about the main idea and the most essential details. *The paragraph is about....; Could you please summary is...; This is what I think is the most crucial from the text...; The main idea is....*

Help sheet for Group Leader

Predicting	Clarifying	Questioning	Summarizing
Ask: who wants to make a prediction what will be happen in the next passage? *Assist:* what may be figured out in the next paragraph? How are the chances to happen? *Feedback:* what could be improved a lot?	*Ask:* who need to clarify the meaning of unfamiliar word? *Assist:* Reread the sentence before and after Ask whether someone in your group could explain this term to you *Feedback:* What could still be improved?	*Ask:* who wants to ask a question? *Assist:* Which of the following questions will assist you help to determine whether or not someone has comprehended the text? Which question might the teacher asks? *Feedback:* What could still be improved?	*Ask:* who wants to summarize the text in your own words? *Assist:* What is the most important information from the text? Summarize in a simple sentence? *Feedback:* What could still be improved?

The RT-CL Worksheet

Name :
Text Title :
Group :

What do you learn from the text?

Predicting:
Clarifying:
Questioning:
Summarizing:

Banking

It is a safe place for financial matters. Many essential services are provided within there. One of the everyday activities is people can store money in this place. Mainly, it can be found in urban areas as well as in remote villages. The customers also come from various circles both individuals, groups, government, private sector, and even non-government organizations also utilize the service of this place. As a student you also use it that is related to financial affairs.

Banks are financial institutions that provide customers with a variety of valuable services, including the bility to wire money to a person or company, the ability to store cash in a checking or savings account, the ability o collect interest on investments, the ability to receive loans, and much more.

Banks are most commonly used by customers who wish to store their money and access it as needed, with debit card (a card that's simply attached to the funds in one's account) or checks (individually numbered paper lips that can be used to designate a transfer of funds). Checking and savings accounts are the primary means of toring money in a bank; a checking account is designed to house money that will be spent, while a savings ccount is designed to house money that will be saved. Banks usually pay a small amount of interest, or a payment n the form of a percentage of a customer's deposited balance, to customers. This is their way of showing support or clients who entrust them with their money.

These funds are then used by banks, along with their credit, to perform other functions and offer additional ervices. For example, many customers use banks to secure home mortgages or multi-year loans through which wnership (or equity) of a home is achieved. Customers demonstrate that they're able to pay a mortgage back usually by providing proof of income and investments, in addition to a down payment or a lump sum paid pfront), and select a time period for this mortgage; short mortgage payment periods require larger monthly ayments, but customers are charged less interest, while more extended mortgage payment periods require smaller onthly payments, but customers are charged more interest.

Lastly, many banking customers request a personal loan. Personal loans are loans issued and approved by inancial experts that are designed to be used by customers for specific purposes. For example, one may secure a ersonal loan for a business plan or an automobile. Personal loans, like home mortgages, are issued based upon a ustomer's ability to pay the borrowed sum back; banks also charge a small amount of interest, meaning, in this ase, a percentage of the borrowed money extra, besides its core balance.

lossary:

Bank	a business that keeps and lends money and provides other financial services
Debit card	a plastic card with your signature on that you can use to pay for things. The money is taken directly from your bank account
Checks	a cheque on which you write a date that is earlier than the actual date
Checking account	a bank account that you can take money out of at any time, and for which you are given checks to use to pay for things
Saving account	a bank account for saving money over a long period of time, usually with higher interest than an ordinary
Customer	a person or organization that buys goods or services from a shop or company
Interest	money paid to you by a bank or financial institution when you keep money in an account there
Fund	an amount of money that is obtained and used for a particular purpose
Home mortgages	a legal arrangement where you borrow money from a bank in order to buy land or a house, and you pay back the money over a period of years
Equity	the amount that would be left for the borrower if the property or asset was sold and the remaining loan repaid
Down payment	a payment you make when you buy something that is only part of the full price, with the rest to be paid later
Personal loan	a loan to a person for their own use rather than to a business

Fig. 1. The RT-CL strategy intervention

3.3 Instrument

A survey questionnaire with 15 items was used. The questionnaire was adapted from [16, 17], and [18] and modified to meet the research goals. Then, the questionnaire was divided into two indicators. Section A involved nine items related to students' activeness, and section B consisted of six statements associated with students' motivation. The items were answered on a 5-point Likert scale of *strongly agree* = 5, *agree* = 4, *neutral* = 3, *disagree* = 2, and *strongly disagree* = 1.

3.4 Data Collection and Data Analysis

The preliminary research was carried out on March 2021 in the calendar academic of 2020/2021 years. The questionnaire was created on Google form for this quantitative study. In addition, a paired sample t-test was used to examine the students' perceptions of the effectiveness of the RT-CL strategy in reading comprehension skills and to test whether the change in students' perception between pre-and post-test reading activeness and motivation was significant.

4 Result and Discussion

All of the 10 participants completed pre-test and post-test questionnaires. The questionnaire was distributed to view students' perception of the effectiveness of the RT-CL strategy in enhancing students' reading comprehension skills. The variable involved students' activeness and motivation in reading comprehension.

Firstly, a normality test was conducted to assess the data distribution. In Table 1. The result showed that the activeness and motivation variables were normally distributed (sig. > 0.05). Therefore, this variable was ready for paired sample *t*-test (Parametric test).

Table 1. Normality test

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre-activeness	.193	10	.200*	.935	10	.504
Pre-motivation	.121	10	.200*	.944	10	.595

In addition, to confirm whether there was an effect of implementing the RT-CL strategy on the two variables studied, it was necessary to carry out a pre-and post-test questionnaire. For statistical measurement for both pre-test and post-test of the paired sample, the *t*-test was presented in Table 2. Below.

Table 2. Paired samples different tests on pre-and post-test

		Mean	N	Std. deviation	Std. error mean	t	df	Sig. (2-tailed)
Pair 1	Pre-activeness	3.2550	10	.28745	.09090	−5.311	9	.000
	Post-activeness	3.9220	10	.38614	.12211			
Pair 2	Pre-motivation	2.9250	10	.46229	.14619	−5.851	9	.000
	Post-motivation	3.7840	10	.45814	.14488			

The result above showed significant differences in the students' perception of activeness and motivation in the experimental group pre-and post-treatment (sig. > .05). Moreover, the pre-and post-questionnaire distribution results indicated that the most significant change was shown by motivation, which was 0.859 (2,925 to 3,784), and then activeness which was 0.667 (3,255 to 3,922).

This change points out that students positively perceive implementing the RT-CL strategy. In addition, it revealed that CL promotes students' engagement in exploring certain learning materials. It agrees with [19] that CL improves students' reading comprehension, enhances learning motivation and interest, and fosters a positive attitude.

Moreover, students also experienced a shift in the level of activeness. Therefore, the RT-CL strategy was believed to increase students' classroom participation. At the same time, [20] indicates that CL effectively enhances peer interaction to promote students' reading comprehension, and motivation, build confidence, and be an active agent in their own and group learning.

4.1 The RT-CL Strategy was Believed to Promote Students' Activeness

Nine items examined the students' perceptions of the RT-CL strategy in promoting students' activeness. Data were presented in Table 3, which focused on the frequency, percentage, mean, and standard deviation post-questionnaire.

Table 3. The RT-CL strategy promote students' activeness

No	Items	D	N	A	SA	Mean	SD
1	I prefer working with a group rather than myself on English reading text	10%	20%	30%	40%	4.00	1.054
2	The strategy has encouraged me to exchange knowledge, information, and experience		10%	70%	20%	4.10	0.568
3	The strategy entails greater responsibility for myself and the group		10%	50%	40%	4.30	0.675
4	The strategy enables students to help the weaker students in the group with English reading text			50%	50%	4.50	0.527
5	The strategy encourages me to actively participate in reading comprehension activities (assignments, discussion, tests)		50%	30%	20%	3.70	0.823
6	The strategy helps stimulate me to become more active through practice activities		20%	50%	30%	4.10	0.738
7	In the strategy activity, I received valuable peer feedback		10%	60%	30%	4.20	0.632
8	The strategy helps group members participate in doing the tasks actively	10%	20%	60%	10%	2.70	0.823
9	After applying the strategy, I can discuss what I have learned from the reading text with other peers		40%	50%	10%	3.70	0.675
Overall mean						3.92	0.386

According to the survey questionnaire result in Table 3. 100% of students (M = 4.50) strongly agreed and accepted that the strategy enables students to help weaker students when they work together. It agrees with research findings [15, 21], emphasizing that everyone was expected to learn from one another in the CL environment. Brighter students could help other group members by sharing their experiences or knowledge.

90% of students (M = 4.00) decided that the strategy encourages them to be responsible for completing the assignments for themselves or the group. At the same time, [12] stated that during the exchange of knowledge and contributing ideas in CL, students become more responsible for one another's learning and their own to understand the academic subject.

In addition, 90% of students (M = 4.20) agreed that peer feedback could be acquired when working together. To this end, [22, 23] mentioned that feedback created students' learning environment that attracted their motivation, engagement, and achievement. Students could give-take building knowledge and assess what their friends have learned. While 80% of students agreed that the strategies help stimulate their activeness through practice activity (M = 4.10). Interaction in a group discussion saves time. [4, 21] studies indicated that students optimize time by reading text collaboratively. However, 50% of students (M = 3.70) agreed that the strategies stimulate actively participating in the activities (assignments, discussion, tests). The strategy was relatively new for the PNK students. Since it was carried out online, this condition affected their performance in discussion to complete the tasks, mainly unreliable internet network access.

90% of students (M = 4.10) agreed that the strategy promoted exchanging knowledge and experience. It agrees with [21] findings that students with various abilities and competencies depend on each other and trust each other as a value of teamwork to achieve a common goal to succeed. Besides, 70% of students (M = 2.70) admitted that the strategy drive group members to participate in tasks actively. At the same time, [24] believed that the positive concerns indicated by CL were centered on students' participation in discussion and active work with the subject material. In group learning, each student has a chance to contribute to completing the assignments successfully.

70% of students (M = 4.00) strongly agreed to work with a group more efficiently than individually. It agrees with [4, 20] findings that learning in a group leads students to deep information processing, self-confidence, engagement in learning activities, development of communication skills, completing tasks quickly, and having a chance to share or even listen to others. On the contrary, 60% of students (M = 3.70) felt more satisfied because they could discuss what they had learned. To this end, CL provided a safe atmosphere for students to be brave to share their ideas or thoughts about the learning material. Each student took part in the task's completion, whereby no one felt underestimated [4, 21].

4.2 The RT-CL Strategy was Perceived as Stimulating Students' Motivation

As illustrated in Table 4, the result of the RT-CL strategy stimulated students' motivation in line with the second goal. Six items view students' perception of the RT-CL in frequency, percentage, mean and standard deviation.

In Table 4. Students agreed that the RT-CL strategy was significantly perceived to stimulate their motivation. Mostly 90% of the students (M = 4.50) strongly agreed that they were motivated to read an English text using the strategy. It agrees with [19, 20] that motivation significantly influences learning outcomes. Students engaging in group work enhances their motivation to participate in group learning and benefits their learning experience. Moreover, peer group interaction in CL positively enhances students' motivation in the learning environment [25].

Table 4. The RT-CL strategy stimulates students' motivation

No	Items	D	N	A	SA	Mean	SD
1	The strategy is convenient for learning and comprehending English reading text		20%	50%	30%	4.10	0.738
2	The strategy is heavy to learn and use in comprehending English reading text	20%	20%	60%		2.40	0.843
3	The strategy encourages me to focus on collective effort than an individual effort on English reading assignments		40%	20%	40%	4.00	0.943
4	I would likely use the strategy to comprehend English reading text. It provides me with a more relaxed atmosphere		50%	10%	30%	3.60	1.075
5	I feel motivated to have a global understanding of the English reading text through the strategy		10%	30%	60%	4.50	0.707
6	The strategy reduces stress and eliminates boredom in learning English reading text		20%	20%	50%	4.10	1.101
Overall mean						3.78	0.458

Additionally, 80% of students agreed that the RT-CL strategy was convenient in comprehending the text well (M = 4.10). To this end, CL was an effective instructional and utilized peer interaction in the text discussion. Students give and receive help, share knowledge, and build on each other's ideas to create a complete solution [4, 26]. 60% of students (M = 2.40) thought the strategy was relatively new to them and was conducted online. They were not accustomed to it yet; however, this study positively promoted students' experience regarding the online learning atmosphere.

According to the result, 70% of students who chose strongly agreed that the RT-CL strategy reduces stress and eliminates boredom in reading comprehension class (M = 4.10). Furthermore, it confirms with [21, 27] that in CL activities, tasks are shared among group members, and students have the chance to discuss its accomplishment with their friends. In fact, in group interaction, students positively experienced meaningful learning [28]. While 40% of students selected neutral, the strategies provided a relaxed atmosphere. However, because it was conducted online, sometimes the internet connection being unstable or unreliable makes students feel uncomfortable in their text discussion (M = 3.60).

Further, 60% of students (M = 4.00) believed the strategy benefited and encouraged them to work in a group to complete the assignments. In discussion, they meet the tasks through collective efforts than individual efforts, and CL emphasized these issues. According to [29], CL allows students to recognize the necessity of working together and among participants instead of being entirely individualistic. Here, students are more responsible and willing to share information with peers and collaborate on learning activities.

5 Conclusion

This study revealed that the RT-CL strategy supported one another to enhance students' reading comprehension skills in less time. In perceived more active, the RT-CL approach stimulated students' activeness through practice activities by engaging them in learning. Emphasized students' participation in-text discussion and active in group work with the subject material. At the same time, most students felt motivated to read an English text. The strategy assists them in grasping knowledge and completing assignments quickly in groups. In addition, in the RT-CL approach, students perceived that its strategy reduces stress and eliminates boredom by doing beneficial and meaningful activities in a group to enhance reading comprehension skills.

Acknowledgments. This research is partially supported by the Ministry of Science and Technology, Taiwan, R.O.C. under Grant No. MOST 108-2628-H-224-001-MY3, MOST 110-2511-H-224-003-MY3, and MOST 110-2622-H-224-001-CC2.

References

1. Tseng, S., Yeh, H.: Integrating reciprocal teaching in an online environment with an annotation feature to enhance low-achieving students' English reading comprehension. Interact. Learn. Environ. **26**, 1–14 (2017). https://doi.org/10.1080/10494820.2017.1412989
2. Johnson, T.E., Archibald, T.N., Tenenbaum, G.: Individual and team annotation effects on students' reading comprehension, critical thinking, and meta-cognitive skills. Comput. Hum. Behav. **26**, 1496–1507 (2010)
3. Dreyer, C., Nel, C.: Teaching reading strategies and reading comprehension within a technology-enhanced learning environment. System. **31**, 349–365 (2003). https://doi.org/10.1016/S0346-251X(03)00047-2
4. Suwantharathip, O.: Implementing reading strategies based on collaborative learning approach in an English class. Read. Matrix Int. Online J. **15**, 91–101 (2015)
5. Wu, T.-T., Chen, A.-C.: Combining e-books with mind mapping in a reciprocal teaching strategy for a classical Chinese course. Comput. Educ. **116**, 64–80 (2018)
6. de H. Basoeki, O., Wu, T.-T., Huang, Y.-M.: Design of reciprocal teaching-collaborative learning approach in enhancing students' reading comprehension Skill. In: Huang, T.-C., Wu, T.-T., Barroso, J., Sandnes, F.E., Martins, P., Huang, Y.-M. (eds.) ICITL 2020. LNCS, vol. 12555, pp. 23–32. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-63885-6_3
7. Palinscar, A.S., Brown, A.L.: Reciprocal teaching of comprehension-fostering and comprehension monitoring activities. Cogn. Instr. **1**, 117–175 (1984)
8. Huang, C.-T., Yang, S.C.: Effects of online reciprocal teaching on reading strategies, comprehension, self-efficacy, and motivation. J. Educ. Comput. Res. **52**, 381–407 (2015)
9. Okkinga, M., Van Steensel, R., Van Gelderen, A.J.S., Sleegers, P.J.C.: Effects of reciprocal teaching on reading comprehension of low-achieving adolescents. The importance of specific teacher skills. J. Res. Read. **41**, 20–41 (2018)
10. Slavin, R.E., Cheung, A., Groff, C., Lake, C.: Effective reading programs for middle and high schools: a best-evidence synthesis. Read. Res. Q. **43**, 290–322 (2008)
11. Vega, N., Stanfield, J., Mitra, S.: Investigating the impact of Computer Supported Collaborative Learning (CSCL) to help improve reading comprehension in low performing urban elementary schools. Educ. Inf. Technol. **25**(3), 1571–1584 (2019). https://doi.org/10.1007/s10639-019-10023-3

12. Roselli, N.D.: Collaborative learning: theoretical foundations and applicable strategies to university. J. Educ. Psychol. y Represent. **4**, 251–280 (2016)
13. Lin, L.: Cultural flows and pedagogical dilemmas : teaching with collaborative learning in the Chinese HE EFL context *. Chin. J. Appl. Linguist. **40**, 21–41 (2017). https://doi.org/10.1515/cjal-2017-0002
14. Howe, N., Della Porta, S., Recchia, H., Ross, H.: "Because if you don't put the top on, it will spill": a longitudinal study of sibling teaching in early childhood. Dev. Psychol. **52**, 1832 (2016)
15. Morgan, A., Wilcox, B.R., Eldredge, J.L.: Effect of difficulty levels on second-grade delayed readers using dyad reading. J. Educ. Res. **94**, 113–119 (2000)
16. Brown, F.A.: Collaborative learning in the EAP classroom: students' perceptions. ESP World **17**, 1–18 (2008)
17. Barrett, R.A.: Reciprocal teaching as a platform for communicative activities in the secondary foreign language classroom: a case study. The University of Akron (2003)
18. Alsamadani, H.A.: The relationship between Saudi EFL college-level students' use of reading strategies and their EFL reading comprehension. Ohio University (2009)
19. Hakkarainen, K., Lipponen, L., Järvelä, S.: Epistemology of inquiry and computer-supported collaborative learning. In: CSCL 2, pp. 151–204. Routledge (2013)
20. Lin, C., Chen, W., Yang, S., Xie, W., Lin, C.: Exploring students' learning effectiveness and attitude in group scribbles-supported collaborative reading activities: a study in the primary classroom. J. Comput. Assist. Learn. **30**, 68–81 (2014)
21. Momtaz, E., Garner, M.: Does collaborative learning improve EFL students' reading comprehension? J. Linguist. Lang. Teach. **1**, 15–36 (2010)
22. Ghavifekr, S.: Collaborative learning: a key to enhance students' social interaction skills. MOJES Malays. Online J. Educ. Sci. **8**, 9–21 (2020)
23. Huang, Y.-M., Silitonga, L.M., Wu, T.-T.: Applying a business simulation game in a flipped classroom to enhance engagement, learning achievement, and higher-order thinking skills. Comput. Educ. **183**, 104494 (2022)
24. Mbirimi-Hungwe, V., McCabe, R.-M.: Translanguaging during collaborative learning: a 'transcollab' model of teaching. South. Afr. Linguist. Appl. Lang. Stud. **38**, 244–259 (2020)
25. Huang, P.-S., Chiu, P.-S., Huang, Y.-M., Zhong, H.-X., Lai, C.-F.: Cooperative mobile learning for the investigation of natural science courses in elementary schools. Sustainability **12**, 6606 (2020)
26. Loes, C.N., An, B.P., Saichaie, K., Pascarella, E.T.: Does collaborative learning influence persistence to the second year of college? J. High. Educ. **88**, 62–84 (2017)
27. Farkas, W.A., Jang, B.G.: Designing, implementing, and evaluating a school-based literacy program for adolescent learners with reading difficulties: a mixed-methods study. Read. Writ. Q. **35**, 305–321 (2019)
28. Wang, T.-H., Lin, H.-C.K., Wu, T.-T., Huang, Y.-M.: A multimethod approach for supporting reflection and creativity in online collaborative courses. J. Internet Technol. **21**, 1097–1106 (2020)
29. Ngcobo, S., Ndaba, N., Nyangiwe, B., Mpungose, N., Jamal, R.: Translanguaging as an approach to address language inequality in South African higher education: summary writing skills development. Crit. Stud. Teach. Learn. **4**, 10–27 (2016)

Design of Hands-On Laboratory Supported by Simulation Software in Vocational High School

Edi Sarwono[1,2], João Barroso[3], and Ting-Ting Wu[1](✉)

[1] Graduate School of Technological and Vocational Education, National Yunlin University of Science and Technology, Yunlin 64002, Taiwan, R. O. C.
ttwu@yuntech.edu.tw

[2] Department Electrical Engineering, Universitas Negeri Semarang, Semarang, Indonesia

[3] Instituto de Educação da Universidade de Lisboa, Lisbon, Portugal

Abstract. Vocational high school is a secondary education whose practice portion is larger than its theoretical portion. This allows students to do more hands-on practice in the laboratory, as skill competency is very important in vocational education. Through practice, students have the skills to become competent and skilled technicians in the future. When students practice in a hands-on laboratory, errors may occur that can injure students, equipment, and components. In addition, short circuits can also endanger student safety. Therefore, to improve practical skills in the laboratory, teachers must find innovative ways to incorporate these methods into the learning process. One of the things that can be done to improve students' practical skills is to use simulation software before doing direct practice in the laboratory. In-depth interviews were conducted with three electrical engineering teachers to verify the perspective of the proposed model. The results suggest that the proposed design is likely to improve problem-solving skills when an error occurs during the simulation, and it will improve practical skills when using hands-on laboratories so that students learn more about hands-on lab practice in vocational high school.

Keywords: Hands-on laboratory · Simulation software · Practical skills · Vocational students

1 Introduction

Vocational high schools offer a formal education that is in great demand because the learning process provides skill training in various fields of expertise. Vocational high schools have a very important role in efforts to improve human resources who are able to have the skills needed in the world of work. In vocational and technical education, an innovative and creative approach to teaching and learning with an active learning environment, dynamic instruction, and science experiments are always being given attention and prioritized [1]. Through practice, it enables students to carry out direct observation, prediction, analysis, and conclusion of experimental outcomes [2, 3]. Therefore, students have the skills to become competent and skillful technicians in the future.

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 382–387, 2022.
https://doi.org/10.1007/978-3-031-15273-3_42

Laboratory-based learning allows students to take on work roles in the development of their competencies. The teacher uses this condition through experiments in the laboratory, and the students are involved in them so that learning becomes more enjoyable for them. Vocational and technical education consists of engineering courses that need experiments. Engineering courses frequently combine lectures and tutorials with laboratory classes in order to maximize student learning and acquire useful skills for future jobs [4, 5]. In science laboratory work, students relate to each other with tools and materials in observing and understanding nature as a learning experience [6]. During an experiment in a hands-on laboratory, there are chances to make errors and have safety problems. Therefore, the hands-on laboratory needs to be supported with simulation before it is done. In the case of simulation, teachers use special simulation software for students [7]. Students also need to have supporting abilities, like the ability to comprehend foreign languages [8] when using simulation software.

The purpose of this study is to propose a design of an innovative model of teaching with a hands-on laboratory method supported by simulation software in order to promote an effective learning environment course that is later expected to enhance students' practical skills outcomes. The research question in this study is how teachers assess the design of hands-on laboratories supported by simulation software in electrical engineering courses.

2 Literature Review

2.1 Hands-On Laboratory

Hands-on laboratory is one of the significant basics for a vocational high school student, so providing students in vocational high school with hands-on laboratory practice is necessary. There is course material delivered in traditional lecture formats that may not grab the attention of students and motivate them [9]. Therefore, students must be motivated to improve learning outcomes with practical experience gained during their studies. There is evidence that hands-on laboratories have a critical role in enhancing student learning outcomes [10]. This is regardless of the fact that laboratory equipment for hands-on experiments and laboratory monitoring of classrooms that requires physical tools can be expensive [11].

2.2 Simulation Software

Simulation is a reliable and interesting method that gives students hands-on learning experiences that motivate and boost them to study. The use of simulation software is also critical for connecting theory to practice, allowing students to build engineering skills and learn how real-time simulations may be used to record process behavior. Students must develop an understanding of the magnitude and sensitivity of system parameters, as well as the relationships between and responses to such parameters, as well as the value and limitations of numerical methods employed in system solutions [12]. Cost and time-consuming adjustments can be made if students know the difference between how things work in real life and how they work in a computer simulation and the simulation game [13–15].

For doing laboratory experiments in vocational and technical education, computer-simulated experiments that use simulation software as a basic operation are becoming increasingly common. One of the reasons is that, in comparison to the specialized laboratory tools necessary in hands-on laboratories, simulation laboratories can help save money. There is the benefit of simulation [16], which comprises:

1. The student can change the parameters and see what happens without putting their lives in danger or saving them.
2. Remove defective components and tools.

As a result, many higher education institutions perform simulation labs in addition to hands-on labs. [10, 17, 18].

3 Research Design

This research was conducted using a qualitative approach. Qualitative research is defined as the collection and analysis of data in order to better understand ideas, assumptions, or experiences [19]. One of the most common qualitative methods is interviewing and observation [20].

3.1 Participants

Three electrical engineering teachers participated in being interviewed; details can be seen in Table 1.

Table 1. Detail of participants

No	Participant	Teaching period	Position	Institution
1	P1	11 years	Head of Electrical Engineering Department	Vocational High School 1 Semarang
2	P2	11 years	Head of laboratory Electrical Engineering Department	Vocational High School 1 Semarang
3	P3	3 years	Teacher of Electrical Engineering Department	Vocational High School 1 Semarang

3.2 Data Collection

Three electrical engineering teachers were interviewed as participants. The purpose of this interview is to gather data or information about the most recent study of research issues. Giving questions to them and getting their answers as information or data on certain things is how interviews work [21].

3.3 Data Analysis

This research uses qualitative data. The researcher uses grounded theory to analyze the research findings. The grounded theory research design is a series of processes for putting together a theory to explain the activity of a significant topic [22]. Interviews and observations can be used to obtain data for a grounded theory [20] (Fig. 1).

4 Propose Design

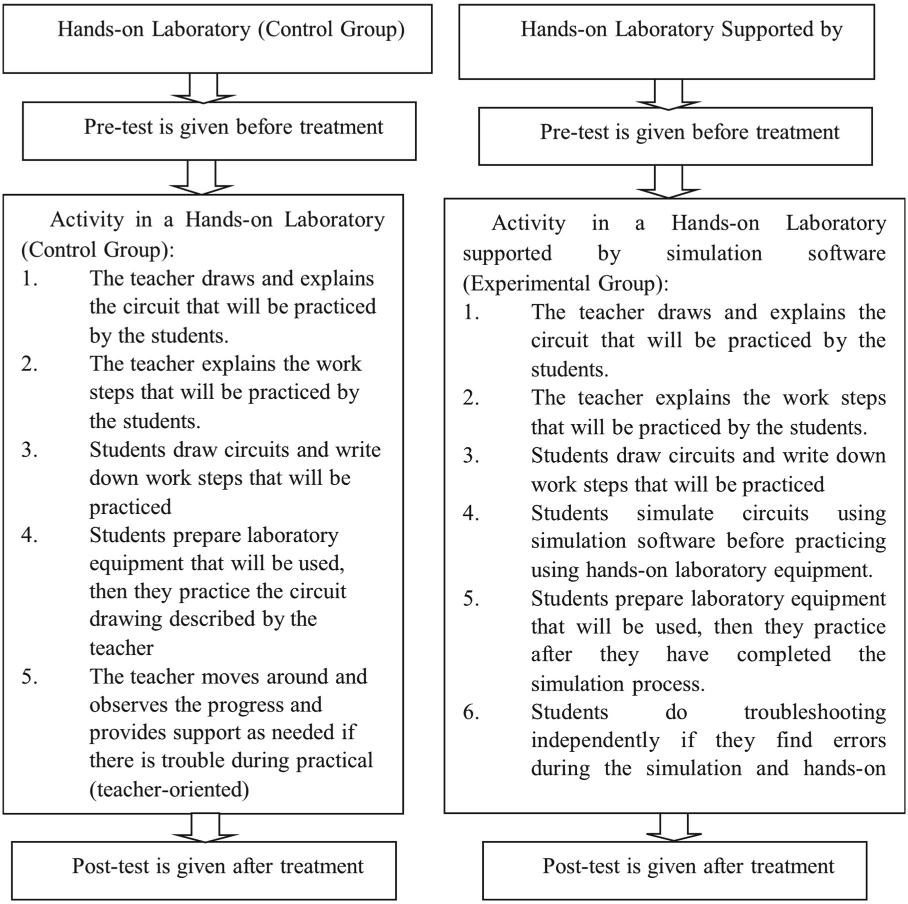


Fig. 1. Experimental design procedure.

5 Result and Discussion

In-depth interviews were conducted to verify the proposed design from hands-on laboratory practice supported by simulation software in the field of electrical engineering. The results showed that the three teachers interviewed agreed that the hands-on laboratory learning process supported by simulation software was a very good approach to apply. They believe that doing a simulation before doing a hands-on laboratory will support students' practical skill competency. In addition, students will be safer doing engineering and troubleshooting when practicing using simulation software before using a hands-on laboratory, because with simulation software, student safety and tools are more secure because they avoid the danger of short circuits and damaged components.

Therefore, they believe that students will be more creative and think critically to do problem-solving when an error occurs during practice with the support of simulation software before doing real practice using a hands-on laboratory. They also believe that this learning design will also reduce anxiety and increase students' confidence to practice using a hands-on laboratory. The head of the department also conveyed related learning policies for vocational high schools. He suggested applying project-based learning to students. With the support of existing computer facilities at the school, he also expressed his hope that this learning design would run smoothly.

6 Conclusions

Overall, the participants supported the design of using simulation software to support the hands-on laboratory in the practice of the electrical engineering department of this vocational high school. The participants, consisting of the head of the department, the head of the laboratory, and also a teacher of electrical engineering at Vocational High School 1, Semarang, thought that this design was a breakthrough in practical learning in the electrical engineering department, and they also thought that this learning design would be useful. According to the participants, this learning design is projected to improve the practical learning process and achieve better goals than just using a hands-on laboratory. Most of them also gave answers stating that the use of simulation software before hands-on laboratory helps improve students' understanding of practical skills in electrical engineering majors. The important advantages conveyed by the participants of this design include interactive, problem-solving, critical thinking, and creativity. Based on the results of this study, the researchers can use a teaching method or approach combined with a hands-on laboratory supported by simulation software in future related studies.

Acknowledgements. This research is partially supported by the Ministry of Science and Technology, Taiwan, R.O.C. under Grant No. MOST 108-2628-H-224-001-MY3, MOST 110-2511-H-224-003-MY3 and MOST 110-2622-H-224-001-CC2.

References

1. Ekmekci, A., Gulacar, O.: A case study for comparing the effectiveness of a computer simulation and a hands-on activity on learning electric circuits. Eurasia J. Math. Sci. Technol. Educ. **11**, 765–775 (2015)
2. Gurvitch, R., Metzler, M.W.: The effects of laboratory-based and field-based practicum experience on pre-service teachers' self-efficacy. Teach. Teach. Educ. **25**, 437–443 (2009)

3. Baranov, A.V: Virtual students' laboratories in the physics practicum of the technical university. In: 2016 13th International Scientific-Technical Conference on Actual Problems of Electronics Instrument Engineering (APEIE), pp. 326–328. IEEE (2016)
4. Magin, D.J., Churches, A.E., Reizes, J.A.: Design and experimentation in undergraduate mechanical engineering. In: Proceedings of a Conference on Teaching Engineering Designers, pp. 96–100. Institution of Engineers Australia, UNSW, Sydney (1986)
5. Faucher, G.: The role of laboratories in engineering education. Int. J. Mech. Eng. Educ. **13**, 195–198 (1985)
6. Hofstein, A., Lunetta, V.N.: The laboratory in science education: foundations for the twenty-first century. Sci. Educ. **88**, 28–54 (2004)
7. Kolb, A.Y., Kolb, D.A.: The experiential educator: principles and practices of experiential learning. Experience based learning systems (2017)
8. Shadiev, R., Chien, Y.C., Huang, Y.M.: Enhancing comprehension of lecture content in a foreign language as the medium of instruction: comparing speech-to-text recognition with speech-enabled language translation. SAGE Open **10** (2020). https://doi.org/10.1177/2158244020953177
9. Rao, A.R., Dave, R.: Developing hands-on laboratory exercises for teaching STEM students the internet-of-things, cloud computing and blockchain applications. In: 2019 IEEE Integrated STEM Education Conference (ISEC), pp. 191–198. IEEE (2019)
10. Steger, F., Nitsche, A., Arbesmeier, A., Brade, K.D., Schweiger, H.-G., Belski, I.: Teaching battery basics in laboratories: hands-on versus simulated experiments. IEEE Trans. Educ. **63**, 198–208 (2020)
11. Roschelle, J.M., Pea, R.D., Hoadley, C.M., Gordin, D.N., Means, B.M.: Changing how and what children learn in school with computer-based technologies. Future Child. 76–101 (2000)
12. Vujičić, V., Dragićević, S., Ocokoljić, D., Milićević, I., Popović, M.: Design and simulation of electro-pneumatic motion control system. Proc. TIE **8**, 354–358 (2020)
13. Shreeve, M.W.: Beyond the didactic classroom: educational models to encourage active student involvement in learning. J. Chiropr. Educ. **22**, 23–28 (2008)
14. Johnson, M., Hayes, M.J.: A comparison of problem-based and didactic learning pedagogies on an electronics engineering course. Int. J. Electr. Eng. Educ. **53**, 3–22 (2016)
15. Huang, Y.-M., Silitonga, L.M., Murti, A.T., Wu, T.-T.: Learner engagement in a business simulation game: impact on higher-order thinking skills. J. Educ. Comput. Res. (2022). https://doi.org/10.1177/07356331221106918
16. Taher, M.T., Khan, A.S.: Effectiveness of simulation versus hands-on labs: a case study for teaching an electronics course. In: 2015 ASEE Annual Conference and Exposition, pp. 26–582 (2015)
17. Steger, F., Nitsche, A., Miley, C., Schweiger, H.-G., Belski, I.: Laboratory learning: hands-on versus simulated experiments. In: Proceedings of 28th Annual Conference of the Australasian Association for Engineering Education (AAEE), pp. 940–947 (2017)
18. Balakrishnan, B., Woods, P.C.: A comparative study on real lab and simulation lab in communication engineering from students' perspectives. Eur. J. Eng. Educ. **38**, 159–171 (2013)
19. Mohajan, H.K.: Qualitative research methodology in social sciences and related subjects. J. Econ. Dev. Environ. People **7**, 23–48 (2018)
20. Jamshed, S.: Qualitative research method-interviewing and observation. J. Basic Clin. Pharm. **5**, 87 (2014)
21. Kelly, S.E., Bourgeault, I., Dingwall, R.: Qualitative interviewing techniques and styles. In: The SAGE Handbook of Qualitative Methods in Health Research, pp. 307–326 (2010)
22. Charmaz, K.: Constructing Grounded Theory. SAGE, Thousand Oaks (2014)

Exemplifying Formative Assessment in Flipped Classroom Learning: The Notion of Bloom's Taxonomy

Noviati Aning Rizki Mustika Sari[1], Winarto[2], and Ting-Ting Wu[1](✉)

[1] National Yunlin University of Science and Technology, Yunlin 64002, Taiwan, R. O. C.
ttwu@yuntech.edu.tw

[2] Semarang State Polytechnic, Semarang, Central Java, Indonesia

Abstract. It is necessary to embed formative assessment within a broader theoretical field to understand it fully as it should be understood in the context of pedagogy. Business education with incentive systems intrigues the new pedagogical concept of a flipped approach divided into distinct levels drawing on Bloom's taxonomy. Bloom's taxonomy plays a significant role in influencing instructional delivery, curriculum planning, and assessment. It allows the instructors to set educational goals and develop evaluation tools based on a more accurate classification of knowledge levels. Students' learning and critical thinking are measured through assessments within the six taxonomy levels, which can challenge educators. Despite the need for careful planning, developing Bloom's taxonomy assessments can be a straightforward process. This research exemplifies how formative assessment can be employed in flipped classroom learning by deliberating Bloom's taxonomy into the classroom's instructional delivery and assessment. Additionally, it extends theories and practices on how formative assessment has recently been discussed and explored as a learning tool in business education and assessment areas.

Keywords: Formative assessment · Flipped classroom learning · Bloom's taxonomy · Business education

1 Introduction

Various studies have proposed the third aspect of assessment, which is assessment as learning, on top of the assessment of learning and assessment for learning. Assessment as learning implies that students should learn something while being assessed. In assessment as learning, students are taught something while being assessed, and it is an incredibly promising concept [1]. The inferences drawn from assessment outcomes indicate whether an assessment is formative or summative. Summative refers to the student or their future potential status. On the contrary, formative implies the kinds of actions that would best assist students in learning.

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 388–397, 2022.
https://doi.org/10.1007/978-3-031-15273-3_43

Perrenoud encompassed that it is necessary to embed formative assessment within a broader theoretical field to understand it fully as it should be understood in the context of pedagogy [2, 3]. Curriculum design transformation creates a discrepancy concerning students' acquisition of competence, skills, relevant knowledge, and other characteristics to be applied to professional work domains [4]. Business education with incentive systems intrigues the new pedagogical concept known as a flipped classroom approach to unveil a much higher prevalence of structured training across coursework [5].

A study conducted by Huang and Lin emphasized that knowledge is divided into distinct levels drawing on Bloom's taxonomy within the flipped classroom approach [6]. The activities performed prior to the class are classified at the lower level in Bloom's taxonomy (remember, understand, and apply). Classroom activities are classified at the higher levels of Bloom's taxonomy (analyze, evaluate, and create) [7]. Studies revealed that Bloom's Taxonomy enhances students' critical thinking and mastery of skills and concepts [8].

Anderson and Krathwohl reevaluated the original taxonomy and revised its terminology and structure to redefine its significant role in influencing curriculum planning, instructional delivery, and assessment [9]. Students' learning and critical thinking are measured through assessments within the six taxonomy levels, which can challenge educators. Despite the need for careful planning, developing Bloom's taxonomy assessments can be a straightforward process. This is remarkably accurate when the instructors use Bloom's taxonomy in the classroom, as the assessment can flow naturally from what instructors have done in class [10]. Furthermore, research confirms that the design of assessment tasks influences students' learning.

This research exemplifies how formative assessment can be employed in such a pedagogy, so-called flipped classroom learning, by deliberating Bloom's taxonomy into the classroom's instructional delivery and assessment. Additionally, it extends theories and practices on how formative assessment has recently been discussed and explored as a learning tool in business education and assessment areas.

2 Literature Review

2.1 Formative Assessment

Assessment implies appraisals on the students' performance quality [11]. Either summarizing students' achievements or awarding them some kind of certification can be accomplished with assessment, so-called summative assessment, or providing students with feedback to support their learning, so-called formative assessment [12, 13]. Formative assessment is performed during the instructional process to improve teaching or learning. The concept of improvement is often associated with a qualitative understanding of learning achievement depicted by students developing insights and new knowledge related to their existing knowledge [14]. Improvement conceptualized along these lines is distinct from the notion of improvement used when students perform better on examinations after multiple drilling and testing [15].

Pryor and Crossouard define formative assessment as the process of responding to student work and providing evidence of learning [16]. Formative assessment is a powerful tool to motivate students to learn and bring them the awareness of their own learning. In addition, it is concluded that formative assessment is complex and is related to powerful learning, which is consistent with the view that formative assessment can enhance learning with understanding and augment the learning process [17]. The nature of the assessment and how information is delivered can affect the quality of formative assessments.

2.2 Flipped Classroom

The flipped classroom is an educational method where teachers aim to reverse the learning sequence by initiating a self-study phase before class that utilizes multimedia resources to facilitate students learning at their own pace before class [18, 19]. As a result, active learning and higher-level cognitive tasks can be promoted as valuable class time is freed up [6, 20, 21].

Changing the assignments and class time allows teachers to assist students who lack understanding and practice the setup skills from the course objectives. Instructors will have prepared pre-class materials, such as online videos, presentations, digital textbooks, etc. As part of this approach, teachers propose activities that promote higher-order thinking, social learning, and 21st-century skills [6, 22, 23].

Flipped classroom involves learning at lower levels in Bloom's taxonomy: remember, understand, and apply taking place outside the classroom at the student's pace. Unlike the higher levels of Bloom's taxonomy, where learning takes place at the school, where analyze, evaluate, and create are the norm.

2.3 Bloom's Taxonomy

The original Bloom's taxonomy was a revolutionary model to classify educational objectives and goals systematically. Bloom further classified learning into three domains of behavior: affective, cognitive, and psychomotor [24]. Educators have used this multi-tiered model extensively to assess course material and test results. The original taxonomy was reevaluated by Anderson and Krathwohl, who revised terminology and structure to redefine its significant role in influencing curriculum planning, instructional delivery, and assessment [9].

Revised Bloom's taxonomy describes six levels of abstraction in educational contexts. As shown in Fig. 1, the graduated six levels are Remember, Understand, Apply, Analyze, Evaluate, and Create.

Remember, information is retrieved from memory at this level, so-called rote memory. At this level, learning facts, acquiring knowledge of major ideas, and memorizing form the foundation for higher levels of cognitive development.

Understand, that this level includes interpreting, illustrating, classifying, summarizing, and comparing cognitive processes. This level is achieved when new information is integrated with existing cognitive frameworks.

Apply, two cognitive processes occur during this level. The first is execution, in which the learner knows what to do on a particular task. The second is implementation, in which the learner is unfamiliar with what to do with the given problem.

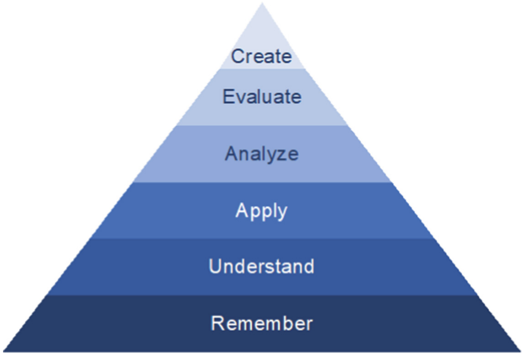


Fig. 1. Revised Bloom's taxonomy.

Analyze, learners should deconstruct the material into its components and explain how they relate to one another and the overall structure. Debating, organizing, and attribution are also part of this level.

Evaluate, this level requires the student to make judgments based on criteria and standards, including monitoring, testing, judging, identifying consistency, and utilizing critical thinking skills.

Create, this final level requires students will combine elements to create a coherent or functioning product by executing three steps: (1) students comprehend the problem and generate solutions; (2) students devise a workable plan; (3) students implement the plan [10].

3 Conceptualizing Bloom's Taxonomy in Flipped Classroom Learning

3.1 Bloom's Taxonomy in Flipped Classroom Learning

According to Morton and Colbert-Getz, the results of flipped classroom studies are driven by providing low levels of knowledge outside the classroom while focusing on the high levels of knowledge in the classroom [25]. Despite this, they did not use Bloom's taxonomy to classify or analyze the results, which may account for some of the mixed results in the studies. A study conducted by Almasseri and AlHojailan pointed out that utilizing Bloom's taxonomy within one approach (e.g., flipped classroom) aims to analyze the results of applying the new approach to learners' academic achievement [26]. Bloom's taxonomy provides a more accurate classification of knowledge levels, enabling teachers to set educational goals and build evaluation tools to achieve educational objectives (Fig. 2).

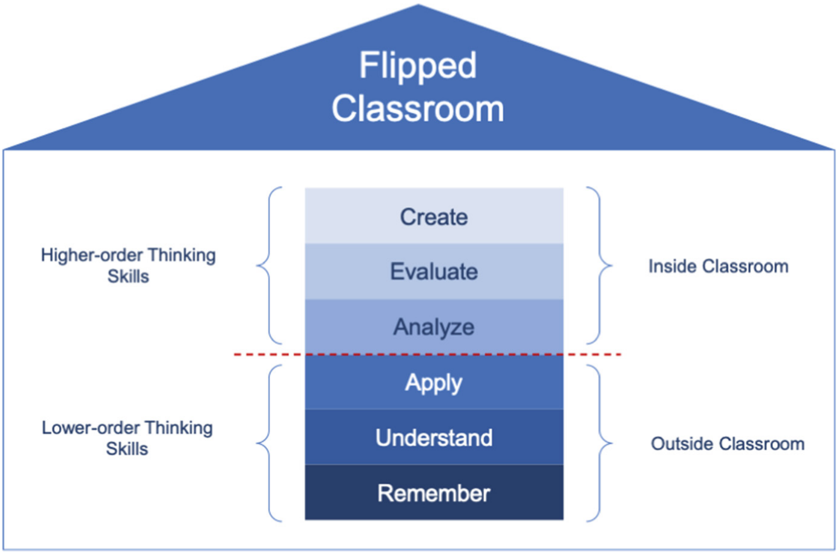


Fig. 2. Bloom's taxonomy in flipped classroom learning

Some scholars have extended the flipped classroom approach to a different paradigm by relating it to Bloom's taxonomy. They stated that flipped form of learning focuses on developing skills at higher levels of Bloom's revised taxonomy. Conceptual understanding is addressed outside of the classroom, and collaboration and application of knowledge are fostered in the classroom [24]. Prashar stressed that lower-order thinking skills are enabled by learning activities that occur outside the classroom, including remember, understand, and apply [7]. Additionally, a series of activities inside the classroom will facilitate higher-order thinking skills involving analyze, evaluate, and create.

3.2 Developing Assessment by Applying Bloom's Taxonomy

The framework provided by Eber and Parker outlined ways to create assessments based on Bloom's taxonomy [10]. A student must be assessed within the curriculum framework at each of the six levels to determine student achievement accurately. This can be accomplished while measuring the higher levels, which requires using principles from the lower levels. For instance, the assessment of create level needs to measure levels of remember, understand, apply, analyze, and evaluate accordingly.

It is of little benefit to tell students that they are right or wrong on an assessment; it is more crucial to let them know where they fall on the continuum to be aware of where they are and where they need to be. Students receive this type of feedback from assessments aiming to measure proficiency levels. By applying Bloom's taxonomy, the instructors should not only introduce higher-order thinking skills but integrate Bloom's taxonomy into students' personal and professional philosophy and perspectives.

Table 1. Assessment based on Bloom's taxonomy framework and examples

Level	Verbs to use in assessments	Potential activities
Remember	Choose, define, describe, distinguish, label, locate, match, recall, recite, record	Definition, fact, fill in the blank, label, list, true or false, workbook
Understand	Classify, compare, contrast, examples, explain, give extrapolate, identify, illustrate, locate, outline, summarize, translate	Differentiate, debate, distinguish, dramatization, story problems, recitation, label, summary
Apply	Calculate, demonstrate, draw, exhibit, experiment, illustrate, interpret, interview, practice, produce, solve, sequence, teach	Design, simulation, relate, diorama, illustration, interview, journal, photograph, poster
Analyze	Analyze, appraise, categorize, compare, debate, differentiate, distinguish, examine, point out, question, research, separate	Categorize, conclude, illustrate, list, outline, report, summary, survey
Evaluate	Choose, defend, determine, evaluate, judge, justify, predict, rank, recommend, reject, select, support, validate	Debate, investigation, judgment, opinion, panel, report, survey, verdict
Create	Compose, create, design, develop, generate, plan, predict, role-play	Invent, plan, project, song, story

Despite the need for careful planning, creating assessments using Bloom's taxonomy can be as simple as following a step-by-step process. As a result, assessments can flow naturally from what the instructors have done in class. This is particularly true when instructors use Bloom's taxonomy in the classroom. The authors adopt a framework developed by Eber and Parker to discuss creating assessments based on Bloom's taxonomy. Table 1. includes a condensed version, along with additional examples, of the levels in academic assessment. Activities and verbs associated with the level are listed. By using these language terms, the assessment measures at the associated level.

4 Formative Assessment in Flipped Classroom Learning: The Notion of Bloom's Taxonomy

This research is inspired by a study done by Gan and Leung, drawing on both general education and L2 assessment fields [15]. The study then illustrated how formative assessment could be in daily ESL classrooms on task-based language teaching. As part of the formative assessment application, the authors adopt the conceptualization that has recently been discussed and investigated as a learning tool in general education and assessment areas by exploring within the context of a pedagogy so-called flipped classroom learning applied in the International Marketing course.

The exemplar demonstrates how a sequence of flipped classroom activities can be used to teach and learn about prepositions of course topics that involve developing an international marketing plan for SMEs' products to be distributed overseas. The authors use this exemplar to exemplify how formative assessment can be employed in the International Marketing Management course within flipped classroom learning by deliberating Bloom's taxonomy into the classroom's instructional delivery and assessment.

		Time & Course Topics					
		Week 1	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**
		Introduction of International Marketing Plan	**International Marketing Idea**	**Objectives and International Marketing Strategy**	**Adaptation Product and Pricing**	**Distribution and Promotion**	**Marketing Budget and Scheduling**
Pre-Class (LOTS)	**Remember**	Definition and Short Summary (Written)					
	Understand						
	Apply	Simulation: Apply Concepts to Students' Works					
In-Class (HOTS)	**Analyze**	Report Outline and Presentation	Report Outline and Presentation	Report Outline and Presentation	Report Outline and Presentation	Report Outline and Presentation	Report Outline and Presentation
	Evaluate						
	Create	-					International Marketing Plan

Fig. 3. Illustration of the proposed formative assessment

The setting of flipped classroom learning in the International Marketing Management course is administered in six out of eighteen weeks, within a one-semester-long period. These six weeks facilitate the class instructor to deliver six different course topics, as each topic will be delivered to students in every week in sequence, and each week will occupy three meetings. Within the context of this research, the proposed formative assessment is designed to monitor and help students' learning. The course instructor constructs each potential activity as a formative assessment considering Bloom's taxonomy levels, as illustrated in Fig. 3.

Pre-class activities (LOTS)	1. The class instructor will distribute teaching material to students (e.g., online videos, online presentations, digital textbooks, etc.) through the school learning management system. 2. Students are assigned to manage self-paced learning before class to review the teaching material any time at home. Each given topic exhibits the elements needed to develop an international marketing plan. 3. In order to cover the first two levels of Bloom's taxonomy, Remember and Understanding, students are required to do simple written tests—define terms and complete a short summary. These activities intend to evaluate students' root memory upon information retrieval and summarize what they have learned autonomously. 4. Students are presented with examples of analysis on the designated topic. They are asked to execute and implement their understanding by applying concepts to their own works based on the given examples. Therefore, the third level of Bloom's taxonomy can be accomplished.

(*continued*)

(*continued*)

In-class activities (HOTS)	5. As students attend school, the learning process is continued with face-to-face interaction between them and the course instructor. 6. The activities started with a quick review on the topic delivered by the course instructor and continued with discussion as students may raise questions. These activities aim to recall students' memories and knowledge gained from the pre-class activities. Also, to confirm that the learning process at home successfully leads to the acquisition of lower-order thinking skills. 7. Learning processes at school will be followed by activities promoting higher-order thinking skills. In order to encompass the fourth level in Bloom's taxonomy, students are given tasks to write a report outline deconstructing the given topic as it is operated on their proposed SMEs' products to be sold abroad. 8. Students are invited to do an oral presentation on their written report outlines. By doing so, students are expected to perform judging, identifying consistency, and utilizing critical thinking skills. Thus, the level of Evaluate can be achieved. 9. The highest level in Bloom's taxonomy is Create. At this level, students must create the full version of an international marketing plan for SMEs' products to be distributed overseas.

5 Conclusion

Extending theories and practices on how formative assessment has recently been discussed and explored as a learning tool in business education and assessment areas, this research exemplifies how formative assessment can be applied in the International Marketing Management course by deliberating Bloom's taxonomy. Bloom's taxonomy allows the instructors to set educational goals and develop evaluation tools based on more accurate classification of knowledge levels. The flipped classroom approach has been extended to a different paradigm by relating it to Bloom's taxonomy. They stated that flipped form of learning focuses on developing skills at higher levels of Bloom's revised taxonomy. In the context of this research, students engage in flipped classroom activities—pre-class and in-class. Conceptual understanding is addressed during pre-class activities, and the in-class activities focus on collaboration and the application of knowledge [27].

Agree upon the third aspect of assessment, assessment as learning in which students are taught something while being assessed [1]. A series of formative assessments are designed to monitor and facilitate students' learning processes to master the target skills associated with the International Marketing Management course by developing an international marketing plan for SMEs' products to be distributed overseas as the main task. Potential activities constructed into formative assessments let students know where they fall on the continuum to be aware of and where they need to be improved. Also, the formative assessments promote social, critical thinking, and higher-order thinking skills and assist students in dealing with both feedback information, either internally or externally generated.

The exemplar illustrates how it is necessary to embed formative assessment within a broader theoretical field such as pedagogy to be fully understood. It is stipulated that formative assessment can be naturally employed in the flipped International Marketing Management classroom. There are opportunities offered by developing formative assessment as a learning tool, mainly when it is linked to Bloom's taxonomy in facilitating knowledge transfer and target skills acquisition. As business education merely solicits traditional pedagogy, utilizing formative assessment combined with certain pedagogies can facilitate the transformation from the traditional approach to a more innovative approach. However, factors associated with the pedagogies and the instructors may influence the successful implementation of formative assessment. Thus, to achieve the effectiveness of formative assessment as a learning tool, those factors need to be synchronized in harmony.

Acknowledgements. This research is partially supported by the Ministry of Science and Technology, Taiwan, R.O.C. under Grant No. MOST 108–2628-H-224–001-MY3, MOST 110–2511-H-224–003-MY3 and MOST 110–2622-H-224–001-CC2.

References

1. Earl, L.M.: Assessment as Learning: Using Classroom Assessment to Maximize Student Learning. Corwin Press, Thousand Oaks (2012)
2. Perrenoud, P.: Assessment in Education (1998)
3. Black, P., Wiliam, D.: Classroom assessment and pedagogy. Assess. Educ.: Principles Policy Pract. **25**, 551–575 (2018). https://doi.org/10.1080/0969594X.2018.1441807
4. Beetham, H., Sharpe, R.: Rethinking pedagogy for a digital age designing for 21st century learning (2013). https://doi.org/10.4324/9780203078952
5. O'Flaherty, J., Phillips, C.: The use of flipped classrooms in higher education: a scoping review. Internet High. Educ. **25**, 85–95 (2015). https://doi.org/10.1016/j.iheduc.2015.02.002
6. Huang, C.K., Lin, C.Y.: Flipping business education: transformative use of team-based learning in human resource management classrooms. Educ. Technol. Soc. **20**(1), 323–336 (2017)
7. Prashar, A.: Assessing the flipped classroom in operations management: a pilot study. J. Educ. Bus. **90**, 126–138 (2015). https://doi.org/10.1080/08832323.2015.1007904
8. Bloom, B.S.: Taxonomy of Educational Objectives: The classification of Educational Goals. Cognitive domain, New York (1956)
9. Anderson, L.W., Krathwohl, D.R.: A taxonomy for learning, teaching, and assessing: a revision of Bloom's taxonomy of educational objectives. Longman, (2001)
10. Eber, P.A., Parker, T.S.: Assessing student learning: applying bloom's taxonomy bloom's taxonomy. Human Serv. Educ. **27**(1), 45–53 (2007)
11. Knight, P.: The local practices of assessment. Assess. Eval. High. Educ. **31**, 435–452 (2006)
12. Sadler, D.R.: Formative assessment and the design of instructional systems. Instr. Sci. **18**(2), 119–144 (1989). https://doi.org/10.1007/BF00117714
13. Weurlander, M., Söderberg, M., Scheja, M., Hult, H., Wernerson, A.: Exploring formative assessment as a tool for learning: students' experiences of different methods of formative assessment. Assess. Eval. High. Educ. **37**, 747–760 (2012). https://doi.org/10.1080/02602938.2011.572153
14. Shepard, L.A.: Linking formative assessment to scaffolding. Educ. Leadersh. **63**, 66–70 (2005)

15. Gan, Z., Leung, C.: Illustrating formative assessment in task-based language teaching. ELT J. **74**, 10–19 (2020). https://doi.org/10.1093/ELT/CCZ048
16. Pryor, J., Crossouard, B.: A socio-cultural theorisation of formative assessment. Oxf. Rev. Educ. **34**, 1–20 (2008). https://doi.org/10.1080/03054980701476386
17. McCallum, S., Milner, M.M.: The effectiveness of formative assessment: student views and staff reflections. Assess. Eval. High. Educ. **46**, 1–16 (2021). https://doi.org/10.1080/02602938.2020.1754761
18. Sailer, M., Sailer, M.: Gamification of in-class activities in flipped classroom lectures. Br. J. Edu. Technol. **52**, 75–90 (2021). https://doi.org/10.1111/bjet.12948
19. Lin, C.-L., et al.: The influence of affective feedback adaptive learning system on learning engagement and self-directed learning (2022). https://doi.org/10.3389/fpsyg.2022.858411
20. Roehl, A., Reddy, S.L., Shannon, G.J.: The flipped classroom: an opportunity to engage millennial students through active learning strategies. J. Fam. Consum. Sci. **105**(2), 44–49 (2013)
21. Huang, Y.M., Silitonga, L.M., Wu, T.T.: Applying a business simulation game in a flipped classroom to enhance engagement, learning achievement, and higher-order thinking skills. Comput. Educ. **183**, 104494 (2022). https://doi.org/10.1016/j.compedu.2022.104494
22. Galway, L.P., Corbett, K.K., Takaro, T.K., Tairyan, K., Frank, E.: A novel integration of online and flipped classroom instructional models in public health higher education. BMC Med. Educ. (2014). https://doi.org/10.1186/1472-6920-14-181
23. Kuo, Y.-C., Lin, Y.-H., Wang, T.-H., Lin, H.-C.K., Chen, J.-I., Huang, Y.-M.: Student learning effect using flipped classroom with WPSA learning mode-an example of programming design course. Innovations Educ. Teac. Int. 1–12 (2022)
24. Chyung, S.-Y., Stepich, D.: Applying the" congruence" principle of Bloom's taxonomy to designing online instruction. Q. Rev. Distance Educ. **4**, 317–330 (2003)
25. Morton, D.A., Colbert-Getz, J.M.: Measuring the impact of the flipped anatomy classroom: the importance of categorizing an assessment by Bloom's taxonomy. Anat. Sci. Educ. **10**, 170–175 (2017). https://doi.org/10.1002/ase.1635
26. Almasseri, M., AlHojailan, M.I.: How flipped learning based on the cognitive theory of multimedia learning affects students' academic achievements. J. Comput. Assist. Learn. (2019). https://doi.org/10.1111/jcal.12386
27. Krathwohl, D.R.: A revision of Bloom's taxonomy: an overview. Autumn (2002)

Study on the Learning Effect of "In-Depth Guidance Strategy" Combined with "Online Digital Teaching Materials" in Multimedia Integrated System Course

Wen-Yen Lin[1](✉), Tien-Chi Huang[1], Hao-Chun Chang[1], Jun-Xiang Soh[1], Hao-Lun Peng[1], and Pei-Ling Chien[2]

[1] Department of Information Management, National Taichung University of Science and Technology, Taichung, Taiwan
{qqnice,tchuang}@nutc.edu.tw
[2] Global Communication Faculty Kobe Gakuin University, Kobe, Japan
chien.peiling@gc.kobegakuin.ac.jp

Abstract. Most of the traditional multimedia introductory or multimedia integration courses focus on the communication of theoretical concepts and multimedia applications and imagery, or are based on unit courses for individual skill development with different tools, or use web pages and websites to present integrated multimedia results, has gradually been unable to meet today's ever-changing multimedia vehicles, but also makes students lack the motivation to integrate applications. In order to understand students' learning differences and cognitive understanding, as well as students' ability to apply reflection, this study come up with the idea of "Flipped Teaching Method of Integrating Virtual and Reality", with virtual online teaching materials for teaching, teachers and teaching assistants are able to solve problems raised by students in online flipped learning classrooms in a timely manner, and achieving the goal of differentiated counseling. Through reflecting and sharing the results of this experiment, we could realize "In-depth guidance strategy" along with "Virtual-reality hybrid integrating flipped teaching" could improve students' learning effectiveness.

Keywords: Flipped teaching · Distance teaching · Mixed teaching · Learning effectiveness

1 Introduction

Most of the traditional multimedia introductory courses or multimedia integration courses focus on teaching theoretical concepts and the appliance of multimedia along with its imagery. The teaching methods of traditional courses, which mainly based on individual skill training with different tools, were unable to meet the needs of ever-changing multimedia nowadays, thus, result in the lack the motivation for students to integrate applications.

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 398–404, 2022.
https://doi.org/10.1007/978-3-031-15273-3_44

In order to understand students’ learning differences and cognitive understanding, as well as students’ application ability of reflection. This study proposes a “Flipped Teaching Method of Integrating Virtual and Real” with narration and hybrid flipped learning. This study introduce WSQ-guided design and virtual online teaching materials for teaching. Through the inspection, sharing and evaluation of course works, we can understand the impact of “in-depth guidance strategy” combined with “Virtual-Real Integration Hybrid Flipped Teaching” on the learning effect of students.

2 Literature Review

2.1 Flipped Teaching Method of Integrating Virtual and Reality

In-class narration is commonly used as traditional teaching methods, but these traditional methods result in lack of opportunities for teacher-student interaction and limited the time for individual instruction in classrooms. A recent teaching method called “The Flipped Teaching” [1, 2, 3] solved the problems through utilizing the Internet. Teachers record part of class lectures as multimedia videos, such as the teaching materials mentioned previously. Class instructors require students to preview class handouts beforehand, so that the limited class time could be utilize for in-class activities such as interactive discussions, in hopes of increasing the knowledge that is learnt by the students in class. The original leading role of teachers has been changed to provide learning guidance and assistance in order to enhance learning effectiveness [4, 5]. However, flipped teaching requires students to prepare before class, which increases their cognitive loads [1, 6]. Some scholars have proposed a “Blended Flipped Instructional Design” for flipped teaching courses in classrooms [7, 8]. Blended flipped teaching method is committed to reducing the learning burden of students’ cognitive load and thus, improving the effectiveness of students’ learning.

Many scholars have proposed that by reflecting on what you have learned, you could understand the relations between knowledges, and achieve the goal of comprehension. After reaching comprehension could one conduct learning transfer and internalization [9, 10]. Doctor Dewey (1986) particularly advocated that by learning in an experiential situation, students could comprehend the relation between things through active reflection and thinking, and the learning experience will be internalized into self-knowledge.

2.2 WSQ-Guided Design

An American teacher, Crystal Kirch, proposed the “WSQ” teaching strategy to enhance the operation of flipped teaching in classrooms. “W” stands for watch, which means that students will try to answer the questions designed by the teacher after watching lesson videos. “S” stands for summary, students will try to summarize what they have learnt after each course, and the teacher could evaluate students’ learning situation according to the summary. “Q” stands for question, after summarizing lesson contents, students will try to come up with questions pertaining to the lesson video. These questions reflected how well students understand the course, and also shows students reflective feedbacks. Crystal Kirch sees the purpose of summarizing as: thinking and organizing at home;

reading, speaking and listening in school. The purpose of raising a "question" is that, students must have an in-depth understanding of what they have learned to come up with in-depth questions [11, 12]. Lastly, students will try to raise questions pertaining to the lesson video, and teachers could understand the degree of deep understanding of each student by reading through their reflections and feedbacks.

3 Methodology

This study adopts the method of questionnaire collecting. The contents of the questionnaires are the General Self-Efficacy Scale (General Self-Efficacy Scale) adapted from the Self-efficacy Questionnaire [13]. The reflected table was adapted from Deep Strategy Score Scale [14]. Cognitive loading questionnaire was adapted from Cognitive Load Measurement and Curriculum Satisfaction Questionnaire [15]. The experimental group collected data from 21 people, and the control group collected data from 33 people. The study experiment framework is briefly shown in Fig. 1:

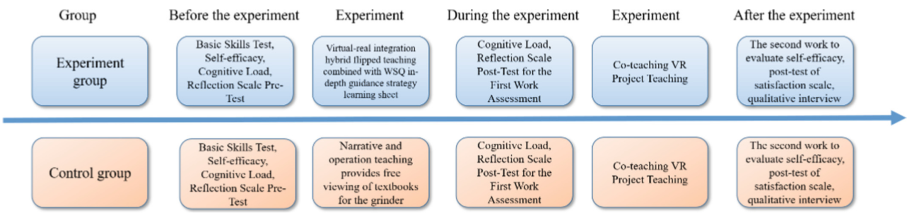


Fig. 1. The experiment framework of "In-depth guidance strategy" combined with "virtual-reality hybrid integrating flipped teaching"

The following points are the methods adopted in this study:
Before the experiment:

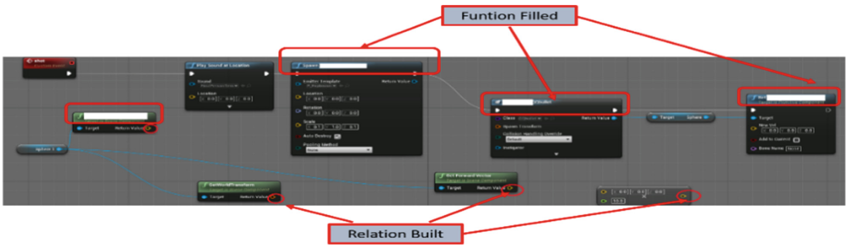


Fig. 2. Graphical development tools

1. Use graphical tools for program development, shown in Fig. 2.
2. Set up online teaching materials and classroom guidance materials on the learning platform beforehand.
3. Design study sheets of the WQS in-depth guidance strategy with online teaching materials. Examples of the study sheets are shown in Fig. 3.

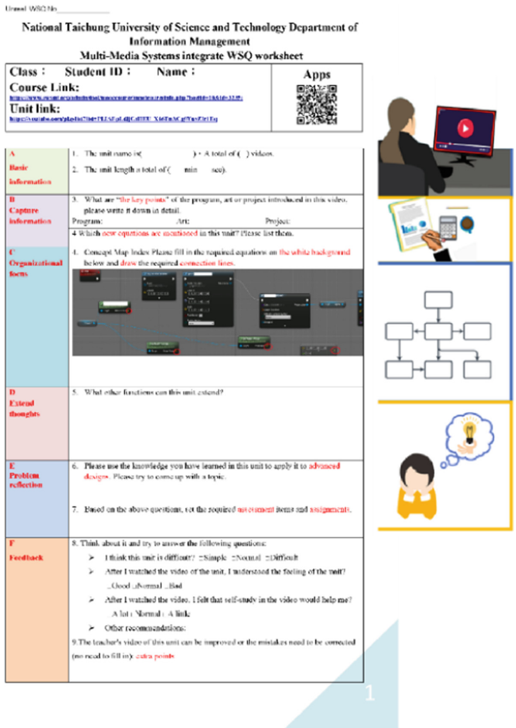


Fig. 3. Example of "WSQ Deep Guidance Strategy Study Sheet".

During the experiment:

1. Teachers should introduce and analyze lesson goals with the help of mind maps at the beginning of the class.
2. Teachers should use online digital teaching materials in classrooms and conduct practical demonstrations to solve problems result in the study abilities of different students.

3. Teachers and teaching assistants should assist students with difficulties during online learning lessons immediately, and acknowledge their learning situation. Example shown in Fig. 4.
4. After online lessons, fill in the "WSQ Study Sheets".
5. Teachers extending course contents on the basis of previous material.
6. Guide students to design applications based on course lessons, record the results and upload them to the system, completing the assignments.

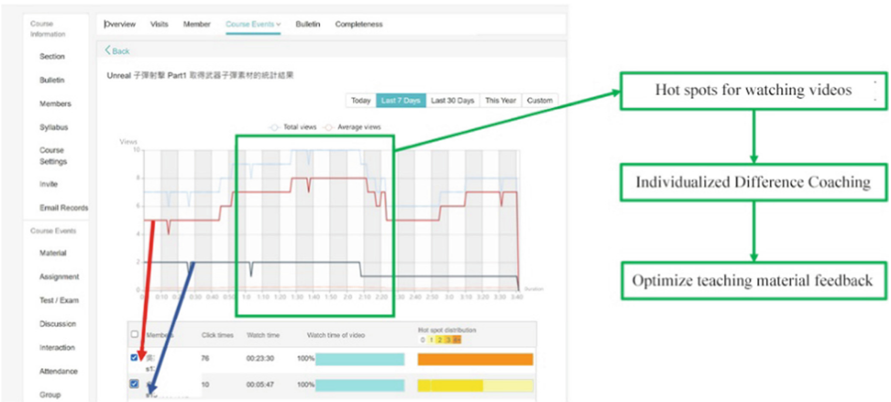


Fig. 4. Students' learning situation recorded and analyzed by the learning platform.

After the experiment:

1. After class, teaching assistants will mark students' homework, and have teaching discussions aiming each student's learning situation with teachers.
2. Teaching assistants and teachers having discussions according to the records on the online learning platform.
3. Reply to questions raised in the online discussion forum.
4. Teaching assistants will mark the study sheets after class and provide guidance on the problems.
5. Teachers respond to the learning feedbacks in the next lesson.

4 Result

The study results are as follows:

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	cooperation_tendency_109_pre - cooperation_tendency_109_pos	-1.45455	4.80293	.83608	-3.15759	.24850	-1.740	32	.092
Pair 2	communication_tendency_109_pre - communication_tendency_109_pos	-.87879	5.72144	.99597	-2.90752	1.14995	-.882	32	.384
Pair 3	creative_thinking_tendency_109_pre - creative_thinking_tendency_109_pos	.09091	6.11537	1.06455	-2.07751	2.25932	.085	32	.932
Pair 4	learning_attitude_109_pre - learning_attitude_109_pos	1.42424	8.33678	1.45125	-1.53185	4.38034	.981	32	.334
Pair 5	learning_motivation_109_pre - learning_motivation_109_pos	.33333	6.63639	1.15525	-2.01983	2.68649	.289	32	.775
Pair 6	personal_self_efficacy_109_pre - personal_self_efficacy_109_pos	.03030	10.36968	1.80513	-3.64663	3.70723	.017	32	.987
Pair 7	group_self_efficacy_109_pre - group_self_efficacy_109_pos	-.48485	7.94560	1.38315	-3.30224	2.33254	-.351	32	.728
Pair 8	cooperative_learning_tendency_109_pre - cooperative_learning_tendency_109_pos	-.15152	7.32343	1.27484	-2.74829	2.44526	-.119	32	.906
Pair 9	Satisfaction_Learning_Modes_109_pre - Satisfaction_Learning_Modes_109_pos	-.60606	10.06212	1.75159	-4.17393	2.96181	-.346	32	.732
Pair 10	mental_load_109_pre - mental_load_109_pos	-1.57576	11.18881	1.94772	-5.54314	2.39162	-.809	32	.424

Fig. 5. The learning effect of the control group.

It can be seen from Fig. 5 that the control group has no significant improvement in terms of cooperation, communication and other factors. The control group has no significant results in learning effects.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	cooperation_tendency_110_pre - cooperation_tendency_110_pos	-4.62500	4.66011	1.16503	-7.10820	-2.14180	-3.970	15	.001
Pair 2	communication_tendency_110_pre - communication_tendency_110_pos	-3.56250	6.18567	1.54642	-6.85861	-.26639	-2.304	15	.036
Pair 3	creative_thinking_tendency_110_pre - creative_thinking_tendency_110_pos	-2.25000	4.87852	1.21963	-4.84958	.34958	-1.845	15	.085
Pair 4	learning_attitude_110_pre - learning_attitude_110_pos	-.43750	5.54940	1.38735	-3.39457	2.51957	-.315	15	.757
Pair 5	learning_motivation_110_pre - learning_motivation_110_pos	.00000	3.11983	.77996	-1.66244	1.66244	.000	15	1.000
Pair 6	personal_self_efficacy_110_pre - personal_self_efficacy_110_pos	-2.00000	6.56252	1.64063	-5.49692	1.49692	-1.219	15	.242
Pair 7	group_self_efficacy_110_pre - group_self_efficacy_110_pos	-2.75000	8.61394	2.15349	-7.34005	1.84005	-1.277	15	.221
Pair 8	cooperative_learning_tendency_110_pre - cooperative_learning_tendency_110_pos	.31250	3.87675	.96919	-1.75327	2.37827	.322	15	.752
Pair 9	Satisfaction_Learning_Modes_110_pre - Satisfaction_Learning_Modes_110_pos	-3.18750	6.96868	1.74217	-6.90085	.52585	-1.830	15	.087
Pair 10	mental_load_110_pre - mental_load_110_pos	1.81250	7.58260	1.89565	-2.22798	5.85298	.956	15	.354

Fig. 6. The learning effect of the experimental group.

It can be seen from Fig. 6 that the factors of cooperation and communication in the experimental group has significantly improved, inferring that the learning effect of the experimental group has a significant outcome.

5 Conclusion

The study results show that, through the teaching method of “Flipped Teaching Method of Integrating Virtual and Real”, both the cooperation tendency and the communication tendency have been significantly improved. Therefore, this study infers the use of the “Flipped Teaching Method of Integrating Virtual and Real” with narration and hybrid flipped learning, and with virtual online teaching materials for teaching, so that teachers and teaching assistants can solve students' problems and difficulties in the classroom in real time, so as to achieve differentiated tutoring. Through the inspection, sharing and evaluation of course works, it is learned that the combination of "in-depth guidance strategy" and "Virtual-Real Integration Hybrid Flipped Teaching" has significantly improved the learning effect of students.

Acknowledgements. We would like to thank to the MOE Teaching Practice Research Program for funding the Teaching Practice Research Program. This work is supported by the MOE Teaching Practice Research Program, Program No. PSK1100704.

References

1. Arnold-Garza, S.: The flipped classroom teaching model and its use for information literacy instruction. Commun. Inf. Literacy **8**(1), 9 (2014)
2. Bergmann, J., & Sams, A.: Flip Your Classroom: Reach Every Student in Every Class Every Day. International society for technology in education (2012)
3. Newman, G., Kim, J.-H., Lee, R.J., Brown, B.A., Huston, S.: The perceived effects of flipped teaching on knowledge acquisition. J. Effective Teach. **16**(1), 52–71 (2016)
4. Hibbard, L., Sung, S., Wells, B.: Examining the effectiveness of a semi-self-paced flipped learning format in a college general chemistry sequence. J. Chem. Educ. **93**(1), 24–30 (2016)
5. Sams, A., Bergmann, J.J.: E. l. Flip your students' learning. **70**(6), 16–20 (2013)
6. Bergmann, J., Sams, A.: Before you flip, consider this. Phi Delta Kappan **94**(2), 25–25 (2012)
7. Arnold-Garza, S.: The flipped classroom teaching model and its use for information literacy instruction. Commun. Inf. Lit. **8**(1), 9 (2014)
8. Wang, T.-H., Lin, H.-C.K., Wu, T.-T., Huang, Y.-M.: A multimethod approach for supporting reflection and creativity in online collaborative courses. J. Internet Technol. **21**(4), 10 (2020)
9. Dewey, J.: Experience and education. Paper presented at The Educational Forum (1986)
10. Dewey, J., Hook, S.: Experience and Nature, 1925: Southern Illinois University (1988)
11. Kirch, C.: Flipping with Kirch, **4**, 2014 (2012)
12. Kirch, C., Bretzmann, J.: Flipping with Kirch: the ups and downs from inside my flipped classroom. Bretzmann Group LLC (2016)
13. Bandura, A.: Social cognitive theory of mass communication. Media Psychol. **3**(3), 265–299 (2001)
14. Anderman, E.M., Young, A.J.: Motivation and strategy use in science: individual differences and classroom effects. J. Res. Sci. Teach. **31**(8), 811–831 (1994)
15. Paas, F., Tuovinen, J.E., Tabbers, H., Van Gerven, P.W.: Cognitive load measurement as a means to advance cognitive load theory. Educ. Psychol. **38**(1), 63–71 (2003)

BSG - A Serious Game Tool to Improve Student's Self-efficacy, Motivation, and Engagement in Entrepreneurship

Budi Dharmawan[1], Anisur Rosyad[1], Lusia Maryani Silitonga[2], Alpha Nadeira Mandamdari[1], Sunendar[1], Lufti Zulkifli[1], and Ting-Ting Wu[2(✉)]

[1] Jenderal Soedirman University, Purwokerto 53123, Indonesia
[2] National Yunlin University of Science and Technology, Douliu 64002, Taiwan
ttwu@yuntech.edu.tw

Abstract. Entrepreneurship education has grown tremendously, as has been extensively documented. Entrepreneurship education has expanded in scope, significantly extending across fields in universities and penetrating all levels of educational systems. Moreover, the notion and measurement of engagement have become increasingly important to academics and practitioners. Some researchers have discovered that an approach for increasing engagement in a beneficial way has been established from games. The study adopts a business simulation game (BSG) as a serious game in the Entrepreneurship course to develop students' self-efficacy, motivation, and engagement. The quasi-experiment was applied to 48 university students. The findings indicate that BSG, based on real challenges in a business environment, allows students to develop their self-efficacy, motivation, and engagement. BSG provides significant opportunities and new alternatives for developing management, leadership, and entrepreneurial skills.

Keywords: Serious game · Simulation · Entrepreneurship education · Classroom teaching

1 Introduction

Entrepreneurship is a critical economic activity in the twenty-first century. Entrepreneurship empowers today's youth to establish their businesses and acquire soft critical skills that will serve them well across their professional careers [1]. Universities are commonly regarded as incubators of entrepreneurial spirit and culture, with the expectation that they will play a critical role in discovering and developing students' entrepreneurial talents and tendencies and enabling them to start their ventures [2]. Numerous researchers and educators define entrepreneurship education's objective as increasing and enhancing students' knowledge of entrepreneurship as a process and prospective vocation and their understanding of how multiple management disciplines interact. Moreover, simulation-based learning, which manipulates learning information frequently and observes the

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 405–414, 2022.
https://doi.org/10.1007/978-3-031-15273-3_45

manipulation outcomes in order to help students better grasp real-world experience and practice, is one of the most popular ways of entrepreneurship education today [2–4].

A serious game is characterized as one that has an educational purpose but also incorporates three essential components: enjoyment, experience, and multimedia [5]. Serious games are created with a definite educational goal, not only for enjoyment. Serious games are a relatively recent addition to entrepreneurship classrooms. According to [4] games combine trial-and-error learning, immediacy, complexity, and point-scoring features.

Several studies have just started investigating the feasibility of employing game-based learning to boost students' self-efficacy in various topic areas [6]. Self-efficacy is a term that relates to an individual's perceived capacity for gaining knowledge or completing tasks at a specified level [7]. Furthermore, Self-efficacy is a critical cognitive factor affecting motivation and engagement [8]. Self-efficacy affects one's motivation and the resilience required to complete a challenging work [7, 9].

However, the application BSGs, as serious games to the study of engagement are a relatively recent area of research [10]. BSG should be designed in such a way that groups of students collaborate, hence increasing engagement. They asserted that participation in the game and enjoyment are the two most significant aspects affecting the success of a BSG [11]. Moreover, [12] stated that students' motivations affect their level of engagement throughout games. The nature and design of gaming activities significantly impact a learner's motivation, engagement, and problem-solving performance.

[2] stated that studies on the influence of simulation games and game-based learning in entrepreneurship education are limited; therefore, this study examines how BSG as a serious game might boost entrepreneurship motivation, self-efficacy, and engagement. The study's objectives were to address the following:

1. Does employing a BSG enhance students' self-efficacy compared to a traditional classroom?
2. Does employing a BSG enhance students' motivation compared to a traditional classroom?
3. Does employing a BSG enhance student engagement compared to a traditional classroom?

2 Introduction

2.1 Serious Game and Business Simulation Game

Mainly, serious games are created with the primary purpose of attaining a fun experience and engaging players. Furthermore, a BSG, as a serious game, can be utilized to boost entrepreneurial motivation and competencies [1]. A simulation game has been found to improve students' comprehension of specific courses by simulating real-world circumstances through frequent manipulations of learning content and examinations of the outcomes of those manipulations [13, 14]. Fun, play, rules, targets, engagement, outcomes or feedback, winning states, competition, and problem-solving are all characteristics of simulations [3]. Moreover, business simulations are most frequently used in management, commerce, financial, budgeting, marketing, project management, and entrepreneurship [4, 15].

Serious games provide educators with more realistic and engaging learning experiences. The entrepreneur's educational method, based on serious games, enables the integration of amusing elements and detailed information, encouraging the learning process and assisting students in feeling more prepared for starting a new firm [1].

2.2 Self-efficacy in Entrepreneurship

A greater sense of self-efficacy has benefited learning, performance, self-regulation, and motivational goals such as activity selection, concentration, resilience, and enthusiasm [7, 16]. Students who are self-efficacious are enthusiastic and engaged in their studies, which enhances their capacity as learners [17].

[7] characterized perceived self-efficacy as "beliefs in one's skills to arrange and carry out the objectives – to achieve certain goals." Furthermore, a significant aspect of this concept is that self-efficacy affects motivation and the level of perseverance required to complete a challenging activity [9]. This is critical for educators since students are expected to develop into motivated and persistent managers. Self-efficacy has been shown to affect behavior significantly and results in various topics, such as human resources, information management, business, and entrepreneurship.

Entrepreneurial self-efficacy is characterized as an individual's confidence in their capacity to fulfill entrepreneurial roles and responsibilities successfully. The study found a significant correlation between entrepreneurial self-efficacy and students' desire to begin their own company [2, 18].

2.3 Motivation

Intrinsic and extrinsic motivation can be classified according to the various reasons or objectives that motivate action. Intrinsic motivation is defined as motivation that originates within an individual rather than from external rewards, whereas extrinsic motivation is defined as motivation produced by tangible rewards or penalties associated with success or failure in a task [2, 19]. In this study, learning motivation is defined as students' intrinsic motivation to learn. Additionally, it refers to students' motivation to continually dedicate themselves to acquiring knowledge and competencies [20].

Previous studies examined a range of applications within the context of game-based learning and the effect of games on learning motivation. For instance, [21] devised a science-learning experiment to determine whether increasing students' engagement and motivation inside an online game-based learning environment may improve their learning accomplishment. According to Kuo's studies, game-based learning can effectively motivate students to engage in science exploration and the learning process [21].

2.4 Engagement

Engagement is characterized as the degree to which students participate in activities, such as active learning, enhancing learning programs, seeking help from faculty, or cooperating with other students [4, 22]. Engagement entails classroom instruction and can relate to both academic and non-academic areas of university education [23, 24]. Moreover, Engagement indicators are internal components of the idea of engagement, and the primary indicators of engagement are commonly acknowledged as cognitive, emotional, and behavioral indicators [10, 11].

In game-based learning research, engagement has been a fundamental concept. However, there are remarkably few researches that analyze psychological engagement in game-based learning [25]. In a game-based learning environment, [26] discovered a correlation between these three engagement characteristics (cognitive, emotional, and behavioral).

3 Methods

3.1 Data Collection and Participants

The quasi-experimental study was conducted at the agribusiness faculty of one state-owned university in Indonesia. A total of 48 students from second and third-year students were enrolled in two classes of the entrepreneurship course. Both classes were taught by the same instructor, using identical course materials but with different instructional strategies. The control group used the conventional learning approach, whereas the experimental group participated in a serious game. Data were collected through a self-administrated questionnaire at the end of the experimental activity. The participants' identities and confidentiality were assured.

3.2 Procedure

This study employed a serious business simulation game developed by United Sates simulation developer Marketplace Simulation. Figure 1 illustrates the experimental procedure used in this study. During the first meeting, the students were informed about the course's aims and objectives and the game's operations exclusively to the experimental group participants. After becoming familiar with the serious game, students were divided into teams of six members. Each team was tasked with managing a company to compete against companies operated by other students. All students in both groups completed the pretest questionnaires that assessed their self-efficacy, motivation, and engagement in the first meeting.

The experimental group of students has hands-on experience in starting a new business and competing in a simulated market. The game featured six decision rounds (meeting 2–7) that created interconnected learning. They are challenged to manufacture and sell carbon fiber bicycles in various market segments. Students were required to formulate business strategies, analyze the market data, plan production, and engage in R&D to gain a competitive edge to serve the customers through interrelated tactical decisions. The control group students learned through the conventional learning approach of PowerPoint lectures, direct instructions, and discussion to start a business. All students completed the posttest questionnaires on self-efficacy, motivation, and engagement in the eight meetings.

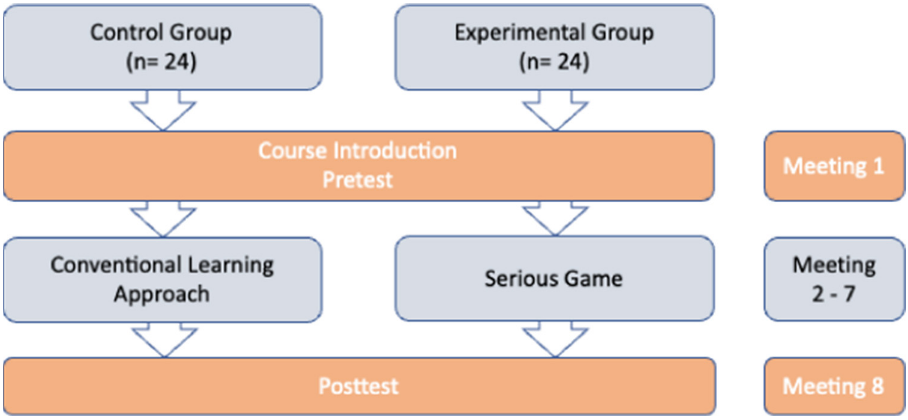


Fig. 1. The experimental procedure

3.3 Procedure

The variable was measured using a well-established questionnaire from prior literature. Student self-efficacy and motivation were assessed using the Motivated Strategies for Learning Questionnaire, developed by [27]. The self-efficacy questionnaire has eight items that assess participants' confidence in their abilities to execute the task—student motivation comprised of 14 items representing various motivational factors. The students' engagement was measured by [28] engagement scale, consisting of 17 items indicating various reasons for engaging in the classroom activity. All items were adapted for this study and served as the pretest and posttest. The items were assessed on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree)—Cronbach's α coefficients for the pretest and post-test of all variables were shown in Table 1.

Table 1. The reliability of the measurement

Variable	Items	Cronbach's alpha α	
		Pretest	Posttest
Self-efficacy	8	0.916	0.818
Motivation	14	0.990	0.898
Engagement	17	0.779	0.936

3.4 Data Analysis

The differential analysis between experimental and control groups was conducted using a one-way analysis of covariances (ANCOVA) to see significant differences in student self-efficacy, motivation, and engagement between the two groups. The pretest scores served as a covariate, whereas the posttest scores served as the dependent variable. Levene's test was employed to determine the homogeneity of the participants, and the findings confirm that both sets of groups were statistically homogenous.

4 Results

4.1 Self-efficacy

The ANCOVA result in Table 3 shows a significant difference in self-efficacy between control and experimental groups ($F = 24.802$, $p < 0.05$, $\eta 2 = 0.305$). Further analysis of the average scores of the two groups in the self-efficacy posttest (Table 2) shows that compared with the control group ($M = 3.8854$, $SD = 0.48471$), the experimental group had stronger self-efficacy ($M = 4.4531$, $SD = 0.4775$). This implies that a serious game can boost students' self-efficacy more than a conventional learning approach.

Table 2. The descriptive results of student's self-efficacy, motivation, and engagement

Variable	Group	Pretest		Posttest	
		Mean	SD	Mean	SD
Self-efficacy	Control group	4.0573	0.64688	3.8854	0.48471
	Experimental group	3.8073	0.58744	4.4531	0.4775
Motivation	Control group	3.3512	0.59647	3.6696	0.4056
	Experimental group	3.5417	0.97823	4.3958	0.34287
Engagement	Control group	3.5368	0.42642	3.4926	0.4536
	Experimental group	3.424	0.4709	4.6054	0.38922

Table 3. The ANCOVA results of student's self-efficacy, motivation, and engagement

Variable	Mean square	F	p	η2
Self-efficacy	4.847	24.802	0.000*	0.305
Motivation	6.220	43.153	0.000*	0.49
Engagement	15.585	96.608	0.000*	0.682

$^{*}p < 0.05$

4.2 Motivation

According to the results of ANCOVA test, there was a significant difference in students' motivation between the two groups ($F = 43.153$, $p < 0.05$, $\eta 2 = 0.49$), as seen in Table 3. The comparison of the motivation posttest indicates that the students in the experimental group feel more motivated ($M = 4.3958$, $SD = 0.34287$) than control group ($M = 3.6696$, $SD = 0.4056$) (Table 2).

4.3 Engagement

Table 3 shows that there is a significant difference between control and experimental groups ($F = 96.608$, $p < 0.05$, $\eta 2 = 0.682$). The comparison of the engagement posttest scores (Table 2) indicates that compared with control group ($M = 3.4926$, $SD = 0.4536$), the experimental group showed more engagement in the learning activity ($M = 4.6054$, $SD = 0.38922$).

5 Discussion

A BSG was used as a serious game in this study to increase students' self-efficacy, motivation, and engagement.

5.1 Effects on Students' Self-efficacy

The findings of this study indicate that using a BSG has a significant and beneficial effect on students' self-efficacy in entrepreneurship. Hence, students who actively participate in the simulation develop a strong belief that they are capable of successfully running their own business. When students in the experimental group participated in BSG activities, they demonstrated a considerably more significant improvement in self-efficacy than students in the control group. Furthermore, students' capacity to engage in various marketing activities in the simulation game may be self-monitored and evaluated to develop and enhance their sense of entrepreneurial self-efficacy.

5.2 Effects on Students' Motivation

This study shows that the use of a BSG had a significant and positive impact on the students' motivation. The game's components, including badges, points, levels, and trophies, promoted student participation. Additionally, the game encouraged student engagement due to its user-friendly and interactive Web application. Earning bonus points and badges as an incentive for simulation accomplishments increased student motivation and satisfaction.

5.3 Effects on Students' Engagement

The BSG increased student participation in general. The simulation's interactions increased student involvement. All simulation game work incorporates debate and critical thinking about market, sales, production, and finance issues. As a result, the experimental group's average level of involvement was higher than that of the control group.

6 Conclusion

The BSG activities required students to quickly overcome barriers and tasks, which enhanced their self-efficacy throughout gameplay. As a result, the results suggested that higher self-efficacy resulted in a higher student engagement, with students focusing on future motivation and commitment to completing the BSG's challenge problems. It is determined that one of the most crucial aspects of game design is sustaining student motivation throughout gameplay. Given that students are inquisitive individuals that enjoy novelty and problem solving, one strategy for addressing the issue of sustainability is to give students with new and demanding game scenarios as they progress through their gameplay assignments. It will keep students engaged and motivated.

Acknowledgments. This research is partially supported by the Ministry of Science and Technology, Taiwan, R.O.C. under Grant No. MOST 108-2628-H-224-001-MY3, MOST 110-2511-H-224-003-MY3, and MOST 110-2622-H-224-001-CC2.

References

1. Buzady, Z., Almeida, F.: FLIGBY—a serious game tool to enhance motivation and competencies in entrepreneurship. Informatics. **6**, 27 (2019). https://doi.org/10.3390/informatics6030027
2. Yen, W.-C., Lin, H.-H.: Investigating the effect of flow experience on learning performance and entrepreneurial self-efficacy in a business simulation systems context. Interact. Learn. Environ. 1–16 (2020). https://doi.org/10.1080/10494820.2020.1734624
3. Fox, J., Pittaway, L., Uzuegbunam, I.: Simulations in entrepreneurship education: serious games and learning through play. Entrep. Educ. Pedagogy **1**, 61–89 (2018). https://doi.org/10.1177/2515127417737285
4. Huang, Y., Silitonga, L.M., Wu, T.: Applying a business simulation game in a flipped classroom to enhance engagement, learning achievement, and higher-order thinking skills. Comput. Educ. **183**, 104494 (2022). https://doi.org/10.1016/j.compedu.2022.104494
5. Laamarti, F., Eid, M., el Saddik, A.: An overview of serious games. Int. J. Comput. Games Technol. **2014**, 1–15 (2014). https://doi.org/10.1155/2014/358152
6. Meluso, A., Zheng, M., Spires, H.A., Lester, J.: Enhancing 5th graders' science content knowledge and self-efficacy through game-based learning. Comput. Educ. **59**, 497–504 (2012). https://doi.org/10.1016/j.compedu.2011.12.019
7. Bandura, A., Freeman, W.H., Lightsey, R.: Self-efficacy: the exercise of control. J. Cogn. Psychother. **13**, 158–166 (1999). https://doi.org/10.1891/0889-8391.13.2.158
8. Schunk, D.H., Mullen, C.A.: Self-efficacy as an engaged learner. In: Christenson, S., Reschly, A., Wylie, C. (eds.) Handbook of Research on Student Engagement, pp. 219–235. Springer, Boston (2012). https://doi.org/10.1007/978-1-4614-2018-7_10
9. Tompson, G.H., Dass, P.: Improving students' self-efficacy in strategic management: the relative impact of cases and simulations. Simul. Gaming **31**, 22–41 (2000). https://doi.org/10.1177/104687810003100102

10. Skinner, E.A.: Engagement and disaffection as central to process of motivational resilience and development. In: Wentzel, K.R., Miele, D.B. (eds.) Handbook of Motivation at School, pp. 157–180. Routledge (2016)
11. Buil, I., Catalán, S., Martínez, E.: Encouraging intrinsic motivation in management training: the use of business simulation games. Int. J. Manag. Educ. **17**, 162–171 (2019). https://doi.org/10.1016/j.ijme.2019.02.002
12. Eseryel, D., Law, V., Ifenthaler, D., Ge, X., Miller, R.: An investigation of the interrelationships between motivation, engagement, and complex problem solving in game-based learning. Educ. Technol. Soc. **17**, 42–53 (2014). https://doi.org/10.2307/jeductechsoci.17.1.42
13. Chang, C.-C., Liang, C., Chou, P.-N., Lin, G.-Y.: Is game-based learning better in flow experience and various types of cognitive load than non-game-based learning? Perspective from multimedia and media richness. Comput. Hum. Behav. **71**, 218–227 (2017). https://doi.org/10.1016/j.chb.2017.01.031
14. Hsieh, Y.-H., Lin, Y.-C., Hou, H.-T.: Exploring the role of flow experience, learning performance and potential behavior clusters in elementary students' game-based learning. Interact. Learn. Environ. **24**, 178–193 (2016). https://doi.org/10.1080/10494820.2013.834827
15. Zulfiqar, S., Sarwar, B., Aziz, S., Ejaz Chandia, K., Khan, M.K.: An analysis of influence of business simulation games on business school students' attitude and intention toward entrepreneurial activities. J. Educ. Comput. Res. **57**, 106–130 (2019). https://doi.org/10.1177/0735633117746746
16. Schunk, D.H., DiBenedetto, M.K.: Handbook of Motivation at School. Routledge, Milton Park (2016). https://doi.org/10.4324/9781315773384
17. Usher, E.L., Pajares, F.: Sources of self-efficacy in school: critical review of the literature and future directions. Rev. Educ. Res. **78**, 751–796 (2008). https://doi.org/10.3102/0034654308321456
18. Chen, C.C., Greene, P.G., Crick, A.: Does entrepreneurial self-efficacy distinguish entrepreneurs from managers? J. Bus. Ventur. **13**, 295–316 (1998). https://doi.org/10.1016/S0883-9026(97)00029-3
19. Liao, Y.W., Huang, Y.M., Wang, Y.S.: Factors affecting students' continued usage intention toward business simulation games: an empirical study. J. Educ. Comput. Res. **53** (2015). https://doi.org/10.1177/0735633115598751
20. Brophy, J.: Synthesis of Research on Strategies for Motivating Students to Learn (1987)
21. Kuo, M.-J.: How does an online game based learning environment promote students' intrinsic motivation for learning natural science and how does it affect their learning outcomes? In: 2007 First IEEE International Workshop on Digital Game and Intelligent Toy Enhanced Learning (DIGITEL 2007), pp. 135–142. IEEE (2007). https://doi.org/10.1109/DIGITEL.2007.28
22. Ding, L., Kim, C., Orey, M.: Studies of student engagement in gamified online discussions. Comput. Educ. **115**, 126–142 (2017). https://doi.org/10.1016/j.compedu.2017.06.016
23. Teng, Y., Wang, X.: The effect of two educational technology tools on student engagement in Chinese EFL courses. Int. J. Educ. Technol. High. Educ. **18**(1), 1–15 (2021). https://doi.org/10.1186/s41239-021-00263-0
24. Huang, Y.-M., Silitonga, L.M., Murti, A.T., Wu, T.-T.: Learner engagement in a business simulation game: impact on higher-order thinking skills. J. Educ. Comput. Res. (2022). https://doi.org/10.1177/07356331221106918
25. Hamari, J., Shernoff, D.J., Rowe, E., Coller, B., Asbell-Clarke, J., Edwards, T.: Challenging games help students learn: an empirical study on engagement, flow and immersion in game-based learning. Comput. Hum. Behav. **54**, 170–179 (2016). https://doi.org/10.1016/j.chb.2015.07.045
26. Pellas, N.: Exploring interrelationships among high school students' engagement factors in introductory programming courses via a 3D multi-user serious game created in open sim. J. Univ. Comput. Sci. **20**, 1608–1628 (2014)

27. Pintrich, P.R.R., Smith, D., Garcia, T., McKeachie, W.: A manual for the use of the Motivated Strategies for Learning Questionnaire (MSLQ) (1991). ED338122
28. Reeve, J., Tseng, C.-M.: Agency as a fourth aspect of students' engagement during learning activities. Contemp. Educ. Psychol. **36**, 257–267 (2011). https://doi.org/10.1016/j.cedpsych.2011.05.002

The Effects of Computational Thinking Strategies in English Writing on Students' Foreign Language Anxiety

Astrid Tiara Murti[1], Frode Eika Sandnes[2], and Ting-Ting Wu[1](✉)

[1] National Yunlin University of Science and Technology, Douliu 64002, Taiwan
ttwu@yuntech.edu.tw
[2] Oslo Metropolitan University, 0176 Oslo, Norway

Abstract. Writing is the most essential and difficult skill to learn. Low proficiency and lack of knowledge trigger the anxious feeling that impairs students' ability to acquire language skills. Computational thinking (CT) strategies were proposed to help students identify patterns and give more guidance on their writing tasks. Therefore, the objective of this study is to understand the benefits and the effects of CT strategies on the anxiety level of EFL students. A total of 58 students enrolled in the English writing course. The experiment group used CT strategies, and the control group used a traditional teaching approach. The results confirm the importance of CT strategies in English writing on students' foreign language anxiety. The data analysis shows that the experimental group had (1) reduced the worry of negative evaluation, (2) increased familiarity with English writing, (3) had less concern about failing the class, and (4) more optimistic approach toward English writing.

Keywords: Language learning · English writing · Computational thinking · Foreign language anxiety

1 Introduction

English is the official language of the world. However, in Taiwan English was recognized as a foreign language. Furthermore, it is difficult for students from non-native countries to learn and become competent in English skills [1, 2]. The problems associated with English learning stem from the language's complexity and a lack of vocabulary and grammatical knowledge [3]. When the students encounter difficulty mastering the fundamental of English language skills (reading, listening, speaking, and writing), their anxiety level and cognitive load increase, resulting in demotivating their efforts and poor performance [4]. Anxiety is a significant factor that affects students' ability to master English; it even has a debilitating influence on students' performance. [5] defined foreign language anxiety as self-perception, attitudes, and beliefs associated with classroom language learning. The feeling of tension, apprehension, nervousness, and worry are all linked explicitly to the foreign language learning process [6].

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 415–422, 2022.
https://doi.org/10.1007/978-3-031-15273-3_46

Computational thinking (CT) is firstly defined by [7] as a thought process used to formulate problems and their solutions that draw on the fundamental concepts of computer science, composed of decomposition, pattern recognition, abstraction, algorithm, and evaluation. Recent studies show that incorporating CT strategies into classroom learning activities can create a more positive impact on student performance [8, 9], motivation [3], and anxiety [10].

Writing is widely regarded as the most challenging skill to master, it included content, organizing, grammar, vocabulary, and mechanics. When students were assigned an essay topic, it was discovered that the majority of them were unable to begin writing on their own due to a lack of knowledge regarding how to begin. Additionally, the constructed phrases featured several grammatical and lexical problems [11]. CT provides a systematic method for structuring sentences in English language writing. CT enables students to build a foundation for problem-solving. CT in language learning can assist students in identifying patterns and analyzing phrases linguistically to ascertain their structure. It is suggested that incorporating CT can help students feel less anxious by providing them with more specific guidance on how to solve problems during their learning activities.

Learning a foreign language is a difficult task, and anxiety is often associated with foreign language learning. Therefore, this study aimed to investigate the benefits and effects of CT strategies on the anxiety level of EFL students. Moreover, the following question was kept in mind while conducting this study, which is: Does integrate CT strategies improve students' anxiety levels in English writing?

2 Literature Review

2.1 English Writing

Writing is an essential skill for students to explicate and articulate their thinking. In comparison to other language fundamental skills such as reading, listening, and speaking, writing is the most difficult to master since it incorporates all language components, including writing mechanics, and paragraph organizations [1]. Writing is a process that needs more thinking to develop the ideas in the paragraph, which enable students to produce language by themselves [3, 11, 12].

2.2 Foreign Language Anxiety

Foreign language learning anxiety is a well-established concept that hinders the acquisition of language. It refers to the objective sensations of tension, trepidation, anxiousness, and worry that occur as a result of the automatic nervous system being stimulated by foreign language learning. Most studies say that speaking is the most stressful part of learning a new language [6, 13, 14]. Similarly, anxiety can be found in other aspects of language learning such as listening [8], reading [15], and writing [1, 10]. In order to help the students reduce their anxiety level, researchers have been exploring the contributors to foreign language anxiety including low proficiency, lack of practice and skills, unpleasant experience, fear of making mistakes, task difficulty, classroom environment, peer pressure, and little preparation [3, 9, 13, 14]. Therefore, teachers can provide fitting test items that match student capabilities [16].

2.3 Computational Thinking

Computational thinking (CT) is a widely recognized model of thinking, not only in computer science but also in other disciplines [17]. CT is described as a thought process in formulating a problem and expressing the solutions in a systematic way that can be effectively carried out [7]. CT is an encompassing approach that introduces students to computing concepts and principles that are relevant to their academic topics. The essence of CT involves the process of decomposing complicated problems into more manageable sub-problems (decomposition), following a sequence of steps (algorithm), reviewing how the solution applies to similar problems (abstraction), and evaluating the various applications (evaluation) [7, 18, 19].

The CT strategies were approached to assist students in identifying patterns and analyzing phrases linguistically to ascertain their structure [10]. CT strategies provide a logical way for students to structure their writing so they can perform better at language learning. This study follows the five steps of CT strategies as proposed by [19, 20] to teach English writing to the students.

3 Methods

3.1 Participants and Data Analysis

An experimental design was carried out to investigate the effect of CT strategies on the anxiety level of EFL students. A total of 58 first-year students, who took an English writing course at a public high school in southern Taiwan, participated in this study. The participants were assigned to control and experimental groups. The control group students studied English writing using a traditional teaching approach, whereas the students in the experimental group were taught using CT strategies in English writing.

The data was collected through pre-and post-test questionnaires. Differential analysis was conducted using SPSS 25.0. A covariance analysis (ANCOVA) was used to measure whether the students in the experimental group had lower anxiety levels than students in the control group. The pretest scores were used as a covariate to eliminate the pre-existing differences between the groups.

3.2 Experimental Procedure

The English writing class was held for nine meetings and lasted for 50 min in one meeting. In the first meeting, the teacher provides the course introduction and hand-over self-reported instruments for students to fill in. The students in this course were divided into two groups, the control and the experimental group. Experimental group students were introduced to the CT strategies, in which they will practice their English writing while following this method. The implementation of CT strategies in English writing courses can be seen in Table 1 below. A conventional learning approach was used in the control group. Both groups have the same pre-writing tasks that they need to finish every two weeks. The pre-writing task was done three times from Meeting 2–7. Meeting 8th, all students will have final writing activity, where they can utilize everything they have learned. Therefore, by the end of this course, all students will have three pre-writing practices and one final writing. At the last meeting, Meeting 9th, students completed the post-test questionnaire. The experimental procedure of this study can be seen in Fig. 1.

Table 1. The implementation of the CT strategies in English writing.

CT strategies	Activities
Decomposition	- Understand the task and the main problem - Break down the problem into smaller parts
Pattern recognition	- Identify the writing concepts
Abstraction	- Use relevant articles, pronouns, and propositions - Use relevant vocabularies
Algorithm	- Write the paragraph in systematic way - Write coherent sentences in the paragraph
Evaluation	- Exchange the draft with peers - Revise the writing accordingly

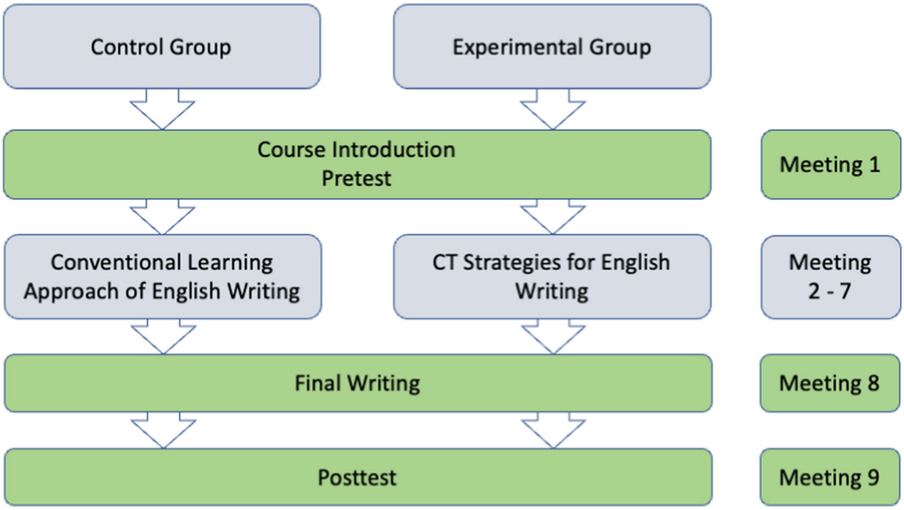


Fig. 1. The experimental procedure.

3.3 Measurement

The foreign language classroom anxiety scale (FLCAS) developed by [5] was a self-report measurement used to investigate the participants' anxiety levels during language classes. FLCAS was designed with four factors concerning fear of negative evaluation, comfort with English learning, fear of failing in the class, and negative attitude toward learning English [15]. The FLCAS comprises 33-items with a 5-point Likert scale ranging from "strongly disagree" to "strongly agree," with an option of neutral. The answer of 'strongly agree' indicates a high level of anxiety, and 'strongly disagree' means a low level of anxiety that the students feel [6]. This study used Cronbach's alpha (α) to assess the scale reliability and the results show that FLCAS α was between 0.734 to 0.918 (Table 2), which is above the suggested value of 0.7 [21].

Table 2. The results of the reliability test.

Variable	Items	Cronbach's α
Fear of negative evaluation	12	0.918
Comfort with English learning	9	0.799
Fear of failing in the class	6	0.734
Negative attitude toward learning English	6	0.880

4 Result

4.1 Fear of Negative Evaluation

The mean and standard deviations of students' fear of negative evaluation scores conducted before and after the course treatment for the control and experimental group are presented in Table 3. The analysis results in Table 3 indicate a significant difference between the control and experiment groups for students' fear of negative evaluation ($F = 7.92$, $p < 0.05$). Students that use CT strategies for English writing had less fear of negative evaluation than those in the control group.

Table 3. The ANCOVA results of students' fear of negative evaluation.

Group	Pretest		Posttest		ANCOVA		
	Mean	SD	Mean	SD	Adj. M	*F*	*p*
Control group	39.3	10.07	39.6	8.82	293.5	7.92	0.007*
Experimental group	39.9	10.00	35.3	5.33			

$^{*}p < 0.05$

4.2 Comfort with English Learning

According to the mean posttest score in Table 4, experimental group students had higher comfort with English learning (M = 25.9, SD = 3.43) compared with students in control group (M = 22.7, SD = 5.33). The ANCOVA test results indicate a significant difference between both groups' pre-posttest on English learning comfortability ($F = 8.09$, $p < 0.05$). Hence, the students that used CT strategies had more comfort with English learning.

Table 4. The ANCOVA results of students' comfort with English learning.

Group	Pretest		Posttest		ANCOVA		
	Mean	SD	Mean	SD	Adj. M	F	p
Control group	21.7	6.64	22.7	5.33	131.0	8.09	0.006*
Experimental group	22.3	6.21	25.9	3.43			

$^{*}p < 0.05$

4.3 Fear of Falling in the Class

The result of the ANCOVA test in Table 5 indicates a significant difference between groups for fear of failing in the class ($F = 8.48$, $p < 0.05$). The mean posttest scores in the experimental group (M = 18.1, SD = 1.81) is lower than the control group (M = 20.1, SD = 3.57). Thus, the students in the experimental group demonstrated less fear of failing than the student in the control group.

Table 5. The ANCOVA results of students' fear of failing in the class.

Group	Pretest		Posttest		ANCOVA		
	Mean	SD	Mean	SD	Adj. M	F	p
Control group	20.1	3.61	20.1	3.57	55.33	8.48	0.005*
Experimental group	20.1	3.57	18.1	1.81			

$^{*}p < 0.05$

4.4 Negative Attitude toward Learning English

The ANCOVA results (Table 6) indicated a significant difference between groups in students' negative attitudes toward learning English ($F = 10.40$, $p < 0.05$). According to the mean posttest score, the experimental group scores (M = 17.4, SD = 3.84) is lower than control group (M = 20.1, SD = 2.90). Hence, the students that learned the CT strategies in their writing courses perceived a more positive attitude toward their English learning.

Table 6. The ANCOVA results of students' negative attitudes toward learning English.

Group	Pretest		Posttest		ANCOVA		
	Mean	SD	Mean	SD	Adj. M	*F*	*p*
Control group	18.6	6.09	20.1	2.90	113.9	10.40	0.002*
Experimental group	18.9	5.68	17.4	3.84			

*$p < 0.05$

5 Conclusion

The results confirm the importance of CT strategies in English writing on students' foreign language anxiety. According to the data analysis, the experimental group students had shown a significant reduction in foreign language anxiety compared to the students in the control group that instead show heightened anxiety by the end of the course. It reveals that students in the experimental group had more familiarity and positive attitudes toward English writing, and also less fear of failing the class.

There are several possible factors that have resulted in the experimental group's positive results regarding the language anxiety level, the CT strategies provide problem-solving support for the writing task. Likewise, the use of CT strategies in the English writing class gives logical structures and a framework for students. The implementation of CT strategies in English writing requires students to decompose the writing tasks into more manageable components, and figure out the concepts and the information needed to develop a logical step-by-step framework. Therefore, it was expected that CT strategies will be more integrated into the English learning classroom.

Acknowledgment. This research is partially supported by the Ministry of Science and Technology, Taiwan, R.O.C. under Grant No. MOST 108-2628-H-224-001-MY3, MOST 110-2511-H-224-003-MY3, and MOST 110-2622-H-224-001-CC2.

References

1. Tsiriotakis, I.K., Vassilaki, E., Spantidakis, I., Stavrou, N.A.M.: The examination of the effects of writing strategy-based procedural facilitative environments on students' English foreign language writing anxiety levels. Front. Psychol. **7**, 1–14 (2017). https://doi.org/10.3389/fpsyg.2016.02074
2. Chien, Y.-C., Wu, T.-T., Lai, C.-H., Huang, Y.-M.: Investigation of the influence of artificial intelligence markup language-based LINE ChatBot in contextual English learning. Front. Psychol. **13** (2022). https://doi.org/10.3389/fpsyg.2022.785752
3. Sabti, A.A., Md Rashid, S., Nimehchisalem, V., Darmi, R.: The impact of writing anxiety, writing achievement motivation, and writing self-efficacy on writing performance: a correlational study of Iraqi tertiary EFL learners. SAGE Open **9**, 1–13 (2019). https://doi.org/10.1177/2158244019894289

4. Shadiev, R., Huang, Y.M.: Investigating student attention, meditation, cognitive load, and satisfaction during lectures in a foreign language supported by speech-enabled language translation. Comput. Assist. Lang. Learn. **33** (2020). https://doi.org/10.1080/09588221.2018.1559863
5. Horwitz, E.K., Horwitz, M.B., Cope, J.: Foreign language classroom anxiety. Mod. Lang. J. **70**, 125 (1986). https://doi.org/10.2307/327317
6. Horwitz, E.: Language anxiety and achievement. Ann. Rev. Appl. Linguist. **21**, 112–126 (2001). https://doi.org/10.1017/S0267190501000071
7. Wing, J.M.: Computational thinking and thinking about computing. Philos. Trans. Royal Soc. A: Math. Phys. Eng Sci. **366**, 3717–3725 (2008). https://doi.org/10.1098/rsta.2008.0118
8. Zhang, X.: Foreign language listening anxiety and listening performance: conceptualizations and causal relationships. System **41**, 164–177 (2013). https://doi.org/10.1016/j.system.2013.01.004
9. Hamid Abbas, S., Al-bakri, S.: The effect of pair writing technique on Iraqi EFL university students' writing performance and anxiety. Arab World Engl. J. **9**, 23–37 (2018). https://doi.org/10.24093/awej/vol9no2.2
10. Parsazadeh, N., Cheng, P.-Y., Wu, T.-T., Huang, Y.-M.: Integrating computational thinking concept into digital storytelling to improve learners' motivation and performance. J. Educ. Comput. Res. **59**, 470–495 (2021). https://doi.org/10.1177/0735633120967315
11. Yu, T.X., Wan Mohammad, W.M.R.: Integration of 21st century learning skills (4C Elements) in interventions to improve English writing skill among 3k class students. Int. J. Contemp. Educ. **2**, 100 (2019). https://doi.org/10.11114/ijce.v2i2.4498
12. Tangpermpoon, T.: Integrated approaches to improve students writing skills for English major students. ABAC J. **28** (2008)
13. Liu, M., Hong, M.: English language classroom anxiety and enjoyment in Chinese young learners. SAGE Open **11**, 1–13 (2021). https://doi.org/10.1177/21582440211047550
14. Gopang, I.B., Ansari, S., Kulsoom, U., Laghari, A.: An empirical investigation of foreign language anxiety in Pakistani university. Int. J. Engl. Linguist. **7**, 21 (2017). https://doi.org/10.5539/ijel.v7n2p21
15. Huang, Q.: Study on correlation of foreign language anxiety and English reading anxiety. Theory Pract. Lang. Stud. **2**, 1520–1525 (2012). https://doi.org/10.4304/tpls.2.7.1520-1525
16. Cheng, S.C., Cheng, Y.P., Huang, Y.M.: To implement computerized adaptive testing by automatically adjusting item difficulty index on adaptive English learning platform. J. Internet Technol. **22** (2021). https://doi.org/10.53106/160792642021122207013
17. Li, Y., et al.: Computational thinking is more about thinking than computing. J. STEM Educ. Res. **3**(1), 1–18 (2020). https://doi.org/10.1007/s41979-020-00030-2
18. Yadav, A., Hong, H., Stephenson, C.: Computational thinking for all: pedagogical approaches to embedding 21st century problem solving in K-12 classrooms. TechTrends **60**(6), 565–568 (2016). https://doi.org/10.1007/s11528-016-0087-7
19. Tsai, M.-J., Liang, J.-C., Lee, S.W.-Y., Hsu, C.-Y.: Structural validation for the developmental model of computational thinking. J. Educ. Comput. Res. **60**, 56–73 (2022). https://doi.org/10.1177/07356331211017794
20. Kale, U., et al.: Computational what? Relating computational thinking to teaching. TechTrends **62**(6), 574–584 (2018). https://doi.org/10.1007/s11528-018-0290-9
21. Hair, J., Black, W., Babin, B., Anderson, R.: Multivariate Data Analysis: A Global Perspective (2010)

Computational Thinking Approach: Its Impact on Students' English Writing Skills

Nurhayati Nurhayati[1], Lusia Maryani Silitonga[2], Agus Subiyanto[1], Astrid Tiara Murti[2], and Ting-Ting Wu[2](✉)

[1] Diponegoro University, Prof. Soedarto Rd, Semarang 50275, Indonesia
[2] National Yunlin University of Science and Technology, Douliu 64002, Taiwan
ttwu@yuntech.edu.tw

Abstract. Writing is a challenging task in the process of foreign language acquisition. Writing strategies are determined ways that students resolve issues that arise during the writing process. A recent academic study considered developing a learning activity incorporating the Computational thinking (CT) approach into English language teaching. This study aims at applying CT to English learning classrooms to enhance the students' English writing skills. The writing strategy of prewriting, peer feedback, and writing introduced computational thinking to students in an English writing classroom. The quasi-experiment was applied to 58 university students for nine meetings. The computational thinking subscales (decomposition, abstraction, algorithmic thinking, evaluation, and generalization) and the writing strategy subscale of "before writing" were analyzed using a non-parametric test (the Wilcoxon and Mann-Whitney test). The writing strategy subscales of "when writing" and "revising" were analyzed using ANCOVA. The findings show that students' writing skills improve significantly after practicing CT and writing strategies.

Keywords: Computational thinking · Writing strategy · Writing skills · Innovative teaching

1 Introduction

English learning has become a significant educational approach and policy in many non-English speaking nations, where the cultivation of skill depends on the balanced development of listening, speaking, reading, and writing [1, 2]. Writing is a challenging skill. Students learning English as a foreign language (EFL) will need a wide range of English writing abilities, from writing simple paragraphs and summaries to producing essays and academic articles. Writing is considered one of the most challenging activities requiring grammar and syntactic instruction. Furthermore, teaching writing to students in a country where English is not their native tongue provides more difficulties than teaching writing to students in an English native country. Educators have long believed that writing is hard to measure, examine, analyze, and grade. Even in the twenty-first century, writing is still viewed as challenging, requiring diverse talents and subskills

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 423–432, 2022.
https://doi.org/10.1007/978-3-031-15273-3_47

[3]. Usually, in writing classes, students cannot be knowledgeable of all the writing skills involved. As a result, teachers should carefully prepare writing strategies that allow students to work on their writings from several viewpoints and provide sufficient opportunity for students to engage their academic English writing skills [4, 5]. Some studies have demonstrated that the application of relevant technology and re-sources could be a possible solution to improve students' English course achievement [1, 2, 6].

Recent research has revealed that computational thinking (CT) has been used to enhance English language learning [7, 8]. CT is a problem-solving ability that can be used to encourage students to study the English language. According to [9] CT is a viewpoint that shows students how to solve complicated problems through the use of computer-based solutions. Furthermore, CT skills are not limited to computer scientists exclusively; however, they are regarded as crucial skills (e.g., writing, reading, and mathematics) that everyone in the present era should understand [9, 10]. CT is a mode of thinking that enable learners to break down large problems into smaller, more manageable parts. Students understand the system through discrete components, problems, or steps and develop instructions that may be implemented for other similar difficulties [8]. According to [11], CT has been proposed to enhance English language proficiency. However, CT-based strategies have not been widely used to improve English learning. Only limited research papers have been conducted on the use of CT in English instruction and learning [12].

Hence, this study aims to fill the gap. by applying CT to English learning classrooms to enhance the students' English writing skills. The purpose of this study is to provide an answer to the following question: Does applying CT strategy to English learning improve students' English writing skills?

2 Literature Review

2.1 Computational Thinking

The impact of CT has been highlighted by policymakers, teachers, academics, and the public [9, 13–15]. Furthermore, several scholars analyzed the various definitions of CT skills. [10] conclude from a review of previous research that students' CT skills encompass the following skills: creativity, algorithmic thinking, cooperation, critical thinking, and problem-solving. Decomposition, pattern recognition, abstraction, and algorithm design are all components of CT, according to [9]. Moreover, [16] elaborated on her study by developing a valid and reliable self-reported assessment, the Computational Thinking Scale (CTS), to assess students' CT characteristics across the exact five domains of computer literacy education. They are decomposition, abstraction, algorithmic thinking, evaluation, and generalization [16]. *Decomposition* measures an individual's ability to break a difficulty down into smaller elements. A*bstraction* is determining what information is required to resolve the issue. A*lgorithmic thinking* analyzes individuals' preferences for problem-solving in a step-by-step approach. Furthermore, *evaluation* analyzes individuals' preferences for reviewing and analyzing alternative solutions to a problem, while *generalization* determines an individual's ability to apply a response to other identical issue environments [16].

Moreover, previous studies have indicated that computational thinking can help individuals enhance their language skills, including their capacity to create sentences [17] and write [18]. CT offers a scientific approach to using the English sentence structure to generate narratives in language writing [19]. Moreover, CT enables students to highlight crucial passages in their English language writing [18].

2.2 Writing Strategies to Improve Writing Skills

Writing strategies are crucial for students to improve their concepts in academic writing [4]. The researchers sought to create creative strategies to overcome obstacles encountered during the writing process and enhance students' writing skills. One of these theories emphasizes the importance of syntactic and linguistic aspects. As a result, the accuracy of vocabulary, syntax, and mechanics such as spelling and punctuation are considered the primary factors of success in the foreign language process of writing [20]. When delivering the writing assignment to students, there are a few points to consider. Teachers should understand that it is not only an issue of language proficiency but also of acquiring students' ability to create a story with coherence in each paragraph [8].

Work strategies are classified as activities or behaviors performed intentionally by writers to improve the effectiveness of their writing [21] Furthermore, the writing strategy used in this study was divided into three stages: prewriting, peer feedback, and writing.

3 Methods

3.1 Research Design

This study employed a pre-posttest experimental design, with the experimental group receiving computational thinking strategies instruction. The procedures involved a pretest, an intervention, and a posttest. The experiment was carried out over nine instruction meetings during the Spring semester of 2022.

3.2 Participants

The participants consisted of 58 students of English majors at a university in Indonesia. All participants were recruited voluntarily, and they were informed that their academic performance would not be evaluated. The students were randomly assigned to a control (N = 29) and experimental group (N = 29).

3.3 Experimental Procedure

Figure 1 shows the experimental process of this study. The instructional approach of both the experimental and control groups was similar in teaching writing. The participants in the experimental group were taught using CT strategies, and the control group used conventional writing strategies. The experiment consisted of nine meetings of 120 min. Prior to the experiment, the researcher planned meetings and discussions with English teachers to ensure they thoroughly understood the research procedure. The teacher administered the pretest questionnaires at the beginning of the first meeting to determine the student's prior position. The teacher also explained the course goals to the students. In the second meeting, the students in the experimental group that learned English writing using CT strategies (decomposition, abstraction, algorithm, evaluation, and generalization) practiced these methods for 60 min and started their first prewriting activity. The students were assigned to compose writing with the topic given by the teacher for sixty minutes. After that, in the third meeting, the students did peer feedback activities in a group of six. Each student exchanged their prewriting draft with other students within their group. They used the rubric given by the teacher to revise the draft. The peer feedback activity was taken 60 min, followed by a discussion on the feedback in a group for another 60 min. After that, the draft was given back to the original writer. The teacher asked students to revise and rewrite their drafts at home.

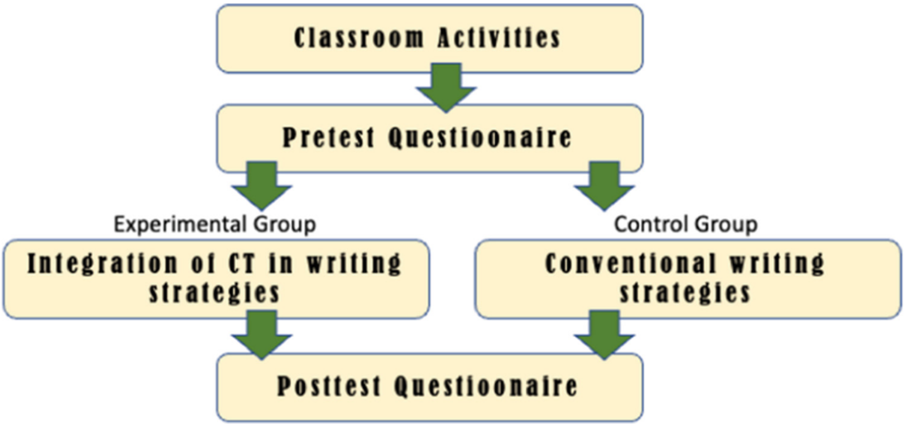


Fig. 1. The experimental design

The prewriting activity was repeated three times (first, second and third prewriting), and the peer feedback activity was also repeated in the third, the fifth, and the seventh meeting. Students spent the whole meeting (120 min) on the final writing in the eighth meeting. The topic of the final draft was more challenging than the prewriting. Seven meetings were spent on perfecting their writing skills. Also, fearing that students might not complete the writing if the task was given as a handwritten homework or online assignment, the students were asked to complete the task in class. In the ninth meeting, students were asked to complete the posttest questionnaire to see whether there was development in students' computational thinking and writing strategies after the treatment or not.

The teacher explained the prewriting activities (the second, fourth and sixth meeting) for 60 min each meeting, and the students practiced CT strategies in writing the topic. *Decomposition* was used as part of the CT approach to break down the writing topic into various main topics; establish the underlying concepts for writing the topics based on *abstraction.* After completing the paragraphs, each paragraph was revised by students (*abstraction*) thereby creating a whole new paragraph reasonable and coherent. Students can express their creative ideas at this step by adding additional sentences to the topic in accordance with their skill and knowledge. *Algorithmic thinking* involves employing CT to create an algorithm that enables students to build phrases and paragraphs sequentially to write the complete topic coherently. Furthermore, the *generalization* dimension examines students' ability to transfer their solutions to similar problem-solving situations. Students studied the process to make broad conclusions about how the writing process could be improved.

The *evaluation* process was practiced during the peer feedback activity. Students discussed and corrected the writing draft of their friend's draft and made some notes on the points of writing errors (content, organization, vocabulary, language use, mechanics). Figure 2 shows a rubric prepared by the teacher for doing the evaluation. After that, evaluation was practiced by the students when they revised the prewriting draft. Moreover, students also practiced the CT strategy in the final writing process (the eighth meeting); students employed the CT approach previously practiced in the prewriting activity in this section. The final writing was considered the final evaluation since students have done three times prewriting activities.

	4 Excellent to Very Good	3 Good to Average	2 Fair to Poor	1 Very Poor	Score
CONTENT	Knowledgeable; Substantive; Relevant to Assigned Topic	Some Knowledge of Subject; Fair Substantive; Mostly Relevant to Topic, but Lacks Detail	Limited Knowledge of Subject; Little Substance; Moderately Relevant to Topic	Does Not Show Knowledge of Subject; Non-Substantive; Less Relevant	
ORGANIZATION	Well-Organized; Logical Sequencing	Organized; Logical but Incomplete Sequencing	Ideas Confused; Lacks Logical Sequencing and Development	No Organization; Not Enough to Evaluate	
VOCABULARY	Use more than 10 Academic Vocabularies	Use 6-10 Academic Vocabularies	Use 1-5 Academic Vocabularies	Use 0 Academic Vocabularies	
LANGUAGE USE	Few Errors of Tense, Number, Word Order/Function, Articles, Pronouns, Prepositions (1-10 errors)	Several Errors of Tense, Number, Word Order/Function, Articles, Pronouns, Prepositions (11-20 errors)	Frequent Errors of Tense, Number, Word Order/Function, Articles, Pronouns, Prepositions (20-30 errors)	Dominated by Errors; Does Not Communicate; Not Enough to Evaluate (more than 30)	
MECHANICS	Few Errors of Spelling, Punctuation, Capitalization, Paragraphing (1-10 errors)	Occasional Errors of Spelling, Punctuation, Capitalization, Paragraphing but Meaning Not Obscured (11-20 errors)	Frequent Errors of Spelling, Punctuation, Capitalization, Paragraphing; Poor Handwriting; Meaning Confused or Obscured (21-30 errors)	Dominated by Errors of Spelling, Punctuation, Capitalization, Paragraphing; Handwriting Illegible; Not Enough to Evaluate (more than 30)	

Fig. 2. Student's peer feedback rubric

3.4 Measurement

Two instruments were used for this research a computational thinking scale (CTS) and a writing strategy questionnaire (WSQ) that was evaluated using a five-point Likert rating scale ranging from 1 (never true of me) to 5 (always true of me). A self-reported instrument of computational thinking scale (CTS) by [16] was used to examine the participants' computational thinking abilities. The CTS included 19 items, that were modified according to the purpose of this study. The reliability of the CTS five subscales: decomposition ($\alpha = 0.778$), abstraction ($\alpha = 0.654$), algorithmic thinking ($\alpha = 0.762$), evaluation ($\alpha = 0.782$), and generalization ($\alpha = 0.625$) shows a high reliability.

The writing strategies questionnaire (WSQ) developed by [21] was used to inquire about the participants writing strategies when required to write in English for academic purposes. The WSQ consists of 38 items covering three subscales, before writing (8 items), when writing (14 items), and revising (16 items). The internal consistency reliability of the scale calculated using Cronbach's α was high at 0.659, 0.768, and 0.728 respectively.

3.5 Data Collection and Analysis

Data were collected by questionnaire, and normal distribution, missing values, and data outliers were checked. The data were then analyzed using SPSS 25.0; the initial analysis of data homogeneity shows that the groups are of the same variance. The normality test shows that subscales of writing strategies (when writing and revising) are normally distributed, and the data are processed by a parametric test (ANCOVA). The computational thinking subscales (decomposition, abstraction, algorithmic thinking, evaluation, and generalization) and before writing will be processed using a non-parametric test (Wilcoxon and Mann-Whitney test).

4 Results

4.1 Computational Thinking

The descriptive statistics of mean and standard deviation for computational thinking are listed in Table 1. When comparing the mean differences between pretest and posttest in each group using the Wilcoxon test, it was noted that the experimental group students showed significant changes between the pre-posttest. Meanwhile, there were no statistically significant changes in control group participants between pre-and post-test (Table 1). The Mann-Whitney test of computational thinking posttest scores show significant differences in terms of abstraction ($z = -6.574$, $p < 0.05$), decomposition ($z = -6.585$, $p < 0.05$), algorithmic thinking ($z = -6.417$, $p < 0.05$), evaluation ($z = -6.355$, $p < 0.05$), generalization ($z = -6.605$, $p < 0.05$) as seen in Table 2.

Table 1. The descriptive results of student's computational thinking

Variable	Group	Pretest		Posttest		Wilcoxon	
		Mean	SD	Mean	SD	Z	p
Abstraction	Control group	2.92	0.454	2.91	0.56	−0.577	.564
	Experimental group	3.04	0.555	4.72	0.294	−4.748	.000*
Decomposition	Control group	3.02	0.526	2.99	0.588	−1.342	.180
	Experimental group	3.06	0.624	4.76	0.417	−4.789	.000*
Algorithmic thinking	Control group	3.19	0.566	3.16	0.345	−1.732	.083
	Experimental group	3.14	0.6	4.72	0.595	−4.737	.000*
Evaluation	Control group	3.19	0.629	3.16	0.659	−1.732	.083
	Experimental group	3.17	0.587	4.76	0.363	−4.731	.000*
Generalization	Control group	3.07	0.552	3.05	0.583	−1.342	.180
	Experimental group	3.26	0.545	4.82	0.29	−4.729	.000*

$^{*}p < 0.05$

Table 2. The Mann-Whitney results of computational thinking posttest

Variable	Mann-Whitney	Z	Asymp. Sig (2-tailed)
Abstraction	1.000	−6.574	.000*
Decomposition	7.500	−6.585	.000*
Algorithmic thinking	12.000	−6.417	.000*
Evaluation	16.500	−6.355	.000*
Generalization	4.000	−6.605	.000*

$^{*}p < 0.05$

4.2 Writing Strategy

The descriptive result of the writing strategy's mean and standard deviation was listed in Table 3. The writing strategy subscale of 'before writing' was analyzed using a non-parametric test of Wilcoxon and Mann-Whitney. The Wilcoxon result significantly changes the experimental group's pre-and post-test scores (Table 4). The between-group difference in Table 5 shows significant differences between the two groups' posttest scores ($z = -6.523$, $p < 0.05$). The writing strategy subscale of 'when writing' and 'revising' were analyzed using ANCOVA. The ANCOVA result in Table 6 indicates a significant difference between the two groups in terms of when writing ($F = 237.169$, $p < 0.05$) and revising ($F = 237.169$, $p < 0.05$).

Table 3. The descriptive results of student's writing strategies

Variable	Group	Pretest		Posttest	
		Mean	SD	Mean	SD
Before writing	Control group	2.8	0.371	2.75	0.518
	Experimental group	2.86	0.41	4.45	0.327
When writing	Control group	3.08	0.382	3.01	0.465
	Experimental group	3.23	0.422	4.63	0.312
Revising	Control group	2.60	0.334	2.61	0.424
	Experimental group	2.71	0.300	4.35	0.533

Table 4. The Wilcoxon results of student's writing strategy (before writing)

Pair	Variable	Group	Z	Asymp. Sig (2-tailed)
Pair 1	Post-pre-Before writing	Control group	−0.579	.563
		Experimental group	−4.707	.000*

$^{*}p < 0.05$

Table 5. The Mann-Whitney results of student's writing strategy (before writing)

Variable	Mann-Whitney	Z	Asymp. Sig (2-tailed)
Before writing	2.000	−6.523	.000*

$^{*}p < 0.05$

Table 6. The ANCOVA results of student's writing strategy (when writing and revising)

Variable	Mean square	F	p
When writing	35.154	237.169	0.000*
Revising	37.707	240.407	0.000*

$^{*}p < 0.05$

5 Discussion and Conclusion

This study describes the computational thinking approach to the writing strategy as a technique for improving students' writing skills. Many studies have been conducted on enhancing students' problem-solving skills; however, despite the CT method's increasing adoption in the classroom, neither has focused on the relationship between computational thinking and language learning. [7, 8, 17, 22].

The current study's findings indicate that students used the CT approach to writing strategies during the prewriting stage, which enabled them to improve their writing skills in vocabulary, organization, language use, mechanics, and content during the writing stage. The three prewriting practices of decomposition, abstraction, algorithm, evaluation, and generalization enabled students to improve their writing skills.

Finally, the experiments show that integrating CT into a writing classroom is an effective strategy for improving students' English writing skills. It appears that the CT approach is substantially more effective in improving students' writing skills than traditional learning methods, according to the experimental findings. However, Teachers must play a significant role in introducing computational thinking processes through writing activities and coaching students to ensure that the learning process runs smoothly.

Acknowledgements. This research is partially supported by the Ministry of Science and Technology, Taiwan, R.O.C. under Grant No. MOST 108-2628-H-224-001-MY3, MOST 110-2511-H-224-003-MY3 and MOST 110-2622-H-224-001-CC2.

References

1. Chien, Y.-C., Wu, T.-T., Lai, C.-H., Huang, Y.-M.: Investigation of the influence of artificial intelligence markup language-based LINE ChatBot in contextual English learning. Front. Psychol. **13** (2022). https://doi.org/10.3389/fpsyg.2022.785752
2. Shadiev, R., Huang, Y.M.: Investigating student attention, meditation, cognitive load, and satisfaction during lectures in a foreign language supported by speech-enabled language translation. Comput. Assist. Lang. Learn. **33** (2020). https://doi.org/10.1080/09588221.2018.1559863
3. Munoz-Luna, R.: Main ingredients for success in L2 academic writing: outlining, drafting and proofreading. PLoS ONE **10**, e0128309 (2015). https://doi.org/10.1371/journal.pone.0128309
4. Alameddine, M.M., Mirza, H.S.: Teaching academic writing for advanced level grade 10 English. Procedia Soc. Behav. Sci. **232**, 209–216 (2016). https://doi.org/10.1016/j.sbspro.2016.10.048
5. Lillis, T., Curry, M.J.: Professional academic writing by multilingual scholars. Writ. Commun. **23**, 3–35 (2006). https://doi.org/10.1177/0741088305283754
6. Cheng, S.C., Cheng, Y.P., Huang, Y.M.: To implement computerized adaptive testing by automatically adjusting item difficulty index on adaptive English learning platform. J. Internet Technol. **22** (2021). https://doi.org/10.53106/160792642021122207013
7. Parsazadeh, N., Cheng, P.-Y., Wu, T.-T., Huang, Y.-M.: Integrating computational thinking concept into digital storytelling to improve learners' motivation and performance. J. Educ. Comput. Res. **59**, 470–495 (2021). https://doi.org/10.1177/0735633120967315
8. Dijaya, S.: Innovation in English language teaching for EFL context: students' perceptions toward writing story activity using computational thinking process. J. Educ. Pract. **8**, 72–78 (2017)
9. Wing, J.M.: Computational thinking. Commun ACM. **49**, 33–35 (2006). https://doi.org/10.1145/1118178.1118215
10. Korkmaz, Ö., Çakir, R., Özden, M.Y.: A validity and reliability study of the computational thinking scales (CTS). Comput. Hum. Behav. **72**, 558–569 (2017). https://doi.org/10.1016/j.chb.2017.01.005

11. Lambert, J.: The world of digital storytelling. In: Digital Storytelling, 5th edn., pp. 37–52. Routledge, Taylor & Francis Group, New York (2018). Fourth edition published in 2013 by Routledge—T.p. verso (2005). https://doi.org/10.4324/9781351266369-5
12. Jacob, S., Nguyen, H., Tofel-Grehl, C., Richardson, D., Warschauer, M.: Teaching computational thinking to English learners. Nys Tesol J. **5** (2018)
13. Korkmaz, Ö., Bai, X.: Adapting computational thinking scale (CTS) for Chinese high school students and their thinking scale skills level. Particip. Educ. Res. **6**, 10–26 (2019). https://doi.org/10.17275/per.19.2.6.1
14. Voogt, J., Fisser, P., Good, J., Mishra, P., Yadav, A.: Computational thinking in compulsory education: towards an agenda for research and practice. Educ. Inf. Technol. **20**(4), 715–728 (2015). https://doi.org/10.1007/s10639-015-9412-6
15. Gong, D., Yang, H.H., Cai, J.: Exploring the key influencing factors on college students' computational thinking skills through flipped-classroom instruction. Int. J. Educ. Technol. High. Educ. **17**, 19 (2020). https://doi.org/10.1186/s41239-020-00196-0
16. Tsai, M.-J., Liang, J.-C., Lee, S.W.-Y., Hsu, C.-Y.: Structural validation for the developmental model of computational thinking. J. Educ. Comput. Res. 1–18 (2021). https://doi.org/10.1177/07356331211017794
17. Yadav, A., Stephenson, C., Hong, H.: Computational thinking for teacher education. Commun ACM. **60**, 55–62 (2017). https://doi.org/10.1145/2994591
18. Fronza, I., Gallo, D.: Towards mobile assisted language learning based on computational thinking. In: Chiu, D.K.W., Marenzi, I., Nanni, U., Spaniol, M., Temperini, M. (eds.) Advances in Web-Based Learning – ICWL 2016. LNCS, vol. 10013, pp. 141–150. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-47440-3_16
19. Vogel, S., Hoadley, C., Ascenzi-Moreno, L., Menken, K.: The role of translanguaging in computational literacies. In: Proceedings of the 50th ACM Technical Symposium on Computer Science Education, pp. 1164–1170. ACM, New York (2019). https://doi.org/10.1145/3287324.3287368
20. Tangpermpoon, T.: Integrated approaches to improve students writing skills for English major students. ABAC J. **28**, 1–9 (2008)
21. Petrić, B., Czárl, B.: Validating a writing strategy questionnaire. System **31**, 187–215 (2003). https://doi.org/10.1016/S0346-251X(03)00020-4
22. Kong, S.-C., Chiu, M.M., Lai, M.: A study of primary school students' interest, collaboration attitude, and programming empowerment in computational thinking education. Comput. Educ. **127**, 178–189 (2018). https://doi.org/10.1016/j.compedu.2018.08.026

Investigation of Multiple Recognitions Used for EFL Writing in Authentic Contexts

Wu-Yuin Hwang[1], Van-Giap Nguyen[1](✉), Chi-Chieh Chin[1], Siska Wati Dewi Purba[2], and George Ghinea[3]

[1] Graduate Institute of Network Learning Technology, National Central University, Taoyuan, Taiwan
giapnv.ictu@gmail.com
[2] Universitas Pelita Harapan, Tangerang, Indonesia
[3] Department of Computer Science, College of Engineering Design and Physical Sciences, Brunel University London, London, UK

Abstract. Recognition technologies had been prevailing and widely used for EFL learning. We investigated the different recognitions used for EFL writing based on image-to-text, translated speech-to-text, and location-to-text recognitions – ITR, TSTR, and LTR. A quasi-experiment was implemented for 12 weeks in a vocational high school with experimental and control groups in two stages. Pre-test, posttests 1 and 2, questionnaires, and interviews were conducted and analyzed. Experimental learners, who wrote writing based on ITR and TSTR, outperformed control learners who wrote that based on TSTR only. Also, the experimental learners, who wore writing based on ITR, TSTR, and LTR, outperformed the control learners who wrote that based on ITR and TSTR. Particularly, LTR was beneficial for identifying controlling ideas and addressing the writing topics. ITR was beneficial for brainstorming and generating more ideas. TSTR was beneficial for yielding and transferring writing contents into words. The multiple recognitions were beneficial for most EFL writers, especially for low-ability language writers. Most writers were interested in describing based on authentic context learning. However, they complained about the low accuracy of LTR and TSTR and the difficulty of ITR texts when writing. Accordingly, the LTR database with various categories of places, the generation of ITR based on the language abilities of learners, and the higher accuracy of TSTR should be strictly considered when applying multiple recognitions for EFL writing.

Keywords: EFL writing · Recognition technology · Multimedia learning · Adaptive technologies

1 Introduction

1.1 Motivation

English as a foreign language (EFL) is the most popular language in the world and EFL writing is a challenging skill [7, 12]. EFL writing is a difficult skill that should be

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 433–443, 2022.
https://doi.org/10.1007/978-3-031-15273-3_48

supported [3, 10, 26]. Writing requires transforming thoughts into words and understanding lexical density, sentence complexity, and grammatical accuracy [26]. Furthermore, EFL students often encounter difficulties to generate ideas and face problems to structure paragraphs or essays in their writing [3]. In other words, EFL writing requires the learner to have higher skills in using various vocabulary terms, correct sentence patterns, conventional grammar rules, and appropriate writing structure. Therefore, enriching students' vocabulary, understanding various sentence patterns, and being good at writing organization could improve EFL writing.

1.2 Related Works

Recognition technologies extract information from signals, analyze it, and then convert it into recognizable outputs [2, 22]. The recognition technologies are based on the diversity of input representations and applied widely for EFL learning like speech voices [8, 11, 21], images [20, 23], body motion, facial statuses [9], current location [19, 27], and so on. Accordingly, STR recognizes English speech and then converts those into English texts [16]. It could enhance EFL vocabulary and reduce the cognitive load when listening to EFL lectures [6]. TSTR is based on STR and translated texts of the target language. Accordingly, TSTR generates EFL texts based on the native language which is beneficial for brainstorming in writing [13]. Image-to-text recognition (ITR) was used to facilitate EFL vocabulary acquisition [23], and to describe descriptions in authentic contexts learning [20]. Moreover, location-to-text recognition (LTR) technology helps learners to enrich vocabularies related to the environments surrounding learners like plants, flowers, trees, and other ones [4, 27]. Therefore, the integration of TSTR, ITR, and LTR texts can be helpful for EFL writing.

The prior studies applied authentic context learning (ACL) for EFL writing and gained some success [7, 12, 14, 20]. Writing in authentic contexts motivated learners to describe more thoroughly and meaningfully, and attracted them to immerse themselves in real-life situations without limitation of time and places [7, 12, 20]. They also found that students could write more vivid words, facilitate them to share more experiences, and enhance their confidence to use English when learning with the authentic learning system [20]. Without doubts, authentic learning is beneficial for EFL writing and would be maintained in this study.

To sum up, the prior studies pointed out that EFL writing is a challenging skill, and ITR, TSTR, and LTR technologies are beneficial for EFL learning. Also, multimedia learning representations attract learners and hold them to learn better, and positively influence English learning. Authentic learning allows EFL learners to immerse themselves in real-life situations that help them learn better. Therefore, we integrated all the features into our learning system, and we expected that it would be useful for EFL writing learning. In this study, we focused on the affordances of the recognitions for EFL writing. According to an experiment, two questions would be answered and discussed deeply in this study:

1. What are the influences of multiple recognitions on EFL writing (RQ1)?
2. What are the perceptions of learners about different recognitions (RQ2)?

2 Instrument and Implementation

2.1 Instrument

We created an app that integrated three recognition technologies including TSTR, ITR, and LTR functions, respectively. The app was based on authentic learning. Accordingly, it allowed learners to immerse themselves in real-life situations to learn EFL writing. TSTR function generates English sentences based on Chinese speech inputs. ITR function generates English vocabularies, phrases, and sentences based on the image inputs. LTR function generates English vocabulary and phrases based on the current location of the user.

The TSTR function (Fig. 1): Learners input their voices or speech in Chinese. Next, the function converted those into Chinese texts. Finally, the function translated the Chinese texts into English texts and showed them on the screen.

(a) Input speech voice (b) TSTR function (c) Edit generated texts (d) STR text result

Fig. 1. Translated STR function

The ITR function (Fig. 2): This function generated nouns, adjectives, and the other vocabularies which are close to the people, things, and features related to the images. Moreover, it generated some phrases and sentences that described the main contents of the images. This function allowed learners to capture many images for each writing; therefore, the generated texts would be more based on the images. Writers could edit the texts, too. The yellow vocabularies were presented that they belong to the vocabularies in their English textbook and should pay more attention to learning. The generated vocabularies were connected to an online dictionary which allowed learners to listen to the pronunciations and to know the means and the examples of them.

(a) image(s) and ITR words (b) Reference dictionary (c) ITR phrases (d) ITR texts result

Fig. 2. ITR texts generation

LTR function (Fig. 3): LTR texts are names, addresses, and types of places like schools, libraries, banks, restaurants, stores, and so on which were provided by Google place API. We also added more nouns, verbs, adjectives, and phrases related to 10 common categories with the writers and the writing topics including libraries, classrooms, schools, gyms, restaurants, stations, and hospitals. The added texts had been gathered from learners' English textbook.

(a) Location (b) Generate texts

Fig. 3. LTR texts generation

2.2 Implementation

We experimented at a vocational high school in Taiwan. One EFL class with 34 eleventh-grade students (16 or 17 years old) participated in our experiment. Both groups used the app but different functions in each stage. Two groups were the experimental group (EG) (N = 17) who learned with both TSTR and ITR in stage 1 and then learned with TSTR, ITR, and LTR in stage 2, and the control group (CG) (N = 17) who learned only with TSTR in stage 1 and learned with TSTR and ITR in stage 2. Each stage had two topics and each topic was learned in two weeks. Four topics were "My classroom", "My campus", "My favorite place", and "Where I am". Pre-test, post-tests 1 and 2, and questionnaires 1 & 2, and interviews were conducted. Posttests 1 and 2 were conducted at the end of stages 1 and 2 respectively. There were 12 weeks in this experiment. A rubric was used to evaluate writing tests based on reasoning, organization, communication, and conventions [7, 20]. Two language experts scored the tests and the Kappa value was $0.845 > 0.81$, $p < .001$. It implies that the inter-rater reliability was perfect and the test could be used to analyze in the next steps. Two questionnaires, which were used for each stage, were conducted with three aspects including ease of use (EOU), usefulness (UF), and intention to use (ITU) [1].

3 Results and Discussion

3.1 Comparison of the Learning Achievement Between Experimental and Control Groups

The analysis of the pre-test showed that no significant differences between EG and CG concerning the total pre-test ($t = -.307$, $p = .761$) that consisted of reasoning ($t = -.317$, $p = .754$), organization ($t = -.333$, $p = .741$), communication ($t = -.375$, $p = .710$), convention ($t = -.134$, $p = .895$). The results implied that both groups were not different in EFL writing before the experiment.

Homogeneity of the score in post-test 1 ($F = 1.291$, $p = .264 > .05$) and the related aspects were not violated ($p > .05$); therefore, ANCOVA analysis was employed. The result of ANCOVA (Table 1) showed that there was a significant difference between the groups concerning the total post-test in stage 1. The experimental students who learned with both TSTR and ITR outperformed the control students who learned with only TSTR concerning total score, communication, and convention aspects. The ITR texts are not only vocabularies like nouns, adjectives, and the other ones related to the objects, people, and things in the input images but also phrases and sentences are described the main content of the images. In addition, an online dictionary was connected to and supported learners to listen to the pronunciations of most ITR vocabularies. The pictorial and verbal representations are useful for memory working [17]. Especially, the pictorial representation helps learners to transfer the learned texts into their long-term memory which is beneficial for EFL vocabularies acquisition [23]. In addition, the pictorial representations had played an important role in stimulating the descriptive contents while the ITR vocabularies and phrases could work as the ingredients to make various sentences in their writing. The use of ITR text could force writers to recall and apply their knowledge about EFL writing; therefore, they would make sentences more carefully and fluently. Prior research also pointed out that authentic learning facilitates EFL learners in generating more ideas and organizing their writings more logically [3]. Consequently, the learners described more contents, more ideas, and more appropriate vocabularies which are related to the communication and conventions aspects. This result is supported by the past research which found that ITR facilitated EFL writers to describe more meaningfully and thoroughly [20].

Table 1. The ANCOVA results of post-test 1 & 2

Stage		Group	Mean	SD	Adjusted mean	SE	*F*	η^2
1	Post-test 1	EG	3.82	1.15	3.87	0.23	6.009*	0.162
		CG	3.13	1.32	3.09	0.23		
	Reasoning	EG	3.88	1.27	3.92	0.27	2.522	0.122
		CG	3.35	1.41	3.31	0.27		
	Organization	EG	3.88	1.41	3.93	0.29	3.380	0.076
		CG	3.24	1.52	3.19	0.29		
	Communication	EG	3.88	1.17	3.93	0.24	7.242*	0.011
		CG	3.06	1.30	3.01	0.24		
	Convention	EG	3.65	1.06	3.67	0.21	7.619*	0.010
		CG	2.88	1.27	2.86	0.21		
2	Post-test 2	EG	4.46	0.48	4.32	0.12	4.366*	0.123
		CG	3.84	0.81	3.97	0.12		
	Reasoning	EG	4.71	0.47	4.63	0.12	12.427**	0.001
		CG	3.94	0.75	4.02	0.12		
	Organization	EG	4.65	0.49	4.54	0.16	2.070	0.160
		CG	4.12	0.99	4.22	0.16		
	Communication	EG	4.47	0.62	4.32	0.17	1.958	0.172
		CG	3.82	0.95	3.98	0.17		
	Convention	EG	4.00	0.61	3.82	0.14	0.613	0.440
		CG	3.47	0.94	3.65	0.14		

Note: $^*p < 0.05$, $^{**}p < 0.01$.

In terms of homogeneity of post-test in stage 2, we found that homogeneity of post-test ($F = .040$, $p = .842$) and the related aspects were not violated ($p > .05$); therefore, ANCOVA was used to analyze. The ANCOVA analysis (Table 1) showed that significant differences between EG and CG groups were found concerning total post-test 2 ($F = 4.366$, $p < .05$). These findings indicated that the EG outperformed the CG in the total post-test of stage 2, especially concerning the reasoning aspect. LTR texts are English vocabularies such as name, address, category, and the other ones of the location. In addition, some nouns, verbs, adjectives, and phrases which were based on the learners' English textbook and were close to the category, were also provided for learners. LTR mechanism wittingly forces learners to move to different places to learn; therefore, they immerse themselves into various situated learning contexts. Learners can approach the objects, plants, people, or atmospheres surrounding them based on sight, hearing, smell, taste, touch, and feel. Based on the situated learning theory, when learners are engaged in authentic contexts, their knowledge is constructed or produced based on social interactions that take place in the surrounding contexts [26]. In addition, the scenarios are mostly related to place descriptions; therefore, those LTR texts can be useful for the writers to state the main subject and controlling idea in the topic sentence or to name the related places as the subjects or objects in their supporting sentences. For example, the writer was at a park, and LTR texts were "new park basketball court leave station position go out run see …"; consequently, the learner made a description "This is a new park basketball court. A lot of people will play here. Especially on holidays, there will be a lot of people. It has outdoor venues and sheltered venues. Every time I pass by here, I see a lot of people playing there". Another one, the writer was nearby an elementary school, and LTR texts were "Hsih Shin elementary school Xinshi park climb up down go way slide educate teach instruct pull stop …", Consequently, the student's description was "This is the outdoor playground in Hsih Shin elementary school. Sometimes, there are many people playing basketball outside the classrooms. The gate is very splendid. The teachers are knowledgeable. The school can make me learn hard.". Hence, LTR is beneficial for addressing the topic and directing controlling ideas in descriptions related to the scenarios.

3.2 Effectiveness of Multiple Recognitions on EFL Writing

Pearson correlation was used to analyze the effect of the multiple recognitions on post-test 1 and 2. We found that the use of ITR vocabularies significantly influenced on the improvement of the aspects related to vocabulary acquisition like communication aspect in post-test 1 ($r = .590$, $p < .05$) and the conventions aspect in post-test 2 ($r = .494$, $p < .05$). Moreover, ITR phrases significantly influenced on the various of sentences in post-test 2 ($r = .516$, $p < .05$). The result ties well with the prior finding that ITR is useful for EFL vocabulary acquisition [23]. TSTR significantly influenced on the number of sentences in post-test 1 ($r = .611$, $p < .05$). Prior research also pointed out that the translated English text based on writers' native language was convenient and useful for them to brainstorm and yield more words and sentences [13]. The use of LTR text did not influence the aspects in the post-test 2. The result implied that ITR had played an important role in EFL writing concerning the aspects related to vocabulary use while TSTR was useful for yielding more sentences. The clear influence of LTR use should be investigated further thus.

3.3 Perception Toward Using Multiple Recognitions for EFL Writing in Authentic Learning

For questionnaire 1, the Cronbach alpha value was 0.965 for 16 items in both groups, and that was 0.940 for all 20 items of EG in questionnaire 1. For questionnaire 2, the Cronbach alpha value was 0.958 for 23 items in both groups, and that was 0.961 for all 27 items of EG in questionnaire 2. Table 2 shows that all the aspects in stage 2 are better and better than those in stage 1 in both groups. It implies that the participants tended to satisfy when learning with more recognition. For EFL learning, the redundancy issues had not been found in EFL learning [15]. Therefore, multiple recognitions have a big potential in EFL writing.

For feedback, the TSTR function has got negative feedback related to the low accuracy (e.g., “The translation function is very good, but it cannot directly improve my English ability” (S01-2.25-3.50-4.75: Student ID-pretest-posttest 1- 2); “The sentences from the translation department are sometimes not accurate” (S03-2.00-4.50-4.50); “TSTR text is sometimes not accurate” (S05-3.00-4.25-4.25); “…the translation function (TSTR) can be used most of the time, it is impossible to distinguish English ability” (S33-2.00-4.00-4.25)). It also has positive feedback related to its usefulness (e.g., “I think the system is doing very well, especially TSTR and ITR, which have very useful functions…” (S19-0.50-4.00-3.75); “most people use the translation function” (S30-4.50-4.25-4.5)). The perceptions revealed that TSTR texts could be more useful for low student abilities, but the accuracy may be its main problem. The ITR function was also useful for low students (S19), but its phrases and sentences were sometimes difficult to use with them (S04-0.50-4.75-4.25). Also, another student complained about the LTR accuracy (e.g., “…But I think LTR sometimes does not detect the location accurately(S19).”) which showed the limitation of the LTR readiness in EFL writing in this study. The small database of the place categories and a lack of innovative technology support could be the main cause of LTR limitation in this study.

For learning activities, almost students gave positive feedback about the authentic context learning (e.g., “very fulfilling” (S01); “allowing us to write outdoor” (S09-2.75-4.75), “diverse activities and very efficient” (S11-4.5-4.75), “allowing me to learn a lot of English knowledge”(S16–1.5–2.5); “We have learned a lot of English sentences and vocabularies and learned from the activities without being bored” (S29-0.0-2.0); “experiment is very fun, I can learn English and go out in the park”(S35-3.5-3.5)). The results revealed that authentic context learning attracted EFL learners, especially low students, and helped them to improve their EFL writing skills.

Generally, for users’ perceptions, both ITR and TSTR texts are useful for EFL writing; however, many ITR texts are still difficult to apply to their writings. TSTR and LTR texts are sometimes incorrect and irrelevant to the context contents of the locations, but TSTR is helpful for low language ability students. Authentic learning should be used for EFL writing to attract the attention of writers.

Table 2. TAM questionnaire results in stages 1 & 2

		Easy of use		Usefulness		Intention to use	
		Mean	SD	Mean	SD	Mean	SD
Stage 1	EG	3.68	0.31	3.20	0.26	3.25	0.25
	CG	3.59	0.71	3.27	0.83	3.07	0.68
Stage 2	EG	3.71	0.33	3.54	0.12	3.33	0.14
	CG	3.66	0.63	3.44	0.86	3.26	0.83

4 Conclusion

For RQ1, both ITR and TSTR are beneficial for EFL writing concerning the communication and conventions aspects which were related to the use appropriate vocabularies and making more meaningful sentences while the LTR is beneficial for EFL writing concerning the addressing writing topic and controlling ideas. The combination between ITR and TSTR is beneficial for EFL writing because ITR facilitates to transfer of the learned texts into learners' long-term memory which is of paramount importance to working memory [17, 23] while TSTR facilitates to convert the ideas into the target language more efficiently. LTR facilitates addressing the topics and controlling the ideas in EFL writing related to the scenario. Without doubts, ITR and TSTR can improve the local aspects of EFL descriptions while LTR can improve the global aspects of those. For RQ2, students tend to satisfy when learning with multiple recognitions. They thought that ITR and TSTR are useful for EFL writing, but some limitations should be improved. ITR can be useful for their imagination and generating more ideas while TSTR can be useful for yielding more words and sentences, especially for the low language ability writers. However, many ITR texts were difficult and advanced for them to use while the low accuracy of TSTR and LTR should be improved. In brief, multiple recognitions open more opportunities for EFL writing and have a big potential in this field.

The small sample, short time experiment, and the problems related to low accuracy of LTR and TSTR were the limitations of our study. We scoped the description paragraphs which should widen other topics and contexts used to practice EFL writing. Although LTR has a big potential in EFL writing, it should be investigated further near future. ITR texts should be refined to meet the needs of different language ability writers. TSTR should be improved with higher accuracy.

References

1. Davis, F.D., Bagozzi, R.P., Warshaw, P.R.: User acceptance of computer technology: a comparison of two theoretical models. Manag. Sci. **35**(8), 982–1003 (1989)
2. Dong, G., Wang, N., Kuang, G.: Sparse representation of monogenic signal: with application to target recognition in SAR images. IEEE Sig. Process. Lett. **21**(8), 952–956 (2014)
3. Fu, Q.K., Lin, C.J., Hwang, G.J., Zhang, L.: Impacts of a mind mapping-based contextual gaming approach on EFL students' writing performance, learning perceptions and generative uses in an English course. Comput. Educ. **137**, 59–77 (2019)

4. Godwin-Jones, R.: Emerging technologies: Mobile apps for language learning. Lang. Learn. Technol. **15**(2), 2–11 (2011)
5. Haug, K.N., Klein, P.D.: The effect of speech-to-text technology on learning a writing strategy. Read. Writ. Q. **34**(1), 47–62 (2018)
6. Huang, Y.M., Shadiev, R., Hwang, W.Y.: Investigating the effectiveness of speech-to-text recognition applications on learning performance and cognitive load. Comput. Educ. **101**, 15–28 (2016)
7. Hwang, W.Y., Chen, H.S.L., Shadiev, R., Huang, R.Y.M., Chen, C.Y.: Improving English as a foreign language writing in elementary schools using mobile devices in familiar situational contexts. Comput. Assist. Lang. Learn. **27**(5), 359–378 (2014)
8. Hwang, W.Y., Li, Y.H., Shadiev, R.: Exploring effects of discussion on visual attention, learning performance, and perceptions of students learning with STR-support. Comput. Educ. **116**, 225–236 (2018)
9. Hwang, W.Y., Manabe, K., Cai, D.J., Ma, Z.H.: Collaborative kinesthetic English learning with recognition technology. J. Educ. Comput. Res. **58**(5), 946–977 (2020)
10. Kotseas, E.: Asian students' challenges in writing with confidence. NYS TESOL J. **4**(2), 78–85 (2017)
11. Kuo, T.C.T., Shadiev, R., Hwang, W.Y., Chen, N.S.: Effects of applying STR for group learning activities on learning performance in a synchronous cyber classroom. Comput. Educ. **58**(1), 600–608 (2012)
12. Lan, Y.J.: Contextual EFL learning in a 3D virtual environment. Lang. Learn. Technol. **19**(2), 16–31 (2015)
13. Lee, S.M., Briggs, N.: Effects of using machine translation to mediate the revision process of Korean university students' academic writing. ReCALL 1–16 (2020)
14. Li, Z., Hegelheimer, V.: Mobile-assisted grammar exercises: effects on self-editing in L2 writing. Lang. Learn. Technol. **17**(3), 135–156 (2013)
15. Liu, Y., Jang, B.G., Roy-Campbell, Z.: Optimum input mode in the modality and redundancy principles for university ESL students' multimedia learning. Comput. Educ. **127**(August), 190–200 (2018)
16. Matthews, J., O'Toole, J.M., Chen, S.: The impact of word recognition from speech (WRS) proficiency level on interaction, task success and word learning: design implications for CALL to develop L2 WRS. Comput. Assist. Lang. Learn. **30**(1–2), 22–43 (2017)
17. Mayer, R.E.: Cognitive theory of multimedia learning. In: The Cambridge Handbook of Multimedia Learning, 2nd edn., pp. 43–71 (2005)
18. Neviarouskaya, A., Prendinger, H., Ishizuka, M.: Affect analysis model: novel rule-based approach to affect sensing from text. Nat. Lang. Eng. **17**(1), 95–135 (2011)
19. Nguyen, T.H., Hwang, W.Y., Pham, X.L., Ma, Z.H.: User-oriented EFL speaking through application and exercise: instant speech translation and shadowing in authentic context. Educ. Technol. Soc. **21**(4), 129–142 (2018)
20. Nguyen, T.H., Hwang, W.Y., Pham, X.L., Pham, T.: Self-experienced storytelling in an authentic context to facilitate EFL writing. Comput. Assist. Lang. Learn. 1–30 (2020)
21. Shadiev, R., Huang, Y.-M., Hwang, J.-P.: Investigating the effectiveness of speech-to-text recognition applications on learning performance, attention, and meditation. Educ. Tech. Res. Dev. **65**(5), 1239–1261 (2017). https://doi.org/10.1007/s11423-017-9516-3
22. Shadiev, R., Hwang, W.Y., Chen, N.S., Huang, Y.M.: Review of speech-to-text recognition technology for enhancing learning. Educ. Technol. Soc. **17**(4), 65–84 (2014)
23. Shadiev, R., Wu, T.T., Huang, Y.M.: Using image-to-text recognition technology to facilitate vocabulary acquisition in authentic contexts. ReCALL **32**(2), 195–212 (2020)
24. Shadiev, R., Zhang, Z.H., Wu, T.T., Huang, Y.M.: Review of studies on recognition technologies and their applications used to assist learning and instruction. Educ. Technol. Soc. **23**(4), 59–74 (2020)

25. Shang, H.F.: Exploring online peer feedback and automated corrective feedback on EFL writing performance. Interact. Learn. Environ. 1–13 (2019)
26. Spector, J.M., Merrill, M.D.: Handbook of research on educational communications and technology. Br. J. Educ. Technol. **35**(4) (2004)
27. Sun, J.C., Chang, K., Chen, Y.: GPS sensor-based mobile learning for English: an exploratory study on self- efficacy, self-regulation and student achievement. Res. Pract. Technol. Enhanc. Learn. **10**, 1–8 (2015)
28. Wang, F., Hwang, W.Y., Li, Y.H., Chen, P.T., Manabe, K.: Collaborative kinesthetic EFL learning with collaborative total physical response. Comput. Assist. Lang. Learn. **32**(7), 745–783 (2019)

AI Chatbots Learning Model in English Speaking Skill: Alleviating Speaking Anxiety, Boosting Enjoyment, and Fostering Critical Thinking

Intan Permata Hapsari[1,2] and Ting-Ting Wu[1](✉)

[1] Graduate School of Technological and Vocational Education, National Yunlin University of Science and Technology, Yunlin 64002, Taiwan, R. O. C.
ttwu@yuntech.edu.tw

[2] English Department, Faculty of Languages and Arts, Universitas Negeri Semarang, Semarang, Indonesia

Abstract. One of the most significant barriers to English learning for EFL (English as a Foreign Language) students is a lack of practice environments. Additionally, in the (EFL) classroom, emotions such as speaking anxiety and language enjoyment may influence students' performance. It is well established that students' achievement is harmed by foreign language anxiety. Artificial Intelligence (AI) advancements present an opportunity to solve this issue. AI chatbots are capable of deciphering the meanings of users' comments and responding appropriately and have been built to engage with users using natural language. Language teachers and researchers have recommended the use of chatbots as tools of learning that would help to facilitate the implementation of language learning by acting as a speaking partner or tutor. In this research design, AI chatbot is employed in Casual Conversation Course as self-regulated learning for facilitating students' speaking performance and interactions during the learning process in a university speaking classroom. By a preceding conversation with AI chatbot, it will alleviate speaking anxiety, boost learning enjoyment, and foster students' critical thinking. In-depth interviews were delivered to four interviewees to ascertain the designed learning model from the teachers' viewpoint. The result indicates that the proposed model is expected to be able to aid the learning process and so achieve the course's objectives more effectively than conventional models.

Keywords: AI Chatbots · Foreign Language Speaking Anxiety · Learning enjoyment · Critical thinking

1 Introduction

The ability to communicate in English has become nearly universal. As English has become a worldwide language, speaking English has become a critical skill and a challenge for people all over the world, particularly students [1]. However,

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 444–453, 2022.
https://doi.org/10.1007/978-3-031-15273-3_49

certain English-speaking concerns persist, such as students' confidence, skills, performance, and views of low-improvement students' interaction behaviors, all of which need students to reflect on their practices during peer and instructor conversations [2]. Numerous English language students encounter tremendous problems when it comes to learning and using the language, particularly in terms of speaking.

It is unsurprising that speaking English as a foreign language in public might be one of the most anxiety-inducing circumstances for Indonesian students. Learning anxiety refers to negative emotions experienced throughout the process of learning, such as fear, worry, and tension [3]. Learner anxiety typically emerges when students believe that their speaking or oral performance is inadequate or unintelligible. Foreign Language Speaking Anxiety (FLSA) is a multifaceted psychological issue that many students encounter while studying a Foreign Language (FL). This phenomenon has been shown to have a detrimental effect on foreign language learners' performance. Therefore, how to reduce FLSA becomes one strategy for increasing students' English proficiency in Indonesia.

Motivating students to study a foreign language is crucial and challenging. The implementation of technology-based learning activities could bridge the gap between the classroom and the real world, making English language learning more engaging, enjoyable, and relaxing while boosting motivation [4]. Therefore, it is required to provide students with proper technology and scaffolding tools to aid them in organizing their information in order to improve their speaking skills. According to [5], the need of incorporating artificial intelligence into education to aid in teaching, learning, and decision-making. By integrating AI technologies to provide various learning activities such as tool, tutor, or tutee, students may be encouraged to generate their opinions, judgements, or predictions. AI chatbots may also be viewed as a tool that is able to provide students with tailored advice, support, or feedback as they learn a language. The usage of artificial intelligence-based chatbots as a versatile tool was deemed to have the potential to increase students' interactions and performance [6, 7].

Positive emotions are now being investigated in studies examining the affective component of language learning shifting from solely conducting investigation of a negative emotions such as anxiety. A correlation between FL enjoyment and FL classroom anxiety, as well as the fact that positive emotions play a significant role in L2 learning as an affective factor [8, 9].

Considering (1) the relevance of cognitive and affective domains in the FL classroom and (2) the potential of AI-chatbots, the purpose of this study is to design a new pedagogical model for teaching speaking using AI-chatbots in order to investigate the cognitive effects on speaking learning and the affective effects on FL speaking anxiety and FL enjoyment that are expected to promote students' critical thinking.

We address the following research questions, hypothesizing that AI-chatbots-based practice has beneficial impacts on both cognitive and affective aspects of language learning:

RQ1. How is the model of AI Chatbot learning to positively impact students' affect in EFL learning, as measured by FLSA and FLE?
RQ2. How do the teachers value the model of AI Chatbot learning in English speaking class?

2 Literature Review

2.1 FL Classroom Anxiety and FL Enjoyment

Foreign Language Speaking Anxiety (FLSA) has been shown to have a detrimental effect on foreign language learners' performance. Among the four language skills, speaking is the most anxiety-inducing skill. Elevated levels of FLSA might make it more difficult for learners to communicate effectively and appropriately in the target language. If teachers are aware of and sensitive to the presence of anxiety, they may be able to provide a comfortable and helpful language learning environment. Creating such an environment will encourage active participation and engagement on the part of all students. Also creating a stimulating learning environment will facilitate learners' comprehension of learning materials and increase their attention and meditation [10]. FL anxiety that is particular to classroom speaking activities is referred to as FL speaking anxiety, and it is likely to hinder students' speaking competency.

In Indonesia, several researches have examined students' anxiety levels during EFL speaking classes. According to [11], many students experience anxiety during speaking activities, which is exacerbated by the speaking tasks' requirement that they deliver individually and spontaneously within the allotted time. Additionally, the majority of learners obsess over how to pronounce each English word accurately and how to compose ideal sentences, and even hesitate to speak out of fear of being criticised and laughed at by others when they make errors [12]. These findings are essential because they reveal that language learning occurs not only cognitively, but also emotionally. As a result, an integrated setting is essential for learners to overcome their fear of public speaking and improve their performance.

Due to the high level of exposure that today's learners have to the internet and technology, more attempts have been made to design and implement technology-based tools that assist learners in reducing their speaking fear. Studies that have been conducted relating to the use of technologies such as Podcasts [13], TedTalks [14], WhatsApp [15], Interactive Holographic Learning Support System [16], Automatic Speech Recognition [17], and AI-Chatbots [18] have found that those technologies are effective in partly reducing learners' speaking anxiety. The pedagogical implication, [19] postulated that FL teachers should "… strive to boost students' enjoyment of foreign languages rather than to be overly concerned about their foreign language (classroom) anxieties" (p. 676). Therefore, it is necessary to ascertain whether learners like activities in the FL classroom. This also suggests that teachers are urged to place a higher premium on fostering fun in language acquisition, and that technology is deemed beneficial.

2.2 AI Chatbot in Language Learning

Researchers have attempted to use artificial intelligence technology to the development of educational apps due to the rapid advancement of computer technology [20]. Besides, With the proliferation of mobile devices and smartphones, artificial intelligence-based systems have been adopted to serve as "Smart Learning Partners," "Smart Teachers," and "Smart Students" in the educational environment [21]. Among the various interactive computer systems, chatbots can become the most recommended ones due to the fact that they use natural language interfaces or even due to the built-in speech recognition [22]. Moreover, chatbots offer great potential as a tool for language learning and can considerably boost students' achievement [23]. Chatbots in the context of language teaching can be generally identified in three characteristics. Firstly, chatbots is available anytime in helping students 24/7 [24]. It tremendously aids language acquisition by allowing the students as users to conduct conversational exercises at any time [25]. Students can train their language skill with chatbots anytime and anywhere they feel like it, where the human as the communicating partner is not available that easily. Secondly, it can give the students enriching information on their language learning where their language partners may have less or even none of it. In reality, most of their EFL/ESL language partners in communication have a similar level of language mastery, thus the students may not get extra lesson also when they become the language partners for their friends [26]. Meanwhile, a well-designed chatbot can provide more information such as a series of phrases, statements, and vocabularies. Third, chatbots can take on the character of a determined partner. This releases people from answering repeated questions as a partner, which enables continuous language training. Chatbots as a learning partner are able to communicate with the students endlessly that offers chances for the students to keep on practicing using the new language continuously.

2.3 Critical Thinking in Language Learning

Critical thinking has been identified as a critical educational objective and is described as reasonable reflective thinking directed toward determining what to believe or do [27]. When students rationally and reflectively decide what to do in order to arrive at an acceptable solution to a challenging issue, they exercise critical thinking by evaluating the methods and presuppositions utilised to generate scientific hypotheses. Because one of the main purposes of learning and education is the development of critical thinking abilities, it is vital in today's educational disciplines to equip students with critical thinking abilities using a variety of processes and approaches. Having appropriate content knowledge is a necessary precondition for critical thinking. If learners lack knowledge or information about the topic, they will be unable to apply critical thinking to the facts; in this situation, they will need to execute the topic in order to determine the optimal solution [28].

In language learning, by allowing learners to learn from the chatbot through their interactions, a chatbot has been utilized to develop critical thinking and aid the user in learning a new language [29]. To assist learners in language learning, a combination of an intelligent tutoring system and learner modelling was used to develop an educational bot [30].

As discussed earlier, AI chatbot is a proposed model for instructional approaches that aim to alleviate students' speaking anxiety and increase their enjoyment, hence promoting students' critical thinking in English speaking classes. Students' ideas will be organized, and they will be prepared to create complicated arguments, as in-depth discussions require critical thinking, which increases the quality of interactions and promotes necessary cognitive growth.

3 Conceptual Model

3.1 Purpose of the Study

The purpose of the study is to investigate the number of conversations and the effects of conversing with an AI chatbot on speaking anxiety, enjoyment, and critical thinking in EFL speaking class. The shift in students' critical thinking following their discussion with their friend will be examined to determine the effect of the AI chatbot in their pre-discussion.

3.2 A Conceptual Model Using AI Chatbot in Speaking Class

The proposed instructional design with AI Chatbot in EFL speaking class (Casual Conversation Course) will be analyzed through the following conceptual model.

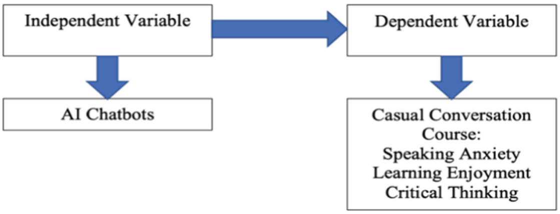


Fig. 1. The proposed AI chatbots learning model and course outcomes correlation

The overall design of the course is intended to support the learning process to meet the course's objectives or outcomes. As illustrated in Fig. 1, there is a correlation between the proposed learning model's benefits and the goals or outcomes of the Casual Conversation Course, which contributes to alleviate speaking anxiety, boost learning enjoyment, and foster students' critical thinking.

For the instructional design, topics to discuss will be shared to students by the teacher through the LMS before class. Students are asked to do an online search for information relevant to the discussion topic in preparation for their conversation with a friend. In this stage, students will have a self-regulated learning environment. Having prepared materials to discuss, students are then required to have speaking practice with AI chatbot. It is expected that by having enjoyment practice with AI chatbot, students will have self-confidence, less speaking anxiety, and more critical thinking when it comes speaking face-to-face with their friend in class.

Having students experience speaking face-to-face with a classmate can be utilized to follow up on their thoughts and discussions as they arrive in class by having pre-materials discussed with an AI chatbot. In this session, the term "teacher-centered learning" has been substituted by "student-centered learning," and teachers' roles have shifted from "sage on the stage" to "guide on the side." Face-to-face instruction fosters critical thinking, social learning, and the cultivation of 21st-century skills. Additionally, by incorporating learning activities into the classroom, students develop an awareness of group and individual tasks. Finally, in each class meeting, the AI Chatbot model is intended to be deployed in a real-world class of speaking.

4 Course Design with AI Chatbot in Speaking Class

4.1 Proposed Participants

The model of AI Chatbot is designed to be implemented in the actual class of speaking (Casual Conversation Course). The planned participant will be one to two two-semester period courses in the English Department at a university, each of which will have a single teacher and a small number of students. As university sophomores, all of students have taken Intensive Course Speaking as freshmen, so they are assumed to have the minimum English-speaking skill required for this study. In these two classes, an AI chatbot will be used to assist students with speaking exercises while the teacher teaches the Casual Conversation Course. Before having face-to-face conversation with their friend, students search online information related to the given topic to discuss and then converse with AI chatbot for practice.

4.2 Overall Design Procedure

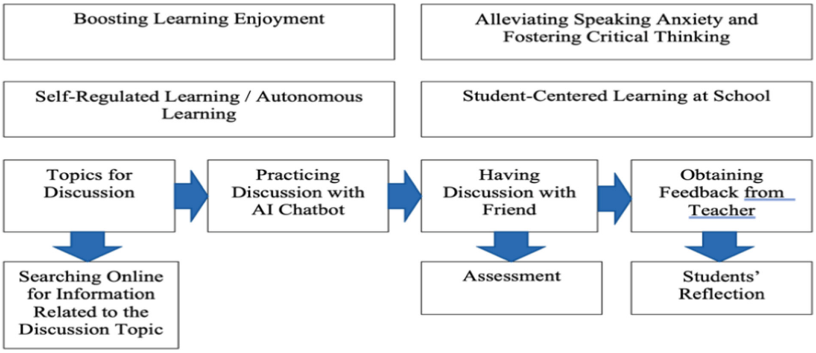


Fig. 2. Overall design procedure

The proposed AI Chatbot learning model in speaking class is illustrated in Fig. 2. Casual Conversation Course will be taught over a one-semester period, which means there will be sixteen meetings (including a mid-term and final test) during which the lecturers will cover a variety of topics. The scenario from the proposed model will be implemented once every sixteen weeks The topics that are selected will be discussed with the English teacher.

In the implementation of learning activities, the very first process is self-regulated learning/self-autonomous learning. Students who have already obtained the topics through LMS are requested to search online information related to the discussion topic. After having completed information to discuss, each student is required to discuss the topic with AI chatbot.

The next phase is in the class in which students will engage in a face-to-face discussion with their friend about the specified topic. This learning activity will focus on a student-centered learning environment. Students will share their opinions and ideas and perform discussions to make the discussed topic more understandable. The results of their discussion with AI chatbot added by the discussion in class are expected to foster students' critical thinking. In the end of learning activities, the teacher will give feedback to students. During the process of face-to-face discussion in class, the teacher gives evaluation and grade supported by designed assessment tools. In measuring students' critical thinking, this study will use two instruments: the critical thinking inventory [31] and critical thinking skill test [32]. Meanwhile questionnaire on Foreign Language Speaking Anxiety (FLSA) modified from [33] and [34] and Foreign Language Enjoyment (FLE) based on [8] will also be given to students to measure students' speaking anxiety and enjoyment while they are using AI chatbot as their partner of discussion in self-autonomous learning environment.

4.3 Assessment Design

The study's proposed model focuses on the shift in students' critical thinking following a discussion with a friend as a result of the AI chatbot's pre-discussion. The assessment will be based on the following factors for critical thinking: (1) awareness of critical thinking, (2) inquiring mindset, (3) objectivity, and (4) importance of evidence [31].

After students are assigned discussion subjects, they are instructed to write down their views and ideas and to conduct an internet search for related information. The students are then demanded to speak with an AI chatbot in order to develop their opinions and thoughts, determine what they already know and what they need to learn, and practice expressing their ideas and thoughts in English. The teacher will observe students' speaking practices with AI chatbot from the log activity available in the chatbot. After the pre-discussion activities with AI chatbot, later students will have face-to-face discussion with their friend in class. The duration of discussion will last 15 min. The students will be assessed by the teacher for their critical thinking.

5 Result and Discussion

In depth-interview was conducted to validate the suggested model of AI Chatbot in the speaking class. As shown in Table 1, the interview included four interviewees. Four lecturers as interviewees teach EFL speaking in their faculties. Prior to the interview, they were informed about the design model for English-language learning via an AI chatbot. Then, they were questioned during a three-part interview. The first session of the interview was intended to elicit general information from the interviewees. Meanwhile, the second and third sessions were used to find out the interviewees' opinions towards AI chatbot, teaching speaking using AI chatbot, and the proposed learning model.

The interview findings indicate that four interviewees believed that AI chatbots are both entertaining and effective teaching tools that are ideal for use in speaking classes. They believe that incorporating an AI chatbot into classroom activities will assist not only teachers but also students in accomodating the process of speaking learning, promoting students' critical thinking, reducing speaking anxiety, and boosting students' enjoyment. Moreover, they have the intention to apply AI chatbot to vary their technologies while

Table 1. Interviewee's information

No	Participant	English Lecturer Placement	Teaching Period	Technology Used in Teaching Speaking
1	Lecturer A	Faculty of Languages and Arts	4 years	LMS, YouTube, Zoom
2	Lecturer B	Faculty of Economics	7 years	LMS, Google Classroom, YouTube Zoom
3	Lecturer C	Faculty of Sport Sciences	8 years	LMS, Zoom
4	Lecturer D	Faculty of Engineering	9 years	Zoom

they are teaching speaking class. Since AI chatbot is new technology for them, they need to learn and get accustomed to use it, so it will be effective and improve students' speaking proficiency.

6 Conclusions

The AI chatbot learning model for English speaking ability is designed to facilitate the learning process and help students achieve the course's objectives or outcomes more effectively than the conventional learning model. For EFL students, situations involving learning English as a foreign language are prone to arouse anxiety, and 'speaking' is regarded as one of the most anxiety-inducing skills. The development of communicative language teaching techniques in English classroom and the widespread usage of the English language have raised the demand for effective communication skills, however anxiety among students may block their progress. As a result, language teachers must be aware of their students' anxiety when learning to speak English to aid them in performing well in the target language. Teachers can use AI chatbots to help students overcome their speaking anxiety. For students who experience severe speaking anxiety, practising English speaking with AI chatbots may be more comfortable and stress-free than speaking in front of a group of individuals.

The purpose of this study is to investigate how learners of English as a foreign language (EFL) engage in a discussion in a speaking class (Casual Conversation Course) and how their discussion is influenced by a preceding conversation with an AI chatbot. Preparation through the use of an AI chatbot may result in an increase in conversation during discussions. The first step toward improved interactions and critical thinking is to enhance dialogue. Teachers can assist the uncritical thinkers by introducing AI chatbots as their tutor, tutee, or tool to stimulate them to form opinions, judgments, or predictions. Critical thinking enables learners to go deeper than the surface and information provided by AI chatbots during the pre-discussion.

There is a connection between the proposed AI chatbot learning model's benefits and the goals or outcomes of speaking skill in Casual Conversation Course that contributes to alleviate speaking anxiety, to boost learning enjoyment, and to foster critical thinking to be mastered by the learners. Nonetheless, the teacher's and students' eagerness and readiness to use AI chatbots as a learning aid would contribute to the proposed model's success. The teacher and students are encouraged to undertake works and to be concerned about issues of technology and computer literacy.

Acknowledgements. This research is partially supported by the Ministry of Science and Technology, Taiwan, R.O.C. under Grant No. MOST 108-2628-H-224-001-MY3, MOST 110-2511-H-224-003-MY3 and MOST 110-2622-H-224-001-CC2.

References

1. Akkakoson, S.: Speaking anxiety in English conversation classrooms among Thai students. Malays. J. Learn. Instr. **13**, 63–82 (2016)
2. Lin, C.J., Hwang, G.J.: A learning analytics approach to investigating factors affecting EFL students' oral performance in a flipped classroom. Educ. Technol. Soc. **21**, 205–219 (2018)
3. Liu, H.L., Wang, T.H., Lin, H.C.K., Lai, C.F., Huang, Y.M.: The influence of affective feedback adaptive learning system on learning engagement and self-directed learning. Front. Psychol. **13**, 1–9 (2022). https://doi.org/10.3389/fpsyg.2022.858411
4. Parsazadeh, N., Cheng, P.Y., Wu, T.T., Huang, Y.M.: Integrating computational thinking concept into digital storytelling to improve learners' motivation and performance. J. Educ. Comput. Res. **59**, 470–495 (2021). https://doi.org/10.1177/0735633120967315
5. Hwang, G.J., Xie, H., Wah, B.W., Gašević, D.: Vision, challenges, roles and research issues of artificial intelligence in education. Comput. Educ.: Artif. Intell. 1 (2020). https://doi.org/10.1016/j.caeai.2020.100001
6. Chen, X., Xie, H., Hwang, G.J.: A multi-perspective study on artificial intelligence in education: grants, conferences, journals, software tools, institutions, and researchers. Comput. Educ.: Artif. Intell. (2020). https://doi.org/10.1016/j.caeai.2020.100005
7. Yin, J., Goh, T.T., Yang, B., Xiaobin, Y.: Conversation technology with micro-learning: the Impact of chatbot- based learning on students' learning motivation and performance. J. Educ. Comput. Res. 1–24 (2020). https://doi.org/10.1177/0735633120952067
8. Dewaele, J.-M., MacIntyre, P.D.: The two faces of Janus? Anxiety and enjoyment in the foreign language classroom. Stud. Second Lang. Learn. Teach. **4**, 237–274 (2014)
9. Dewaele, J.-M., MacIntyre, P.D.: Foreign language enjoyment and foreign language classroom anxiety: the right and left feet of FL learning? In: MacIntyre, P.D., Gregersen, T., Mercer, S. (eds.) Positive Psychology in SLA, pp. 215–236. Multilingual Matters, Bristol (2018)
10. Shadiev, R., Huang, Y.M.: Investigating student attention, meditation, cognitive load, and satisfaction during lectures in a foreign language supported by speech-enabled language translation. Comput. Assist. Lang. Learn. **33**, 301–326 (2019). https://doi.org/10.1080/09588221.2018.1559863
11. Padmadewi, N.N.: Students anxiety in speaking class and ways of minimizing it. J. Ilmu Pendidikan. **5**(Supp), 60–67 (1998)
12. Yaniafari, R.P., Rihardini, A.A.: Face-to-face or online speaking practice: a comparison of students' foreign language classroom anxiety level. J. Engl. Educ. Linguist. Stud. **8**, 49–67 (2021)
13. Korucu-Kis, S., Sanal, F.: Bridging in-class and out-of-class learning through podcast-intertwined collaborative tasks to reduce EFL speaking anxiety among higher proficiency learners. Int. Online J. Educ. Teach. **7**, 636–653 (2020)

14. Arifin, N., Mursalim, M., Sahlan, S.: Enhancing speaking performance and reducing speaking anxiety using ted talks. J. Lang. Educ. Educ. Technol. (JLEET). **5**, 41–58 (2020)
15. Shamsi, A.F., Altaha, S., Gilanlioglu, I.: The role of m-learning in decreasing speaking anxiety for EFL learner. Online Submiss. **2**, 276–282 (2019)
16. Chen, Y.: Reducing language speaking anxiety among adult EFL learners with interactive holographic learning support system. In: Wu, T.T., Huang, Y.M., Shadiev, R., Lin, L., Starčič, A. (eds.) Innovative Technologies and Learning, vol. 11003, pp. 101–110. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-99737-7_10
17. Bashori, M., van Hout, R., Strik, H., Cucchiarini, C.: Web-based language learning and speaking anxiety. Comput. Assist. Lang. Learn. (2020). https://doi.org/10.1080/09588221.2020.1770293
18. Han, D.-E.: The effects of voice-based AI Chatbots on Korean EFL middle school students' speaking competence and affective domains. Asia-Pac. J. Converg. Res. Interchange **6**, 71–80 (2020). https://doi.org/10.47116/apjcri.2020.07.07
19. Dewaele, J.M., Witney, J., Saito, K., Dewaele, L.: Foreign language enjoyment and anxiety: the effect of teacher and learner variables. Lang. Teach. Res. **22**, 676–697 (2018)
20. Anghelescu, P., Nicolaescu, S.V.: Chatbot application using search engines and teaching methods. In: In 2018 10th International Conference on Electronics, Computers and Artificial Intelligence (ECAI), pp. 1–6 (2018)
21. Benotti, L., Martinez, M.C., Schapachnik, F.: A Tool for introducing computer science with automatic formative assessment. IEEE Trans. Learn. Technol. **11**, 179–192 (2018)
22. García Botero, G., Questier, F., Cincinnato, S., He, T., Zhu, C.: Acceptance and usage of mobile assisted language learning by higher education students. J. Comput. High. Educ. **30**(3), 426–451 (2018). https://doi.org/10.1007/s12528-018-9177-1
23. Cakmak, F.: Mobile learning and mobile assisted language learning in focus. Lang. Technol. **1**, 30–48 (2019)
24. Chang, C.Y., Hwang, G.J.: Trends in smartphone-supported medical education: a review of journal publications from 2007 to 2016. Knowl. Manag. E-Learn.: Int. J. **10**, 389–407 (2018)
25. Chien, Y.C., Wu, T.T., Lai, C.H., Huang, Y.M.: Investigation of the influence of AIML-based Line Chatbot in contextual English learning. Front. Psychol. **13**, 1–8 (2022). https://doi.org/10.3389/fpsyg.2022.785752
26. Chen, H.L., Widarso, G.V., Sutrisno, H.: A chatbot for learning Chinese: learning achievement and technology acceptance. J. Educ. Comput. Res. **58**, 1–29 (2020)
27. Patamaporn Thaiposria, P.W.: Enhancing students' critical thinking skills through teaching and learning by inquiry-based learning activities using social network and cloud computing. Procedia Soc. Behav. Sci. **174**, 2137–2144 (2015)
28. Willingham, D.T.: Critical thinking: why is it so hard to teach? Am. Educ. 8–19 (2007)
29. Goda, Y., Yamada, M., Matsukawa, H., Hata, K., Yasunami, S.: Conversation with a chatbot before an online EFL group discussion and the effects on critical thinking. J. Inf. Syst. Educ. **13**, 1–7 (2014)
30. Kerly, A., Hall, P., Bull, S.: Bringing chatbots into education: towards natural language negotiation of open learner models. Knowl. Based Syst. **20**, 177–185 (2007)
31. Hirayama, R., Kusumi, T.: Effect of critical thinking disposition on interpretation of controversial issues: evaluating evidences and drawing conclusions. Japan. J. Educ. Psychol. **52**, 186–198 (2004)
32. Starkey, L.: Critical Thinking Skills Success In 20 Minutes A Day. Learning Express, New York (2010)
33. Horwitz, E.K., Horwitz, M.B., Cope, J.: Foreign language classroom anxiety. Mod. Lang. J. **70**, 125–132 (1986)
34. Öztürk, G., Gürbüz, N.: Speaking anxiety among Turkish EFL learners: the case at a state university. J. Lang. Linguist. Stud. **10**, 1–17 (2014)

The Effectiveness of Incorporating Augmented Reality Board Game into Temple Culture

Yu-Chen Liang[1], Hao-Chiang Koong Lin[1], and Yu-Hsuan Lin[2](✉)

[1] Department of Information and Learning Technology, National University of Tainan, Tainan, Taiwan

[2] General Research Service Center of National Pingtung University Science and Technology, Pingtung, Taiwan

yu.hsuan@mail.npust.edu.tw

Abstract. In human civilization, religious belief is the accumulation of spirit and even the attribution of spirit. At the same time, temples are an important cultural property inherited from ancient Taiwan, with rich beliefs, history, and values. To improve students' learning effectiveness and understanding of temple culture, this study designs a set of augmented reality table games to integrate temple culture and use table games as the media to enable students to understand temple culture knowledge in game learning. The participants were 39 students from a university in Tainan. The results show that the AR board games developed in this study can improve students' learning effectiveness. Through the analysis of the interview results, we know that this board game has a good usability and teaching significance so that learning is no longer boring.

Keywords: Augmented reality · Board game · Game-based learning · Temple culture

1 Introduction

In human civilization, religious belief is the accumulation of spirit and even the attribution of spirit. At the same time, temples are an important cultural property inherited from ancient Taiwan, with rich beliefs, history, and values. Nowadays, many countries regard religious culture as an important tourism asset. Whether it is temple buildings, religious rituals, religious festivals, etc., they can be used as unique cultural tourism resources. However, how to convert these resources into tourist attractions and attract tourists to visit has become an important subject.

In recent years, augmented reality has become more and more popular, and its application has become more and more extensive. With the popularization of augmented reality technology, many scholars apply augmented reality to education, which has become the focus of research in recent years [1]. Teachers in the educational field have begun to explore how to use games to teach and learn, and game-based learning is an effective learning tool. Many studies have pointed out that game-based learning can help learners by improving students learning effectiveness and increasing learning motivation [2–4].

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 454–460, 2022.
https://doi.org/10.1007/978-3-031-15273-3_50

Therefore, this study added game-based learning and augmented reality to the teaching of temple culture to overcome the insufficiency of traditional guided tours or the attractiveness of traditional education and improve the learning effect of temple culture. Among them, the combination of board games can enable learners to explore knowledge in games, and many studies have confirmed that board games have a positive help effect on learning [5, 6].

Based on the above, this research designs a set of "AR Temple Culture Board Game", which focuses on teaching temple culture and takes Yingyuan Temple in Tainan City as an example. Students can learn about temple culture knowledge through game-based learning during the game. The teaching content is presented on mobile devices through augmented reality, combining present technology and traditional temple culture, allowing users to absorb different knowledge through this AR temple culture tabletop game. Therefore, this study explores the learning effectiveness of integrating AR board games and hopes to increase cultural literacy through game-based learning of temple knowledge. More people can better understand temple culture and achieve inheritance.

Based on the background and motives of this study as well as the abovementioned discussion, the objectives of this study were as follows:

1. To discuss the effect of incorporating AR temple culture board game on learning effectiveness.
2. What are the learners' perceptions of an AR temple culture board game?

2 Literature Review

The researchers of this study developed an AR temple culture board game to facilitate learning. The literature review thus aims to introduce the following concepts game-based learning, augmented reality, and incorporating board game into teaching.

2.1 Game-Based Learning

Game-based learning means that learners learn through games, so that learners can solve problems and complete levels in the game situation. At the same time, they can also learn knowledge in the game process, integrate the game into the learning subject, and achieve the effect of teaching in fun.

Wu, Huang, and Society [7] used a mobile game-based English vocabulary practice system to improve learning interest, attention, learning effectiveness, a sense of accomplishment and triumph.

Irwansyah & Izzati [8] implementing quizizz as game-based learning and assessment in the English classroom. The findings show that the students display a positive attitude toward quizizz and become more motivated to learn English.AM courses, guiding students to gradually complete the creative design and production of AR/VR and maker education and obtain more specific knowledge about AR/VR and maker education.

2.2 Augmented Reality

Augmented reality is to add virtual objects in the real environment and superimpose virtual information or virtual objects on the real world of users. Chin, Wang, and Chen [9] integrates the impact of the augmented reality system on the academic performance and learning motivation of liberal arts students. This study shows that the combination of augmented reality technology can effectively improve the learning effectiveness of liberal arts students and enhance their confidence in acquiring new knowledge to improve the overall learning performance and learning motivation. Cai et al. [10] integrates the augmented reality technology into the physics classroom, which can improve students' physics learning self-efficacy, understanding of concepts, higher-level cognitive skills, practice and communication, guide students to higher-level physics learning ideas, and stimulate students' motivation to learn more deeply.

It can be seen from the above literature that in the field of teaching, augmented reality can not only increase users' understanding of learning content, but also improve learners' learning effectiveness, but also bring learners learning fun to improve their learning motivation and enthusiasm.

2.3 Incorporating Board Game into Teaching

Kesuma et al. [11] used the MANSA history board game to explore the impact of history students' creativity and learning outcomes. The research results pointed out that using this board game can improve students' creativity and learning effectiveness. Júnior et al. [12] through the innovative teaching method of the stereochemistry board game, help students learn the concept of stereochemistry, jointly solve stereochemistry problems in an interesting board game, and provide an effective alternative to the traditional learning method.

In summary, the effects of board games have been approved to be positive. This motivated the researchers of this study to employ a board game to achieve teaching goals and improve learning effectiveness.

3 Research Methods

3.1 Research Process

This study investigates the effect of incorporating an AR board game into temple culture. The participants are divided into small groups, with a mobile device and AR temple culture board game allocated for each group. Figure 1 presents the research process in a flowchart. The experimental flow is about 90 min, and the pre-test is about 10 min before the experiment. Then introduce the AR temple culture board game instructions for about 10 min. After the explanation, start the game for about 50 min. Then the post-test was conducted for about 10 min, and the interview was conducted for about 20 min after the experiment as the experimental analysis. Figure 2 below shows the learners playing the AR board game for temple culture.

Fig. 1. Research process flowchart

Fig. 2. Learners playing the AR temple culture board game

3.2 Subjects

In this study, 39 students from a university in southern Taiwan were divided into 10 groups with an average age of 19, the youngest was 18, and the oldest was 20.

3.3 Research Tool

This research uses pre-/post-tests as instruments, as described below:

Pre- and Post-Learning Performance Scale. Based on the information provided by the temples and the information on the official website, this study produced the guide content, and the pre- and post-test temple knowledge learning performance scale has content validity. The questions of the pre- and post-test temple knowledge learning performance scale are the same. Only the order of questions and the order of options are changed. A total of 45 test questions are true and false.

4 Results

4.1 Evaluation of Learning Motivation

This subsection mainly discusses the learning effectiveness of using the AR board game for temple culture. Comparison on the familiarity with temple culture before and after board game playing led to analysis on changes in knowledge levels. Table 1 presents results of paired-samples t-test, which show significant improvement of learners' temple culture knowledge after the game board intervention (t (38) $= -12.948$, $p = .000$, d $= 2.87$). Post-test learning outcomes were significantly better than those of pre-test. The statistical results reveal the effectiveness of using the AR board game to enhance learning outcomes about temple culture.

Table 1. Differences in learning motivation of the two groups

Dimension	Mean (SD)		df	*t*	*p*	d
	Pre-test	Post-test				
Score	59.18(9.05)	82.21(6.85)	38	−12.948	.000	2.870

4.2 Interview Analysis

Four students were invited to conduct interviews after the experimental activity to further discuss the ideas and suggestions after using the AR temple culture board game. The discussion will focus on the board game's usability, advantages, and disadvantages, areas for improvement, specific explanations and suggestions, etc. According to the analysis of the interview data, the interview content is divided into two core categories, namely, the usability of board games and the expected effect. The usability of the board game is the user's feeling about using the AR temple culture board game. The desired result is that if there is an opportunity to use the AR temple culture board game in the future, the user expresses their expected thoughts.

Based on the analysis and discussion of the above coding results, the following points can be summarized:

AR Temple Culture Board Game: The game is interesting, and the operation method is simple and easy to understand. Learning through the board game has teaching significance and makes learning no longer boring. It has good usability for this board game.

Future Suggestions: AR images are mostly 2D graphic information, and 3D temple cultural relic models can be added in the future to enhance the richness of board games.

5 Conclusion

To improve students' learning effectiveness and understanding of temple culture, this study aims to build a set of AR temple culture board game, explore the benefits of integrating ar board game in temple culture learning, and evaluate users' experience of using the game. The results show that the application of this board game in temple culture teaching can improve students' learning effectiveness of temple culture and make significant progress in their understanding of temple culture. This result echoes the previous research on AR board game. Integrating it into teaching can improve learning effectiveness [13, 14]. According to the interview results, this ar board game has good usability and teaching significance, so learning is no longer boring.

In the future, in addition to further improving the quality of board game, it is also planned to provide this research game to temple tourists to play so that more people can know more about the temple, and it is suggested that the follow-up research can analyze the learning motivation and further understand the learning status of students. However, this study adopts the experimental design of a single group, and it can be considered to join the control group for more in-depth analysis in the future.

References

1. Akçayır, M., Akçayır, G.: Advantages and challenges associated with augmented reality for education: a systematic review of the literature. Educ. Res. Rev. **20**, 1–11 (2017)
2. Partovi, T., Razavi, M.R.: Motivation: the effect of game-based learning on academic achievement motivation of elementary school students. Learn. Motiv. **68**, 101592 (2019)
3. Eltahir, M., Alsalhi, N.R., Al-Qatawneh, S., AlQudah, H.A., Jaradat, M.: The impact of game-based learning (GBL) on students' motivation, engagement and academic performance on an Arabic language grammar course in higher education. Educ. Inf. Technol. **26**, 3251–3278 (2021). https://doi.org/10.1007/s10639-020-10396-w
4. Tokac, U., Novak, E., Thompson, C.G.: Effects of game-based learning on students' mathematics achievement: a meta-analysis. J. Comput. Assist. Learn. **35**, 407–420 (2019)
5. Lin, H.-C.K., Lin, Y.-H., Wang, T.-H., Su, L.-K., Huang, Y.-M.: Effects of incorporating augmented reality into a board game for high school students' learning motivation and acceptance in health education. Sustainability **13**, 3333 (2021)
6. Cardinot, A., Fairfield, J.A.: Game-based learning to engage students with physics and astronomy using a board game. In: Research Anthology on Developments in Gamification and Game-Based Learning, pp. 785–801. IGI Global (2022)
7. Wu, T.-T., Huang, Y.-M.: A mobile game-based English vocabulary practice system based on portfolio analysis. J. Educ. Technol. Soc. **20**, 265–277 (2017)
8. Irwansyah, R., Izzati, M.J.T.J.: Implementing Quizizz as game based learning and assessment in the English classroom. TEFLA J. **3**, 13–18 (2021)
9. Chin, K.-Y., Wang, C.-S., Chen, Y.-L.: Effects of an augmented reality-based mobile system on students' learning achievements and motivation for a liberal arts course. Interact. Learn. Environ. **27**, 927–941 (2019)
10. Cai, S., Liu, C., Wang, T., Liu, E., Liang, J.C.: Effects of learning physics using Augmented Reality on students' self-efficacy and conceptions of learning. Br. J. Educ. Technol. **52**, 235–251 (2021)

11. Kesuma, A.T., Putranta, H., Mailool, J., Kistoro, H.C.A.: The effects of MANSA historical board game toward the students' creativity and learning outcomes on historical subjects. Eur. J. Educ. Res. **9**, 1689–1700 (2020)
12. da Silva Júnior, J.N., de Andrade Uchoa, D.E., Sousa Lima, M.A., Monteiro, A.J.: Stereochemistry game: creating and playing a fun board game to engage students in reviewing stereochemistry concepts. J. Chem. Educ. **96**, 1680–1685 (2019)
13. Wang, P.-Y., Lin, H.-T., Wang, S.-M., Hou, H.-T.: The development and evaluation of an educational board game with augmented reality integrating contextual clues as multi-level scaffolding for learning ecosystem concepts. In: 2019 IEEE International Conference on Consumer Electronics-Taiwan (ICCE-TW), pp. 1–2. IEEE (2019)
14. Nordin, N., Mohd Nordin, N.R., Omar, W.: The efficacy of REV-OPOLY augmented reality board game in higher education. Int. J. Emerg. Technol. Learn. **17**, 1–17 (2022)

The Effect on Students' Learning Efficacy by Using Self-regulated Learning Combined with Game-Based Learning in Learning Idioms

Yu-Chen Liang[1(✉)], Hao-Chiang Koong Lin[1], and Yu-Hsuan Lin[2]

[1] Department of Information and Learning Technology, National University of Tainan, Tainan City 70005, Taiwan
ycliang.khh@gmail.com
[2] General Research Service Center of National Pingtung University Science and Technology, Pingtung County, Taiwan
yu.hsuan@mail.npust.edu.tw

Abstract. Idiom's teaching has always been an important course in Chinese. But there are no specifically designed idioms teaching in current elementary school Chinese courses. Usually, the Idioms teaching is only part of supplementary materials in vocabularies teaching. Therefore, without full guidance from teachers, students can only learn idioms through repetition and memorization, causing their low interest in learning idioms. Therefore, how to enhance students' motives and pique their interests to learn idioms, and how to help them memorize idioms better, is a very important topic. The purpose of this study is to understand the learning effects of students learning idioms through self-regulated learning combined with game-based learning. First, students are taught the strategy of self-regulated learning, so they can set their own learning goals, choose teaching materials they like and the way they'd like to learn, and arrange learning time. In the process teachers will guide students to learn idioms through the game-system or books, record students' learning situation and process. Finally, students are allowed to sort out the learned materials so they can review them whenever they like. The result of this research shows that through the strategy of self-regulated learning combined with game-based learning, students' grades have greatly improved, indicating that this learning model is better than traditional way, and can provide substantial enhancement in learning effect.

Keywords: Self-regulated learning · Game-based learning · Idioms teaching

1 Introduction

In the past, the most common way of teaching is using traditional teaching model. Namely, the teacher is usually the center, the interaction with students is one-way, and the teaching contents are dull and boring. Due to the lack of interaction students are much more likely to lose focus, thus fail to see the problems and try to find ways to fix the problems by themselves. In recent years the educational environment tends

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 461–470, 2022.
https://doi.org/10.1007/978-3-031-15273-3_51

to adopt the teaching and learning theory that emphasized that learners should be the center, advise that in teaching process, teachers must pay attention to students' cognitive changes and process of learning. A meaningful learning is constructed greatly on the students' willingness to participate and interact. These concepts are also very important in teaching and learning a language, especially in learning basic skills like reading and writing. It's an important topic for teachers to let students develop self-learning strategy. Currently the way to learn idioms in elementary schools is through new vocabularies and new words in Chinese textbook. Some teachers will write an idiom on blackboard each day and ask students to memories it or make sentence out of it as homework. Limited by teaching schedule or other reasons, teachers sometimes are forced to explain only the basic meaning of the idiom and they don't have the chance to elaborate or explore its usage. In an environment where idioms are seen everywhere, the teaching strategy and teaching materials are apparently not enough. Furthermore, some teachers will order idioms teaching materials to use as practice for students' morning study or homework. This way of teaching is also dependent on students, who can only accept idioms learning passively. Therefore, if idioms learning can utilize some more energetic teaching methods, the literature value of idioms can be much more appreciated. Thus, this study will enhance students' learning efficacy in idioms learning by employing different teaching strategies.

2 Literature Review

2.1 Self-regulated Learning

When facing topics that are interested to them, people will find that learning is not a painful experience anymore. And they will face the frustration and challenges in learning fearlessly and bravely. That is, when learners know what to learn, why to learn, and highly identify with the topic, they will do whatever they can to achieve the learning goal. Zimmerman (1995) thought by trying to develop a self-discipline learning mode for students, they can control learning activities themselves [36]. Once the goal is set by themselves, they can develop strategies to meet the self-regulated learning requirements, and they will continuously find learning motives and drive themselves into learning spontaneously. Therefore, self-regulated learning is a very important key to students' inner learning motives. For learners the most important thing is how to achieve self-regulated learning status. The strong inner learning motives generated by learners with self-regulated learning will help him face all the difficulties and challenges. There are several similar terms for self-regulated learning, such as self-directed learning, self-planned learning, etc. Skager (1978) Self-regulated learning is that learners can set learning goals and plans by themselves, carried them out, and then evaluated learning results by themselves [23]. Gelpi (1979) Self-regulated learning is that learners can control educational goals, contents, methods themselves [6]. Mok, Ma, Liu & So (2005) view self-regulated learning as both the aspect of self-teaching and self-managing to participate the process of learning [14]. Although due to the differences in scholars' professional background there are slightly differences in each scholar's definition about self-regulated learning, the common ground is they all describe a scenario where students can participate in constructing the knowledge actively and willingly and can plan and manage learning by using metacognitive skills. What is self-regulated learning? It includes: 1. Students make learning goal about a learning topic. 2. Adopt proper learning strategy and control progress. 3. Self-evaluate in the process to self-award or revise learning strategy. 4. The teacher's role is to offer help or provide guidance. 5. Develop a positive feedback loop of self-regulated learning, initiative and deep learning. Other researchers about self-regulated learning include emphasis on the trigger and source of motives, attention to enhance students' self-efficacy, focus on usage and control of students' learning skills, and emphasis on how the teacher's guide students to do self-regulated learning. In school, students who want to learn voluntarily are often favored by teachers and are also likely to make more achievement in study. The so-called voluntarily, in correspondence with what we called self-displace in educational vocabulary, is also the common factor in self-regulated learning. In order to reach the level of self-discipline, students must first set goals, device plausible strategy, and do self-monitor constantly when implementing the strategy to make sure it is carried out accurately, and then evaluate the learning efficacy as an important reference to make adjustment and improvement. In educational field students with higher learning results, when compared with students with lower learning results, are found to set more specific learning goals, concentrate more on the effectiveness of strategy execution, the result, and how to improve. They also often show more complete control and confidence of their learning abilities. And this is the learning type most self-regulated learners adopted (Zimmerman, B. J., Bonner, S., & Kovach, R., 1996) [37]. Bandura (1986) thought that a person's self-adjustment, appearance of behavior, adjustment of environment scenario could possibly change the impact of person, behavior, and environment on the learner [1]. Researchers found that after teaching cognition or self-adjust strategy, students will show improvement in self-efficacy and academic performance (Pintrich & De Groot, 1990) [17]. It indicates that through the teaching of self-adjust strategy, students' learning behaviors are affected, learning results enhanced, and students' inner efficacy changed accordingly. So, self-adjust strategy is very important to individual learning.

2.2 Game-Based Learning

Wozny (1985) indicated that using game in courses to pique learning interest and reduce the dullness of course has been popular for many years [29]. It has been proven that in recent years educational game is a much better approach than traditional teaching method in reinforce study efficacy and can be a positive influence in high-level thinking abilities and interaction. Prensky (2001) Game-based learning, when combined with teaching goal effectively, will enhance students' learning motive and guide them to learn more spontaneously [19]. Digital Game-Based learning was proposed by Prensky in 2001. The impact of Digital Game-Based on learners lies in that it provides learners an environment to learn interactively and triggers their inner learning motives. While Prensky (2004) thought that digital games can have positive impact on learners by heighten their visual focus [20], Papastergiou's (2009) research also showed that digital games can be used as an effective learning tool for information education, and to promote cooperative learning and problem-solving ability [16]. Game-Based learning is a revelational idea (Tham & Tham, 2015) [25]. It views game as a cognitive tool and makes the process of entertainment a measurable learning goal and with educational meaning. Through unknown storyline, control, and interesting interaction, it brings out 5 learning merits: trigger constant challenges, help memory retain, master skills through practice, self-evaluate through feed-back, integrate what you've learned, and improve advanced skills (Hogle, 1996; Rieber, 1996) [9, 21]. It can also apply to idioms learning. In the developing technology, the types of game-based learning are getting more and more, and the educational topics can be covered more extensively. Prensky (2001) pointed out that there are 6 distinctive characteristics that made digital games attractive: rule, purpose and goal, output and feedback, conflict and competition, interactivity, and narration [19]. More and more research show that a good educational game can create an immersive experience, frequent information handling, decision-making, application, and problem solving, and involve team members' coordination. It can lower cognitive burden, invoke self-learning, add interaction, and make courses more interesting (Oblinger, 2006) [15]. With additional techniques like bonus system, condition exchange, potential developing, cooperative learning of teachers and students, and peer assistances, we can heighten motives, promote learning results and deep learning, or strengthen the confidence of middle and low achievers (Hung, Sun, & Liu, 2019) [10], and apply to many fields and cross-fields. For example, by using mobile game and group discussion, English grammar structure cognition of students with lower achievement is improved (Chu, Wang, & Wang, 2019) [3]. The fun, interactive, competitive, new English learning feedback system can help learners better their inner and outer motives and concentration (Sun & Hsieh, 2018) [24]. Game-based learning should also adopt proper learning strategy. Progressive help prompts play an important part in support and guide the mission in interactive environment (Yang, Chu, & Chiang, 2018) [31]. In addition, Gamification needs to consider students' cognitive abilities, provide proper missions (Yang, Chang, Hwang, & Zou, 2020) [34] and adequate teaching method to evaluate if it meets students' requirement, in order to achieve learning goals (Rigóczki, Andrei, & Kristóf, 2017) [22]. In contrast to traditional digital learning with web-page learning model, game-based learning can incite stronger learning motives and attract learner's devotion (Pivec, 2007) [18]. And, since the rule and purpose of game design is learning through entertaining, the game can guide people into progressive learning (Mcloughlin, 2002) [13]. So, gameplay is a high-level learning activity that needs a lot of devotion (Prensky, 2001) [19]. Therefore, game-based learning primarily means a learning model that, by using a digital game integrated with learning elements and contents, players must face constant challenge and feedback systematically in the game, thus achieve the learning result with specific goal (Garris, Ahlers & Driskell, 2002) [4].

2.3 Idioms Teaching

Idiom's learning is undoubtedly an important part of Chinese language courses. Even though we use plain Chinese nowadays, idioms are still used frequently because they have been in existence for a long time. Idioms not only are the accumulated ancient wisdom but also the pith of Chinese language. Their importance is unquestionable. The usage of idioms greatly helps the learners to learn Chinese, no matter in reading or writing. Therefore, the design to help the students comprehend the idioms effectively is an important topic. Idioms is a combination of several letters to convey a concise and power meaning. Though the number of letters used are not fixed, but idioms with 4 letters are most common. Idioms are not only the literal meanings of individual letters. Most idioms have their sources and their implied meanings. Teaching means the process for the teachers to pass their knowledge and skills on to students. Combining both the definitions of idioms and teachings, idioms teaching means teachers use different teaching strategies to teach students one language, the idioms, which are the fixed words with specific number (4 being the most common) of letters and have been used for a long time. From Ho Yong-Ching's mentioning, we can analyze the merits of learning idioms from 3 perspectives: cognitive, affective, and psychomotor. From cognitive perspective, the more idioms you learn, the higher and superior language level you master. From affective perspective, students who understand more idioms stories will have sharper minds and stronger creativity. From psychomotor perspective, the more students remember vocabularies, the greater their ability to write. It is not advisable for teachers to teach students strictly by textbook or always teach the same material. Teachers should make teaching strategy beforehand, know students' levels, make teaching materials, and edit schedule. Everything should be prepared previously and thoroughly, so by following the goal, idioms teaching can save efforts and lead better results. Or else teaching activities without directions could put students in confusion and thus prevent students from fully developing their abilities. Teachers can use multiple instructions and try to heighten students' learning interests from different aspects.

2.4 Related Works

Many past research shows that the game-based learning not only can promote students' learning results and cognitive ability performances (Garris, Ahlers, & Driskell, 2002; Mayer et al., 2014; Wouters et al., 2013) [4, 11, 28], but also show more positive influences than traditional teaching on psychological aspect such as learning motives, cognitive load, and flow experience (Hsieh, Jang, Hwang, & Chen, 2011; Tortorella & Graf, 2015; Yeh & Wang, 2013) [8, 26, 35]. Game-based learning can successfully maintain students' participations and motives. It has lower wear off effect and can still keep students' interests after several activities (Wang, 2015) [27]. Yang and Chang (2013) discovered that by employing game-based learning in computer program learners' learning interests are heightened [33]. By applying digital learning to social study related subjects, Chu and Chen (2016) discovered that multiple teaching methods can promote learners' learning motives, learning efficacy, and learning attitudes [2]. Game-based learning environment like this can help students learn related knowledge and apply it into everyday lives. Both digital game-based learning and mobile learning should take learning process into consideration and combine with learning strategy to construct a proper game-based learning activity, in order to achieve ideal learning results (Hsiao & Chen, 2016) [7]. Hogle (1996) showed some merits of digital game-based learning. 1. It can trigger learners' inner motive and heighten their interests. 2. Compared to traditional teaching, the game has better results in remembering. 3. The game can provide learners many opportunities to practice and can get feedback effectively. 4. By merging teaching contents into game, students can sort out what they've learned while solving problems [9]. In learning process students must understand the logic and thread of the teaching materials, and then after they master the rules, they can decide what learning method to adopt and they control the self-regulated learning themselves (Gee, 2005; McFarlane, Sparrowhawk, & Heald,2002) [5, 12].

3 Methods

The processes of this research include initial research purpose and motive, related documentation collection, game design, experiment activities, experiment data collection and analysis, statistical data, and final thesis results.

3.1 Game System Design

Chinese myths are incorporated into storyline through role-playing (see Fig. 1). In the game there are 3 chapters, each with 15 idioms and 3 little levels (see Fig. 2). There are explanation and instruction about the game before each level. The test in first level is of easier learner mode, designed for beginner players. As the players' learning abilities increase, players can choose their own level, set the difficulties of each level, to improve learners' learning confidence and learning willingness. At the more difficult levels there will be items to help learners pass. Learners can also see what they have already learned by the package system in the game. This is the goal of self-regulated learning.

Fig. 1. Game screenshot

Fig. 2. Design of game level

3.2 Setting of Self-regulated Learning Strategy

At the beginning of the course students are taught the basic concept and strategy of self-regulated learning to help them understand the meaning of self-regulated learning, know how to use the learned strategy to help them learn by themselves, and keep record of the learned self-regulated learning strategy in learning sheet. After learning self-regulated learning strategy, students will set learning goals for themselves, devise effective learning methods accordingly, and then fill out the learning sheet.

Self-regulated learning strategy includes:

1. I will use the methods I like or understand, to sort out learned teaching materials.
2. I will use internet to collect data that are relevant to teaching materials.
3. I will make plans for learning time.
4. I will review learned teaching materials any time.
5. I will record my learning situation during study.

3.3 Experiment Design and Research Tools

The subjects of the experiment are the Seventy-five 5-grade students in some elementary school from the north in Taiwan. They are divided into control group (A) and experiment group (B) according to classes. Control group (A) are given teaching materials and required to fill out learning sheet online. Experiment group (B) are given game system, teaching materials, and required to fill out learning sheet online. The duration of this experiment is 3 weeks. Before first week, pretest questionnaires are filled out to check that there are no big differences between the two experiment groups before experiment. After the third week, posttest questionnaires are filled out. Shown as Fig. 3.

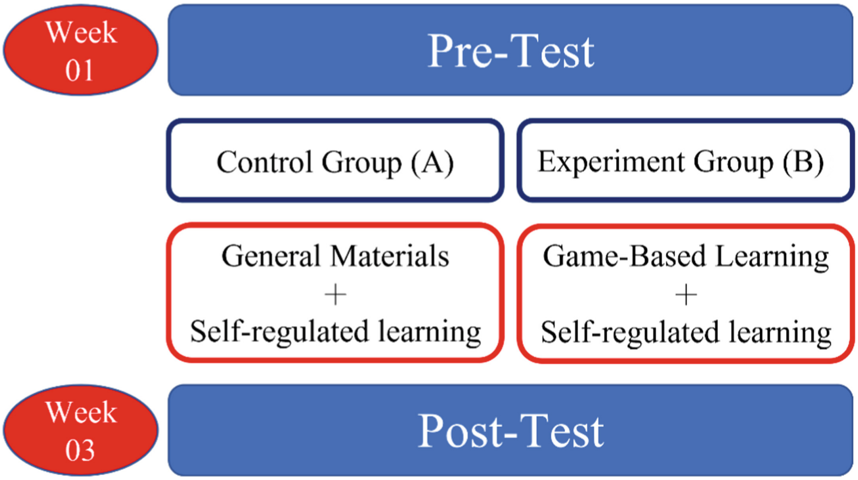


Fig. 3. Experiment process flowchart

4 Results

4.1 Data Collection and Analysis

There are 75 valid samples in this research, mainly to explore the learning results of self-regulated learning with and without game-based learning. The pretest and posttest results are analyzed to compare the changes of learning results of the two self-regulated learning groups. Table 1 shows the independent sample t is analyzed for the academic results of the 2 groups before and after the experiment. In pretest, the different of average academic results of both groups are nonsignificant, $t\ (74) = -1.108$, $p = 0.373$. Score of experiment group (B): $M = 40.44$, $SD = 19.34$. Score of control group (A): $M = 40.31$, $SD = 18.30$. After analyzing the 2 group get $p = 0.373 > 0.05$, indicating the differences in 2 groups are nonsignificant. The result can conclude that the differences between the idioms level in the 2 groups are nonsignificant before experiment. In posttest, the differences in average academic results in both groups are significant, $t\ (74) = 2.413$, p = 0.036. Score of experiment group (B): M = 66.75, SD = 19.45. Score of control group (A): M = 50.46, SD = 66.75, p = 0.036 < 0.05, indicating the differences in 2 groups are significant after experiment. This shows that although the learning strategy is clear for both groups in self-regulated learning process, the result of learning idioms is much more significant for the group that employs game-based learning.

Table 1. Independent t test of two groups with and without game-based learning

	M (SD)		df	t	p
	Control group (N = 25)	Experimental group (N = 50)			
Pre-TEST	40.44 (19.34)	40.31 (18.30)	74	−1.108	.373
Post-TEST	50.46 (26.03)	66.75 (19.45)	74	2.413	.036*

$^{*}p < .05$

5 Conclusion and Discussion

An idioms learning system is designed for this research. Digital game-based learning, unlike traditional learning from books, heightened students' interests in learning idioms and increase their willingness to learn. The difficult idioms learning has been incorporated into the game through visual and audio game sceneries, Chinese myth elements, role-playing, and level design. It actually heightens students' motives and interests. Digital Game-based learning has a very good learning effect on idioms learning. In addition, the integration of self-regulated learning and game-based learning can help students change their learning pattern. The result shows that students of self-regulated learning, when encountering difficulties, will encourage himself, and will try to face problems and find solutions continuously. Students feel that this learning model is different from traditional classroom, that you can choose learning materials, learning methods, and learning times. High degree of freedom makes them relax and, in this stress-free learning environment they tend to express themselves more, not afraid of making mistakes, and have more confidence in learning. Self-regulated learning changes students' learning model, turning them from passive to active gradually. Students are allowed to learn by the way they like or want, thus the feelings of exclusion and frustration are greatly reduced. Students can help create their own learning space, make plan for learning, hence increase their courage to take responsibility for learning results. They will try to solve problems encountered, in order to reach the learning goal. Students will try to use many learning methods and techniques, such as note-taking, review, self-encouraging, self-recording and schedule planning, etc., to help themselves study better. Students will form the habit of set learning goals and self-monitoring learning. This is consistent with the self-controlled learning goal, content, and method previously mentioned by researchers [6]. Students can participate their own learning journeys through self-teaching and self-managing [14]. In the meantime, students' participation level and learning motives are successfully maintained. Self-adjustment, behavior, and scenario-adjustment can change impact on learners by personal, behavior and the environment [1, 17]. Due to the time limitation of this project, the data collection of students' self-regulating learning is only of the first stage. Therefore, the future research should stretch the time period, acquire deeper and more detailed information, to understand students' self-regulating learning behavior.

References

1. Bandura, A.: The explanatory and predictive scope of self-efficacy theory. J. Clin. Soc. Psychol. **4**, 359–373 (1986)
2. Chu, H.C., Chen, J.M., Yang, K.H., Lin, C.W.: Development and application of a repertory grid-oriented knowledge construction augmented reality learning system for context aware ubiquitous learning. Int. J. Mob. Learn. Organiz. **10**(12), 40–60 (2016)
3. Chu, H.C., Wang, C.C., Wang, L.: Impacts of concept map-based collaborative mobile gaming on English grammar learning performance and behaviors. Educ. Technol. Soc. **22**(2), 86–100 (2019)
4. Garris, R., Ahlers, R., Driskell, J.E.: Games, motivation, and learning: a research and practice model. Simul. Gaming **33**(4), 441–467 (2002)
5. Gee, J.P.: Learning by design: good video games as learning machines. E-Learn. Digit. Media **2**(1), 5–16 (2005)
6. Gelpi, E.: The Future of Lifelong Education. University of Manchester Press, Manchester (1979)
7. Hsiao, H.S., Chen, J.C.: Using a gesture interactive game-based learning approach to improve preschool children's learning performance and motor skills. Comput. Educ. **95**(151), 162 (2016)
8. Hsieh, S.W., Jang, Y.R., Hwang, G.J., Chen, N.-S.: Effects of teaching and learning styles on students' reflection levels for ubiquitous learning. Comput. Educ. **57**(1), 1194–1201 (2011)
9. Hogle, G.J.: Considering games as cognitive tools: in search of effective "edutainment". University of Georgia Department of Instructional Technology (1996)
10. Hung, C.Y., Sun, J.C.Y., Liu, J.Y.: Effects of flipped classrooms integrated with MOOCs and game-based learning on the learning motivation and outcomes of students from different backgrounds. Interact. Learn. Environ. **27**(8), 1028–1046 (2019)
11. Mayer, I., et al.: The research and evaluation of serious games: toward a comprehensive methodology. Br. J. Edu. Technol. **45**(3), 502–527 (2014)
12. McFarlane, A., Sparrowhawk, A., Heald, Y.: Report on the Educational Use of Games. TEEM (Teachers Evaluating Educational Multimedia), Cambridge (2002)
13. Mcloughlin, C.: Learner support in distance and networked learning environments: ten dimensions for successful design. Distance Educ. **23**(2), 149–162 (2002)
14. Mok, M.M.C., Ma, H.S., Liu, Y.F., So, Y.P.: Multilevel analysis of primary students' perception and deployment of self-learning strategies. Educ. Psychol.: An Int. Exp. Educ. Psychol. **25**(1), 129–148 (2005)
15. Oblinger, D.G.: Games and learning. Educ. Q. **3**, 5–7 (2006)
16. Papastergiou, M.: Digital game-based learning in high school computer science education: impact on educational effectiveness and student motivation. Comput. Educ. **52**, 1–12 (2009)
17. Pintrich, R.R., DeGroot, E.V.: Motivational and self-regulated learning components of classroom academic performance. J. Educ. Psychol. **82**, 33–40 (1990)
18. Pivec, M.: Editorial: play and learning: potentials of game-based learning. Br. J. Educ. Technol. **38**(3), 387–393 (2007)
19. Prensky, M.: Digital Game-Based Learning. McGraw-Hill, New York (2001)

20. Prensky, M.: The Emerging Online Life of the Digital Native (2004). http://www.marcprensky.com/writing/Prensky-The_Emerging_Online_Life_of_the_Digital_Native-03.pdf. Accessed 9 Oct 2013
21. Rieber, L.P.: Seriously considering play: designing interactive learning environments based on the blending of microworlds, simulations, and games. Educ. Technol. Res. Dev. **44**(2), 43–58 (1996)
22. Rigóczki, C., Andrei, D., Kristóf, G.A.: Gamification on the edge of educational sciences and pedagogical methodologies. J. Appl. Tech. Educ. Sci. **7**(4), 79–88 (2017)
23. Skager, R.: Lifelong Education and Evaluation Practice. UNESCO Institute for Education, Hamburg and Pergamon Press, Oxford (1978)
24. Sun, J.C.Y., Hsieh, P.H.: Application of a gamified interactive response system to enhance the intrinsic and extrinsic motivation, student engagement, and attention of English learners. Educ. Technol. Soc. **21**(3), 104–116 (2018)
25. Tham, R., Tham, L.: Game-based learning in Singapore higher education – a pilot study. People: Int. J. Soc. Sci. **1**(1), 571–581 (2015)
26. Tortorella, R.A., Graf, S.: Considering learning styles and context awareness for mobile adaptive learning. Educ. Inf. Technol. 1–19 (2015)
27. Wang, A.I.: The wear out effect of a game-based student response system. Comput. Educ. **82**, 217–227 (2015)
28. Wouters, P., Van Nimwegen, C., Van Oostendorp, H., Van Der Spek, E.D.: A meta-analysis of the cognitive and motivational effects of serious games. J. Educ. Psychol. **105**(2), 249–265 (2013)
29. Wozny, C.: The invention of board games by a group of teenagers from a special school. Simul./Games Learn. **15**, 118–125 (1985)
30. Yang, J., Lin, M., Chen, S.: Effects of anxiety levels on learning performance and gaming performance in digital game-based learning. J. Comput. Assist. Learn. **34**(3), 324–334 (2018)
31. Yang, K.H., Chu, H.C., Chiang, L.Y.: Effects of a progressive prompting-based educational game on second graders' mathematics learning performances and behavioral patterns. Educ. Technol. Soc. **21**(2), 322–334 (2018)
32. Yang, K.M., Lee, L.C., Chiu, C.Y.: The effects of a self-designed tabletop game and learning achievement. J. Comput. **32**(1), 174–182 (2021)
33. Yang, Y.T.C., Chang, C.H.: Empowering students through digital game authorship: enhancing concentration, critical thinking, and academic achievement. Comput. Educ. **68**(334), 344 (2013)
34. Yeh, Y., Wang, C.W.: Effects of multimedia vocabulary annotations and learning styles on vocabulary learning. CALICO J. **21**(1), 131–144 (2013)
35. Yang, Q.-F., Chang, S.-C., Hwang, G.-J., Zou, D.: Balancing cognitive complexity and gaming level: effects of a cognitive complexity-based competition game on EFL students' English vocabulary learning performance, anxiety and behaviors. Comput. Educ. **148**, 103808 (2020)
36. Zimmerman, B.J.: Self-regulation involves more than metacognition: a social cognitive perspective. Educ. Psychol. **30**, 217–221 (1995)
37. Zimmerman, B.J., Bonner, S., Kovach, R.: Developing Self-Regulated Learners: Beyond Achievement to Self-Efficacy. American Psychological Association, New York (1996)

The Study on Critical Thinking of Using Blocks Vehicle in STEAM Course for Grade Two Elementary School Students

Wei-Shan Liu and Ting-Ting Wu(✉)

Graduate School of Technological and Vocational Education, National Yunlin University of Science and Technology, Douliou, Taiwan
ttwu@yuntech.edu.tw

Abstract. STEAM education, which is considered one of the important curriculum topics for current education learning, can be used to cultivate critical thinking ability, thereby greatly enhancing the judgment and thinking abilities for students in this generation. For STEAM curriculum learning, literature mentioned that in STEAM curriculum, a method of cooperative learning is used for curriculum learning. However, from the feedback of curriculum learning, only the effect of curriculum learning is assessed, and no special attention is paid to whether the curriculum is implemented in the way of cooperative learning. Moreover, for the curriculum learning of building block self-propelled vehicle, there are seldom studies taking second grade students as subjects for curriculum learning. Therefore, in this study, based on the STEAM curriculum, in combination with building block self-propelled vehicle, the cooperative learning and individual learning strategies were applied to second grade students from elementary school. After the curriculum, critical thinking was used to verify and assess their critical thinking abilities, and assessment and analysis were made at the same time. The analysis results showed that there was no significant difference between the test scores of the two groups. However, in the critical thinking test, the average score of the experimental group was higher than that of the control group. The results indicate that for the critical thinking assessment of the second grade students from elementary school, the cooperative learning strategy obtained a better effect than the individual learning strategy in the STEAM curriculum of building block self-propelled vehicle.

Keywords: STEAM · Critical thinking · Building block vehicle · Cooperative learning

1 Introduction

Under rapid changes and development, 21 century has entered the era of knowledge economy. In order to improve national competitiveness, talent cultivation is a topic emphasized by many countries at present. In 2009, Barack Obama, President of the United States, launched a policy of “ten-year plan of educational innovation” to initiate training for 100,000 STEAM teachers [1]. STEAM teachers are the key for the United

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 471–479, 2022.
https://doi.org/10.1007/978-3-031-15273-3_52

States to cultivating technological innovative talents, and the creativity and practical ability of students are also cultivated during the educational reform [2]. Affected by the STEAM education of the United States and the pressure from increasingly global technological competition, countries all over the world begin to actively promote the STEAM education [3]. The importance of the STEAM curriculum includes: Starting from the problems or scenarios, combined with the actual life scenarios, the plan and the critical thinking ability obtained by students can also be used in the same or different life scenarios [4]. Attention is paid to the learning process. In addition to the knowledge transmission, practical exercise and innovative thinking, emphasis is attached to the in-depth participation in the learning process and the improvement of the learning interest [5].

In this study, second grade students from elementary school were taken as the subjects for the experiment. The effects of cooperative learning and individual learning in STEAM curriculum for critical thinking of students were explored [6]. An interdisciplinary STEAM curriculum was designed and planned in this study, and students were required to make building block self-propelled vehicles on hand. The learning content was combined with life to stimulate the curiosity to explore, and the knowledge was applied to life. In this way, the students could freely make exploration and learning, and may further connect their life problems [7]. Through a combination between the STEAM curriculum and the courses of elementary school, the professional knowledge can be learned, and skills of different fields can also be learned, which may improve the technical importance in students. Furthermore, the students can learn about teamwork, take responsibility for their own behavior and cultivate their professional attitude and behavior for curriculum learning [8].

Therefore, in this study, an interdisciplinary STEAM curriculum learning was taken for two classes of second grade students from elementary school. Cooperative learning and individual learning were used for teaching respectively to explore the effect of STEAM curriculum for critical thinking.

2 Literature Review

2.1 STEAM Curriculum

By integrating fields of Science, Technology, Engineering Mathematics and Art, STEAM curriculum is a teaching method that emphasizes interdisciplinary cooperation [9]. The purpose of STEAM education is to design and explore, and to solve problems with science and technology and scientific thinking [10]. The curriculum content, activities and assessment can be designed by connecting with the current technological development or the relevant life experience. From the process of practical exercise and critical thinking cultivation, the students could understand the relationship between disciplines. STEAM can be defined as the education to improve students' interest and understanding of science and technology, and the education to improve STEAM literacy based on science and technology and practical problem solving ability [11]. With the emphasis on science education in the United States, many science education policies and corresponding solutions have been introduced. For STEAM curriculum integration, cooperative learning and technological teaching are used, and learning curriculum and diverse assessment methods are explored, so as to cultivate students to learn teamwork, good communication skills and critical thinking ability by means of group cooperation [12]. For STEAM curriculum integration, with student-centered teaching philosophy, connection with real social scenarios is focused on, and integrated scientific knowledge and skills are learned through active knowledge course construction, so as to enhance students' interest in science and technology [13, 14].

During the STEAM education learning, importance is attached to practical exercise and critical thinking, and plan exploration-oriented teaching can cultivate children's internal and external comprehensive abilities, including exploration ability, critical thinking ability, creative thinking ability and critical thinking. Therefore, STEAM education can cultivate children's patience, willpower and frustration tolerance, and self-responsibility learning [15].

2.2 Critical Thinking

In many countries, such as United Kingdom, Australia and New Zealand, critical thinking is an important basic ability. Many countries all over the world pay attention to critical thinking teaching, and even list it as national education [16]. However, although its importance is considered, such issue is neglected in education for a long time, which is also indisputable. Critical thinking may be advocated as an educational objective throughout the whole century in a strong manner, but many objectives are not achieved yet [17].

The beginning of critical thinking includes five processes, namely, suggestion, rationalization, hypothesis, reasoning, and test and hypothesis. Ruggiero [18] regarded thinking as any psychological activities that can help explain or solve problems, and make decisions to achieve knowledge intention, which focuses on searching for answers and fulfilling its meanings therefrom. Critical thinking is: "to assess the concepts understood or listened from the experienced activities, test their effectiveness and accuracy, and improve them when necessary." Ennis [19] proposed that critical thinking is rational and reflective thinking; in other words, determining what is credible, and what may be done. According to such definition, critical thinking covers creative activities, including systematic description of project hypothesis, problems, alternatives and actual activities. Swartz [20] held that critical thinking is a kind of basic enterprise spirit, that is, we apply appropriate standards and criteria to our own creations, including the key concepts of background and operational knowledge based on appropriate standards, psychological ability of effective exploration and some important psychological habits.

2.3 Cooperative Learning Strategy

Nattiv [21] proposed that cooperative learning is a kind of teaching method, and students work together in a way of groups and face the common objectives. Each member takes respective responsibility for their learning, they are "interdependent" whether in terms of pay, work, materials or roles, and team members are usually heterogeneous in achievement, gender and race. Cooperative learning is a group teaching design that combines pedagogy, social psychology and group dynamics: Learning is made mainly through the division of labor and cooperation among group members as well as mutual support [22].

Social and psychological atmosphere of group assessment and inter-group competition is also used to improve the learning effect. The purpose is to make learning activities a cooperative activity, and its success or failure is related to the honor or disgrace of the group.

Therefore, cooperative learning has its uniqueness, which is different from other teaching methods. Cooperative learning is not simply placing students in group learning, its importance lies in organizing cooperative teams and promoting the cooperative learning within the teams. Cooperative learning is not just letting students sit around to do their homework. In actual cooperative learning team, each member is interdependent, helps each other, shares resources, and promotes each other in learning.

3 First Section

3.1 Research Subjects

In this study, second grade students from an elementary school in Yunlin County were taken as the subjects. They did not receive any teaching related to STEAM education curriculum before the experiment of STEAM education teaching, so they were at the beginning stage of STEAM curriculum learning. In this study, the class was taken as the unit, second grade students from this school were selected as the subjects. There were a total of 48 students; 24 students in the experimental group carried out STEAM curriculum learning in a way of cooperative learning, and 24 students in the control group carried out STEAM curriculum learning in a way of individual learning. Each student was equipped with a set of STEAM building block self-propelled vehicles and a remote controller, which could be used after their building block self-propelled vehicles are assembled.

3.2 Assessment Tool - Critical Thinking Test

In this study, the questions in A1 and A2 of Think A Minutes A1 introduced by Dr. Funster's were mainly used for critical thinking test. The questions in this test were compiled based on A1 and A2 to assess the performance of the following four sub-abilities, including deductive construction ability, inductive ability, reasoning ability and creative thinking ability. Such questions were used in group tests, each test question included multiple-choice questions and question-and-answer questions, and the answer rate of each item was taken as the scoring principle. The critical thinking assessment tool with form, content and scoring method designed based on the previous experience was used to analyze the difference of learning effects of second grade students from elementary school in the ways of group learning and individual learning after STEAM curriculum learning.

3.3 Experimental Process

The experiment in this study was divided into 12 weeks, with 24 classes, each class lasting 40 min. The students were second grade students from elementary school, with a total of 48 students, as shown in Fig. 1.

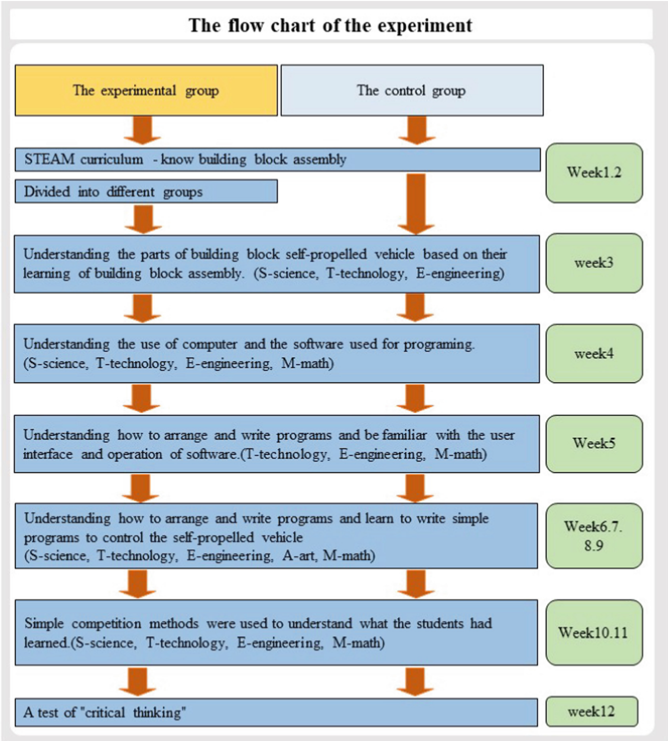


Fig. 1. The experiment in this study

In the first and second weeks of the experiment, “STEAM curriculum - know building block assembly” and “grouping by experimental group” were carried out. The purpose was to make the students understand the method of splicing the parts of the building block assembly vehicle with the building blocks, including the fields in the STEAM education curriculum such as science, technology and engineering, with a period of two weeks. In the third week of the experiment, “STEAM curriculum - design one’s own vehicle” was carried out. The purpose was to make the students understand the parts of building block self-propelled vehicle based on their learning of building block assembly, including the fields in the STEAM education curriculum such as science, technology and engineering, with a period of one week. In the fourth week of the experiment, “STEAM curriculum - programing warm up” was carried out. The purpose was to make the students understand the use of computer and the software used for programing of building block self-propelled vehicle, including the fields in the STEAM education curriculum such as science and technology engineering and mathematics, with a period of one week. In the fifth week of the experiment, “STEAM curriculum - programing scratch exercise” was carried out. The purpose was to make the students understand how to arrange and write programs and be familiar with the user interface and operation of software, including the fields in the STEAM education curriculum such as science, technology, engineering and mathematics, with a period of one week. In the sixth, seventh, eighth and ninth weeks of the experiment, "STEAM curriculum - programing scratch exercise - let building block self-propelled vehicle straight forward, turn, figure and wander" was carried out. The purpose was to make the students understand how to arrange and write programs and learn to write simple programs to control the self-propelled vehicle, including the fields in the STEAM education curriculum such as science, technology, engineering, art and mathematics, with a period of four weeks. In the tenth and eleventh weeks of the experiment, "STEAM curriculum - programing scratch control competition" was implemented. In these two weeks, test was carried out to check the results of curriculum learning during these weeks. Simple competition methods were used to understand what the students had learned, including the fields in the STEAM education curriculum such as science, technology, engineering and mathematics, with a period of two weeks. In the twelfth week, the last week, a test of "critical thinking" was carried out to verify the effect of critical thinking after the STEAM curriculum learning. The data was analyzed upon completion of the curriculum and the research results and conclusions were written.

3.4 Learning Aids

The parts of the building block self-propelled vehicle represented by Kodorobot Enterprise were used for building block assembly exercises. The parts of such series are shown in Fig. 2. DIY variety building block vehicle is a set of teaching tools that can train children's creative ability and logical thinking ability on hand. The preliminary building block assembly may stimulate different imaginations and creativity of the subjects. Besides allowing the subjects to practice building block assembly, hand muscle application and hand-eye coordination can be trained through parts assembly, and the habit of concentration may be formed. After the building block vehicle is assembled, the remote controller may be used to control the building block vehicle. In practicing remote controller, the matchable remote controller and control mode need to be selected, and logical thinking ability and mathematical reasoning ability need to be used. After knowing the control mode of the remote controller, programming may be started to control the movement of the building block vehicle, and solutions or new innovative ideas may be produced, so that problems can be further thought and solved. Through the learning of the building block vehicle, the learned content can be internalized and applied to life, so as to face future challenges.

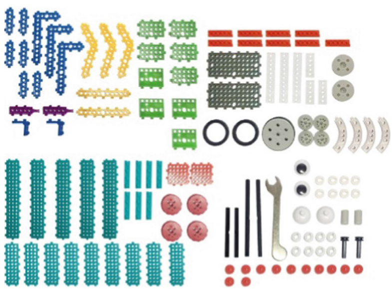


Fig. 2. The parts of such series

4 Research Results and Discussion

4.1 Post-test Scores After Critical Thinking Test in the Experimental Group

The data shown in Fig. 3 was a line chart of critical thinking test scores of students in the experimental group and the control group. According to the chart, the scores of most students in the experimental group were higher than those in the control group, and the final average score in the experimental group was also higher than that in the control group.

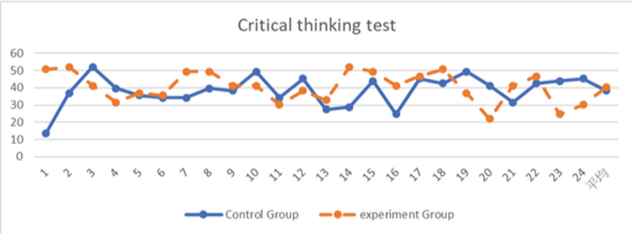


Fig. 3. A line chart of critical thinking test scores

4.2 Post-test Scores After Critical Thinking Test of the Two Groups

After the STEAM building block self-propelled vehicle curriculum was applied to cooperative learning and individual learning, in order to understand the impact of learners' participation in the curriculum on critical thinking, independent sample t-test analysis was made on the scores of learners' critical thinking test. The analysis results are shown in Table 1. As p = .398, although there was no significant difference in the performance of learners' critical thinking test between the experimental group and the control group, according to the average score results, the cooperative learning strategy showed certain results for critical thinking after learners took STEAM building block self-propelled vehicle curriculum in the ways of cooperative learning and individual learning.

Table 1. The independent sample t-test analysis of the critical thinking test

Item	N	M	SD	*t*	df	*p*
Critical thinking score	Experimental group (24)	40.47	8.81	.852	46	.398
	Control group (24)	38.30				

5 Conclusions and Future Directions

After the learning of building block self-propelled vehicle and interdisciplinary STEAM curriculum, according to the research results, the critical thinking test scores showed that the critical thinking of learners in the cooperative learning group was significant. Therefore, STEAM education strategy could be combined with the science, technology, engineering, art and mathematics through relevant curriculum. The combination of the five fields can bridge the gap between different disciplines, and let students learn knowledge through multiple channels in different environments and plan activities. In this study, as advocated by STEAM education, cooperative learning, mutual discussion and communication in curriculum learning showed certain results in improving critical thinking. Through interdisciplinary STEAM curriculum learning, practical combination with hands-on practice, innovative thinking inspiration, deep participation in the learning process and improvement of learning interest, when a good learning method is used to interact with the curriculum learning in the learning process, the learners' learning and absorption in the learning process can achieve better results for the course learning.

In the future, in-depth exploration and analysis may be made focusing on the correlation from more dimensions. For example, the increase of creative thinking mentioned by STEAM curriculum and the test of trail error and critical thinking may be comprehensively assessed and understood in the study.

References

1. Obama, B.: "The White House." crisis (2011)
2. Breiner, J.M., et al.: What is STEM? A discussion about conceptions of STEM in education and partnerships. Sch. Sci. Math. **112**(1), 3–11 (2012)
3. English, L.D., King, D.T.: STEM learning through engineering design: fourth-grade students' investigations in aerospace. Int. J. STEM Educ. **2**(1), 1–18 (2015)
4. Sanders, M.E.: STEM, STEM Education, STEMmania (2008)
5. Kim, Y., Park, N.: Development and application of STEAM teaching model based on the Rube Goldberg's invention. In: Yeo, S.S., Pan, Y., Lee, Y., Chang, H. (eds.) Computer Science and Its Applications. LNEE, vol. 203, pp. 693–698. Springer, Dordrecht (2012). https://doi.org/10.1007/978-94-007-5699-1_70
6. Han, S., Capraro, R., Capraro, M.M.: How science, technology, engineering, and mathematics (STEM) project-based learning (PBL) affects high, middle, and low achievers differently: the impact of student factors on achievement. Int. J. Sci. Math. Educ. **13**(5), 1089–1113 (2015)
7. Chen, Y., Chang, C.-C.: The impact of an integrated robotics STEM course with a sailboat topic on high school students' perceptions of integrative STEM, interest, and career orientation. EURASIA J. Math. Sci. Technol. Educ. **14**(12), em1614 (2018)
8. Watson, J., Foster, R.: The Attending Nurse Caring Model: integrating theory, evidence and advanced caring-healing therapeutics for transforming professional practice, pp. 360–365 (2003)
9. Henriksen, E.K.: Introduction: participation in science, technology, engineering and mathematics (STEM) education: presenting the challenge and introducing Project IRIS. In: Henriksen, E.K., Dillon, J., Ryder, J. (eds.) Understanding Student Participation and Choice in Science and Technology Education, pp. 1–14. Springer, Dordrecht (2015). https://doi.org/10.1007/978-94-007-7793-4_1
10. Pu, Y.-H., et al.: The design and implementation of authentic learning with mobile technology in vocational nursing practice course. Br. J. Educ. Technol. **47**(3), 494–509 (2016)
11. Thuneberg, H.M., Salmi, H.S., Bogner, F.X.: How creativity, autonomy and visual reasoning contribute to cognitive learning in a STEAM hands-on inquiry-based math module. Think. Skills Creat. **29**, 153–160 (2018)

12. Wu, T.-T.: Improving the effectiveness of English vocabulary review by integrating ARCS with mobile game-based learning. J. Comput. Assist. Learn. **34**(3), 315–323 (2018)
13. Kim, P.W.: The wheel model of STEAM education based on traditional Korean scientific contents. Eurasia J. Math. Sci. Technol. Educ. **12**(9), 2353–2371 (2016)
14. Becker, K.H., Park, K.: Integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: a meta-analysis. J. STEM Educ.: Innov. Res. **12**(5) (2011)
15. Shepard, L.A., Penuel, W.R., Pellegrino, J.W.: Using learning and motivation theories to coherently link formative assessment, grading practices, and large-scale assessment. Educ. Meas. Issues Pract. **37**(1), 21–34 (2018)
16. Boluk, K.A., Cavaliere, C.T., Higgins-Desbiolles, F.: A critical framework for interrogating the United Nations Sustainable Development Goals 2030 Agenda in tourism. J. Sustain. Tour. (2019)
17. Kereluik, K., et al.: What knowledge is of most worth: teacher knowledge for 21st century learning. J. Digit. Learn. Teach. Educ. **29**(4), 127–140 (2013)
18. Ruggiero, V.R.: Teaching Thinking Across the Curriculum. Harper & Row (1988)
19. Ennis, R.H.: Critical thinking dispositions: their nature and assessability. Informal Logic **18**(2) (1996)
20. Swartz, R.J.: Structured teaching for critical thinking and reasoning in standard subject area instruction. In: Informal Reasoning and Education, pp. 415–450 (1991)
21. Nattiv, A.: Helping behaviors and math achievement gain of students using cooperative learning. Elem. Sch. J. **94**(3), 285–297 (1994)
22. Järvelä, S., et al.: "Enhancing socially shared regulation in collaborative learning groups: designing for CSCL regulation tools. Educ. Technol. Res. Dev. **63**(1), 125–142 (2015)

Employing Portable Eye Tracking Technology in Visual Attention of Cognitive Process: A Case Study of Digital Game-Based Learning

Chun Chia Wang[1](✉), Hsuan Chu Chen[2], and Jason C. Hung[3]

[1] School of Information and Design, Chang Jung Christian University, Tainan City 711, Taiwan
toshiwang@mail.cjcu.edu.tw

[2] Department of Digital Media Design, Chang Jung Christian University, Tainan City 711, Taiwan

[3] Department of Computer Science and Information Engineering, National Taichung University of Science and Technology, Taichung 404, Taiwan

Abstract. In recent years, digital game-based learning (DGBL) has received more and more attention as a form of digital learning. This study used a portable eye tracker to explore the learners' visual attention and cognitive process during DGBL. The study recruited 38 students in the third year of study in the school of information and design at a university in southern Taiwan. According to students' performance in the English courses at the university, participants were divided into High Competence Group (n = 5), Intermediate Competence Group (n = 8), and Low Competence Group (n = 25). By collecting the participants' eye movement data with eye tracker, eye movement indicators were acquired to investigate the correlation between the participants' external behavior and cognitive process among regions of interest (ROIs). The finding results of this study were as follows: (1) The fixation sequence of ROIs from participants of different groups is different; (2) During the experiment, ROI3 (English definitions of the vocabulary) was the first ROI of fixation for participants of Intermediate and Low Competence Groups, showing a difference from participants of the High Competence Group in terms of visual attention during the first fixation; (3) By examining the total fixation duration and total fixation count of the ROIs from all participants, the same pattern can be found, indicating that as participants answered the questions in this DGBL context, their visual attention was distributed more towards the English definitions of the vocabulary, in order to successfully answer the vocabulary-related questions.

Keywords: Eye tracking · Game-based learning · Visual attention · Cognitive process

1 Introduction

Sanders and McCormick believed that 80% of the information received by humans comes from the eyes, and that the eyes are not only a main input device, but also an output device [1]. The foundation of the use of eye tracking in psychology is based on

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 480–490, 2022.
https://doi.org/10.1007/978-3-031-15273-3_53

the eye-mind hypothesis, first proposed by [2], stating that the fixation of the eye is where the information is being processed by the mind. Eye movement is a process in which light reflects off an object at which we are looking, enters the eye, and falls on the central fovea to enable us to see a clear image. This process involves continuous movement of the eye, and the detection technology to observe eye movement information is called eye tracking technology.

In daily life, whether it is recognizing objects, reading, looking at pictures, or looking for things, eye movement is required to collect the necessary information in various tasks. In this sense, eye tracking was regarded as the most effective method in visual information processing [3], and also a multi-functional tool of cognitive comprehension. Rayner pointed out that eye tracking technology provides an important tool for natural and real-time exploration of cognitive thinking [4]. The information receiving process can reflect the correlation between eye movement and psychological change(s) of the reader. This method was hence widely used to understand the reading process and other related topics in various research experiments (e.g. eye movement characteristics, perceptual breadth, information integration, etc.). Eye movement data were also used to test the cognitive process during different cognitive tasks [5]. In recent years, with the development of hardware and the innovation of software technology, the collection and analysis of eye-movement trajectory data has become easier [6], which allows researchers to record individual fixation, saccade, and blink events in real time. The first two, i.e. fixation and saccade, are the two most widely used parameters in the field of image cognition. In research, “fixation” is usually defined as visual attention in a specific area, a gaze eye movement which lasts for 200–300 ms or longer; on the other hand, “saccade” is defined as rapid, ballistic movement of the eyes between different points of fixation, which is a rapid eye movement that helps the eyes land on a specific visual target. During such eye movement, although some peripheral information can be obtained, information processing is constrained [4]. The reading process includes a series of saccades and fixations, and the sequence is called a scan path [7, 8].

Based on the two basic eye movement behaviors, i.e. fixation and saccade, Lin and You pointed out in an empirical research on the application of eye tracking technology to the reading of scientific graphs and texts that commonly-used eye movement indicators include: total fixation duration, fixation count, number of saccades, sequence of fixation, ratio of total fixation duration, times of regression in a text zone, and saccade amplitude. Molina, Navarroa, Ortega, and Lacruz believed that in the process of eye tracking data analysis, the heat map can be qualitatively interpreted, and regions of interest (ROIs) can be defined according to research purposes or hypotheses for quantitative analysis, e.g. the number of fixation points in each ROI, fixation duration, or the sequence of fixation points among different ROIs [9].

Mayer believed that eye tracking technology provides a unique opportunity to understand learners’ perceptual processing in learning [10], and helped examine the influence of specific teaching methods on learning, which can serve as a reference for teaching material design [11]. At present, desktop (fixed) eye trackers are adopted in most research, where 2D materials are presented to subjects on the computer monitor. By capturing the reflection of the infrared light off of the user’s eyes, an image processing algorithm (based on the pupil position and the point of light on the eye) can determine where on a computer monitor the user is currently looking [5]. With the vigorous development of information technology, many teachers now use multimedia materials in their teaching. This trend has received considerable attention, and has helped many learners by providing an easier access to the content. However, these multimedia materials are dynamic stimuli, and present limitations in their application for desktop eye trackers, such as the definition of ROIs and analysis software support issues. To solve the problems above, portable eye trackers have been used in many studies, which are more user-friendly as they allow users to watch the actual 3D environment or objects. In addition, the eye tracking images can also be projected back to the 3D environment with ideal processing speed and accuracy [12]. In recent years, many researchers have been devoted to the study of game-based learning, through which learners can acquire knowledge and solve problems at the same time. Since games can easily stimulate learners' interests, they usually prove to be great incentives. In addition, psychological experiments have also confirmed that the incorporation of multimedia can stimulate learners' multiple senses (e.g. sight, hearing, taste, touch, etc.) in the process of learning, which can stimulate the brain and facilitate success in terms of learning purposes. Thus, eye tracking technology has been frequently used in multimedia learning research lately, as instructional designers attempt to revise multimedia learning materials by tapping into research of visual attention via eye tracking technology, in order to improve learners' cognitive processing and learning effectiveness [13].

Therefore, this study used portable eye tracker and development tools to design a set of game-based English vocabulary learning materials for the experiment. Based on the aforementioned research background, this study aimed to answer the following questions:

1. In the DGBL context, what is the participants' cognitive processing sequence among different ROIs?
2. In the DGBL context, what can be inferred from the participants' eye tracking data among different ROIs?

2 Methods

2.1 Participants

The present study recruited 38 students in the third year of study in the school of information and design at a university in southern Taiwan. Due to the limitations of the eye tracker used in this study, those with high myopia (≤ -10 diopters) or severe astigmatism (≥ 2 diopters) are not qualified for the experiment. Regardless of gender, the 38 participants are divided into High Competence Group ($n = 5$), Intermediate Competence Group ($n = 8$), and Low Competence Group ($n = 25$), according to their performance in the English courses at the same university.

2.2 Materials

The experiment material in this study is an English vocabulary game developed (with HTML5) and designed by the researcher for the purpose of Digital Game-Based Learning (DGBL). The "English Vocabulary Learning Game" have three types of questions (i.e. elementary, intermediate, and advanced). Each type consists of four questions, which are randomly presented on the monitor. The game is three minutes long and its start page was shown in Fig. 1. As the participant pressed the start button, he or she would immediately enter the answering mode interface; at the same time, the eye tracker would record the participant's eye movement data throughout the game so that the game itself can help achieve the goals of teaching. The presentation of an example word in the "English Vocabulary Learning Game" was shown in Fig. 2.

Fig. 1. Start page of the "English Vocabulary Learning Game".

Fig. 2. Layout of an example word in the "English Vocabulary Learning Game".

2.3 Instruments

This study used a portable eye tracker (EyeNTNU_p) to conduct eye tracking. This eye tracker has an infrared pupil detection lens which can record wide-angle (up to 120°) real-life scenes and is very suitable for the angle of view of human eyes. The equipment can record the points and durations of fixation in the actual view of the participant as he or she perceives the external 3D environment, thus proving highly adequate for eye tracking which records dynamic reading behaviors. The hardware and software equipment of the portable eye tracker in this study was shown in Fig. 3. During the actual experiment, the 5-point calibration process was carried out under the guidance of the researcher or the assistant. A photo of participant wearing the eye tracker during the actual experiment was shown in Fig. 4.

Fig. 3. The portable eye tracker and tablet device used in the present study.

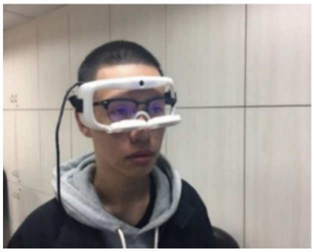


Fig. 4. A participant wearing the eye tracker.

In this study, the game was created and designed based on the game design methodology to ensure that the game content can incentivize the participants' learning motivation [14]. Two professional English teachers with competence in game design were commissioned to review the content validity, so as to successfully construct cognitive processing in the present study.

2.4 Experimental Process

Before the portable eye tracker started to record eye movement data, it would first undergo a 5-point calibration so that the system could accurately collect eye-movement data. After the research team had assisted the participant to correctly put on the portable eye tracker, the participant would receive a series of instruction for calibration, with participant's head moving as little as possible. When the calibration was in progress, both eyes of the participant are making saccadic movements, and will move quickly in the same direction and amplitude. In order for the eyes to focus on the stimulus, the fovea will be aligned at the same position. After calibration was completed, the formal experiment was conducted. A photo of the portable eye tracker-enabled experiment was shown in Fig. 5.

Fig. 5. The portable eye tracker-enabled experiment in progress.

2.5 Data Analysis

In this study, the eye tracking experiments were enabled by the portable eye tracker, and two auxiliary tools (i.e. Dynamic ROI Tool and Fixation Calculator Tool) were adopted to execute the preliminary compilation of eye movement data. Then, the participants' eye movement data were processed in terms of fixation patterns to analyze the participants' visual attention distribution when they were exposed to the DGBL content. The system architecture of the portable eye movement analysis software was shown in Fig. 6.

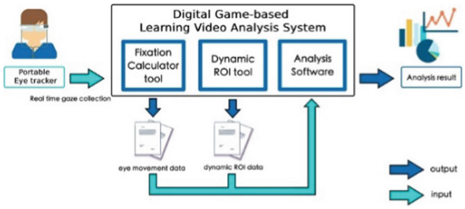


Fig. 6. System architecture of the portable eye movement analysis software

After participants viewed the DGBL content, the eye tracking system used in this study automatically exported a video file (.wmv) to help define the dynamic ROIs. After the dynamic ROIs had been defined for the entire video, the ROI definition tool module would generate a dynamic ROI file, which would be subsequently imported into the visualization analysis software for eye movement indicator analysis. In this study, a digital game-based English vocabulary learning game was designed as the experiment material, with its layout divided into four ROIs based on the eye tracking data analysis program. The four ROIs and their respective names were shown in Fig. 7, with the red boxes signifying the regions which needed to be defined after the experiment. Once the participant had finished the questions in the game-based learning content, he or she could raise a hand to inform the researcher or assistant, which marks the completion of the experiment.

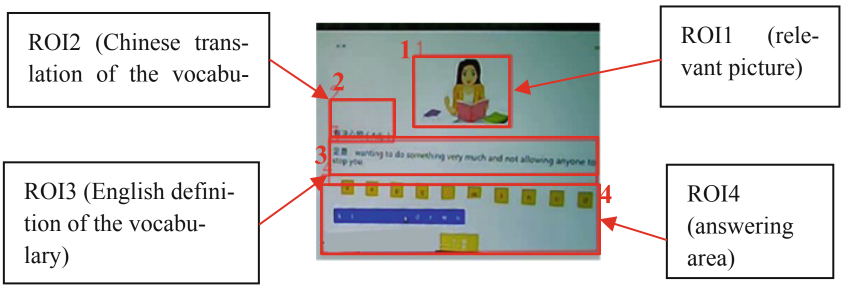


Fig. 7. The four ROIs defined in this study.

The present study collected eye movement and fixation data via portable eye tracker and analyzed such data with eye movement trajectory visualization analysis software. The eye movement indicators applied in this study were as follows:

1. Latency of First Fixation (LFF): The latency from the onset of the stimulus to the initial fixation on the defined ROI, when the participant is involved in the DGBL content.
2. Duration of First Fixation (DFF): The duration of fixation when a participant's first fixation is formed in an ROI as he or she is involved in the DGBL content.
3. Total Fixation Durations (TFD): The total fixation duration when a participant's fixation falls into a certain ROI, as he or she is involved in the DGBL content.
4. Fixation Counts (FC): Fixation counts reflect the importance of the ROI. More fixation counts indicate that the participant considers the ROI more important or thinks that it can provide more clues.

3 Results and Discussions

3.1 Differences in the Participants' Visual Attention Patterns

The latency of first fixation (LFF) indicator illustrated that the 38 participants' sequence of first fixation at the four ROIs was ROI3→ROI4→ROI2→ROI1, as shown in Table 1. In addition, differences in the first fixation sequences can be observed among the three different groups. The LFF indicator illustrated that the High English Competence Group's sequence of first fixation at the four ROIs was ROI4→ROI1→ROI2→ROI3, as shown in Table 2. The Intermediate English Competence Group's sequence of first fixation at the four ROIs was ROI3→ROI2→ROI4→ROI1, as shown in Table 3. The Low English Competence Group's sequence of first fixation at the four ROIs was ROI3→ROI4→ROI2→ROI1, as shown in Table 4. Hence, it can be observed that the fixation sequence of the four ROIs from participants of different groups was different.

As for the duration of first fixation (DFF) indicator, the data collected illustrated that the ROI which received the longest DFF from the 38 participants was ROI3, as shown in Table 1. In addition, the DFF indicator showed that the ROI which received the longest DFF from the High English Competence Group was ROI4, as shown in Table 2. The ROI which received the longest DFF from the Intermediate English Competence Group was ROI3, as shown in Table 3. The ROI which received the longest DFF from the Low English Competence Group was also ROI3, as shown in Table 4. Hence, it can be seen that during the experiment, for participants of Intermediate and Low Competence Groups, ROI3 (English definitions of the vocabulary) was the ROI which received the most visual attention, showing a difference from participants of the High Competence Group in terms of visual attention during the first fixation.

According to the indicators of total fixation durations (TFD) and fixation counts (FC) from the 38 participants, the sequence of ROIs with different levels of fixation was ROI3, ROI4, ROI1 and then ROI2, in terms of both TFD and FC, as shown in Table 1. This result showed that when participants were answering the questions in the digital game-based English vocabulary learning material, their visual attention was more focused on the definitions of the vocabulary in order to successfully complete the tasks. As for the Chinese translations of the vocabulary, it received the least TFD and FC, probably since it is the native (first) language of the participants. In addition, the TFD and FC indicators also showed different patterns among the groups. For the Intermediate English Competence Group, the sequence of ROIs in terms of TFD was ROI3, ROI1, ROI4, and then ROI2. However, in terms of FC, the sequence of ROIs was ROI3, ROI4, ROI1, and then ROI2, as shown in Table 3. This result showed that in the digital game-based English vocabulary learning context, the Intermediate English Competence Group's visual attention was, as in the overall trend, more focused on the definitions of the vocabulary. However, they were also paying attention to the visual cues (i.e. the relevant pictures) so as to successfully complete the tasks assigned. On the contrary, participants from the High and Low English Competence Groups simply focused on the definitions of the vocabulary to answer the questions, as shown in Tables 2 and 4.

Table 1. List of LFF, DFF, TFD, and FC in each ROI from all participants

ROI	LFF (time unit: ms)		DFF (time unit: ms)		TFD (time unit: ms)		FC	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
R1	5861.26	711.68	205.15	18.03	2752.04	355.27	9.48	1.03
R2	4730.40	303.79	186.40	10.77	1128.93	98.22	4.4	.28
R3	2186.65	189.72	334.35	44.04	3963.05	375.66	16.16	1.35
R4	2771.68	351.58	312.97	37.86	3114.28	295.27	13.15	1.13

Note: SE is the abbreviation for "Standard Error".

Table 2. List of LFF, DFF, TFD, and FC in each ROI from the High English Competence Group

ROI	LFF (time unit: ms)		DFF (time unit: ms)		TFD (time unit: ms)		FC	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
R1	3069.20	321.06	177.60	3.58	2009.20	311.35	6.20	0.72
R2	3200.00	217.40	237.50	14.92	1096.00	60.45	5.50	0.30
R3	3760.25	568.68	184.80	9.87	4145.40	294.89	18.00	1.25
R4	2005.25	196.77	278.80	13.01	2670.80	370.98	10.20	1.17

Note: SE is the abbreviation for "Standard Error".

Table 3. List of LFF, DFF, TFD, and FC in each ROI from the Intermediate English Competence Group

ROI	LFF (time unit: ms)		DFF (time unit: ms)		TFD (time unit: ms)		FC	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
R1	5882.80	819.46	160.60	11.34	2542.40	287.95	7.2	0.72
R2	2195.00	229.63	95.00	3.59	618.00	23.35	5.0	0.18
R3	1404.33	124.01	422.86	58.36	3982.00	421.73	15.58	1.46
R4	3335.50	350.69	221.75	19.88	2412.25	207.13	11.75	1.01

Note: SE is the abbreviation for "Standard Error".

Table 4. List of LFF, DFF, TFD, and FC in each ROI from the Low English Competence Group

ROI	LFF (time unit: ms)		DFF (time unit: ms)		TFD (time unit: ms)		FC	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
R1	6676.11	754.40	226.35	21.06	3032.18	389.01	11.11	1.15
R2	5196.75	342.04	185.50	10.98	1177.00	114.48	4.17	.31
R3	2119.96	254.94	339.48	44.40	3921.28	389.84	15.96	1.39
R4	2812.20	382.94	336.26	43.99	3332.78	302.12	14.04	1.15

Note: SE is the abbreviation for "Standard Error".

3.2 Cognitive Comprehension in the Game-Based Learning Setting

According to the 38 participants' final results of the game, the percentage of correct answers was 50%, the percentage of incorrect answers was 25%, and the percentage of missing answers was 25%. In terms of different levels of English proficiency, the percentage of correct answers was 83.3% for the High Competence Group, 58.3% for the Intermediate Competence Group, and 33.3% for the Low Competence Group. However, it was worth noting that the percentage of missing answers was as high as 25%, and most missing answers were submitted by participants from the Low Competence Group. This result was likely due to the fact that this digital vocabulary game consisted of a number of more advanced English words, which created nuisances in cognitive comprehension for the said participants. Although each word is accompanied by its definition as well as a relevant picture, participants from the Low Competence Group could only answer the simple questions correctly due to the difficulty arising from issues of cognitive comprehension. As a consequence, they either had an incorrect answer or decided to simply skip the question when the English word is of intermediate or advanced difficulty.

4 Conclusions and Suggestions

The present study aimed to explore differences in visual attention of participants with different levels of English proficiency in the DGBL context based on eye movement data. The results of the study can not only pinpoint discrepancies in the participants' cognitive comprehension and corresponding visual behaviors, but also serve as reference for the design of DGBL materials in the future. The conclusions of this study are presented below in terms of 1) eye movement behaviors and 2) cognitive comprehension in the game-based learning setting:

1. Eye movement behaviors: In terms of LFF, the learners' fixation sequence was ROI3→ROI4→ROI2→ROI1. Nonetheless, for the three groups with different levels of English proficiency, different fixation sequences of the four ROIs can be observed. In terms of DFF, the ROI which received the longest DFF from the learners was ROI3. Nonetheless, differences can also be identified among the groups with different levels of English proficiency. For learners of Intermediate and Low Competence Groups, ROI3 was the ROI which received the most visual attention, showing a difference from learners of the High Competence Group in terms of visual attention during the first fixation. According to the indicators of Total Fixation Durations (TFD) and Fixation Counts (FC) from the learners, the sequence of ROIs with different levels of fixation was ROI3, ROI4, ROI1 and then ROI2, in terms of both TFD and FC. This result showed that when learners were answering the questions in the digital game-based English vocabulary learning material, their visual attention was more focused on the definitions of the vocabulary in order to successfully complete the tasks.
2. Cognitive comprehension: According to the final results of the game, the overall percentage of correct answers is relatively low and the percentage of missing answers is relatively high. In terms of different levels of English proficiency, learners from the High Competence Group do have a higher percentage of correct answers as compared to the learners from the Intermediate and Low Competence Groups, which is consistent with the learners' academic performance in English courses. As for the relatively high percentage of missing answers, it is very likely contributed by learners from the Low Competence Group, who encountered difficulties in cognitive comprehension when the English word in question was of intermediate or advanced difficulty. As a consequence, they either had an incorrect answer or decided to skip the challenging questions. Hence, this digital English vocabulary game can reflect the discrepancies in the cognitive comprehension of the learners with different levels of English proficiency.

References

1. Sander, M.S., McCormick, E.J.: Human Factors in Engineering and Design. McGraw-Hill, New York (1987)
2. Just, M.A., Carpenter, P.A.: Eye fixations and cognitive processes. Cogn. Psychol. **8**, 441–480 (1976)

3. Han, C.C., Tsai, J.L.: Eye tracker: a rising star in exploring science education. Sci. Educ. Mon. **310**, 2–11 (2008)
4. Rayner, K.: Eye movements in reading and information processing: 20 years of research. Psychol. Bull. **124**(3), 372 (1998)
5. Chen, H.C., Lai, H.D., Chiu, F.C.: Eye tracking technology for learning and education. J. Res. Educ. Sci. **55**(4), 39–68 (2010)
6. Josephson, S., Holmes, M.E.: Attention to repeated images on the world wide web: another look at scan path theory. Behav. Res. Methods Instrum. Comput. **34**(4), 539–548 (2002)
7. Pan, B., Hembrooke, H.A., Gay, G.K., Granka, L.A., Feusner, M.K., Newman, J.K.: The determinants of web page viewing behavior: an eye-tracking study. In: Proceedings of the 2004 Symposium on Eye Tracking Research & Applications, pp. 147–154. Association for Computing Machinery, New York (2004)
8. Vernet, M., Kapoula, Z.: Binocular motor coordination during saccades and fixations while reading: a magnitude and time analysis. J. Vis. **9**(7), 1–13 (2009)
9. Molina, A.I., Navarro, Ó., Oetrga, M., Lacruz, M.: Evaluating multimedia learning materials in primary education using eye tracking. Comput. Stand. Interf. **59**, 45–60 (2018)
10. Mayer, R.E.: Unique contributions of eye-tracking research to the study of learning with graphics. Learn. Instr. **20**(2), 167–171 (2010)
11. Tang, D.L., Chang, A.W.Y.: Exploring eye-tracking methodology in communication study. Chin. J. Commun. Res. **12**, 165–211 (2007)
12. Zhang, X.B., Yuan, S.M., Chen, M.D., Liu, X.L.: A complete system for analysis of video lecture based on eye tracking. IEEE Access **6**, 49056–49066 (2018)
13. Holsanova, J., Holmberg, N., Holmqvist, K.: Reading information graphics: the role of spatial contiguity and dual attentional guidance. Appl. Cogn. Psychol. **23**, 1215–1226 (2009)
14. Tsai, F.H., Yu, K.C., Hsiao, H.S.: Exploring the factors that influence learning behaviors and learning transfer in digital game-based learning. J. Res. Educ. Sci. **55**(2), 167–206 (2010)

The Design and Development of the Mobile Based Learning Environment to Enhance Computational Problem Solving in Programming for High School Students

Kanyarat Sirimathep[1](✉), Issara Kanjug[2], Charuni Samat[3], and Suchat Wattanachai[4]

[1] Doctor of Philosophy in Education Technology, Faculty of Education, Khon Kaen University, Khon Kaen, Thailand
kanyarat.siri@kkumail.com
[2] Division of Computer Education, Faculty of Education, Khon Kaen University, Khon Kaen, Thailand
issaraka@kku.ac.th
[3] Division of Educational Technology, Faculty of Education, Khon Kaen University, Khon Kaen, Thailand
[4] Division of Surgery, Faculty of Veterinary Medicine, Khon Kaen University, Khon Kaen, Thailand
suchat@kku.ac.th

Abstract. A good algorithm design and problem solving process are required for programming, which will result in effective programming. This study used the computational problem solving approach's principles of applied problem solving, computational thinking, and programming concept to enhance students' programming ability in order to accurately design internet of things innovations. The purpose of this research was to design and develop a model of a mobile based learning environment to enhance computational problem solving in programming for high school students. The methodologies used in this study's implementation of developmental research were as follows: 1) analyze the principles and theories 2) synthesize the design framework 3) design and develop the model of mobile based learning environment to enhance computational problem solving in programming for high school students. According to the findings, 1) the model of mobile based learning environment to improve computational problem solving in programming consists of eight components, which are as follows: (1) Problem base, (2) Resources, (3) Related Case Room (4) Cognitive Tools, (5) Collaboration, (6) Computational problem solving room, (7) Scaffolding, and (8) Coaching 2) The effectiveness of this learning environment is demonstrated in the following ways: 1) The Experts reviews 2) Learners' opinions 3) The computational problem solving abilities of the students in programming.

Keywords: Designing framework · Learning environments · Constructivist theories · Computational problem solving · Programming · Microbit · Mobile based Learning

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 491–500, 2022.
https://doi.org/10.1007/978-3-031-15273-3_54

1 Introduction

Rapid technological change or digital disruption has changed people's behavior and completely transformed various industries today. Technological advancements have resulted in a more comfortable way of life for people today, which is a step forward in digital technology. Organizations that fail to adapt to digital technology changes will face the same fate as the education sector. Mobile Learning and On-demand Learning, MOOC, Cloud technology, Big Data, Internet of Things (IoT), 3D printing, Deep Learning, and Artificial Intelligence (AI). All of these things are things that every educator should be aware of and learn how to use to their advantage in learning management and innovation.

Innovations in learning management are characterized by Disruptive Innovation. It can attract the attention of students as well. Learners can concentrate on learning activities, no matter how complex the learning activities are, learners have their own learning goals and self-direction, self-discipline, and use of a variety of learning processes to achieve goals. In general, disruptive innovation in learning management will always use digital technology to support it. Because students spend the majority of their time online.

The World Economic Forum [1] has surveyed and analyzed labor market demand for essential skills for the twenty-first century. Including technology trends in large organizations around the world, researchers discovered that children who will survive in the digital age and be able to adapt to learn how to adjust to different situations at any time must have both creative thinking, critical thinking, problem solving, information technology, communication, and teamwork skills, Usage of media and technological skills, as well as work and life skills, that must be flexible and able to adapt initiative social skills and cross-cultural learning. To improve work efficiency, computer software must be developed in collaboration with agencies and organizations. According to the Thailand Development Research Institute's (TDRI) report on the results of the software market survey and software services, this maximizes work efficiency while minimizing operating costs. It was discovered that the previous ten years had seen exponential growth. As a result, it is critical to train personnel and youth in computer software development to support the current growth in the use of information technology.

Programming is the process of developing or creating computer programs by developers or programmers. A person who has knowledge and understanding of programming language can transform problem solving steps to become an algorithm for computers, design the structure of the program and test the program's functionality to develop computer programs that can work correctly as needed and meet the efficiency. Problem solving and analytical thinking abilities are required for programming. These skills necessitate a high-level learning style that focuses on comprehension of the material being studied. One skill that can be used to develop programming ability is computational problem solving.

Writing code is only one aspect of programming. During programming, students are exposed to computational problem solving; programming generally requires a variety of skills, particularly computational problem solving. Thinking skills for creating knowledge, exploring information from a variety of sources, and correctly analyzing and making decisions should be emphasized in teaching and learning. Students can solve problems as a process; however, practicing this computational problem solving skill will prevent students from linking what students have learnt in class to real-world situations.

Programming on a mobile device, which we always have with us, provides students with instant gratification because they can demonstrate their applications to their friends, and Students can also complete their homework or practice whenever and wherever they like.

Computational problem solving based on Ricky J. Sethi. (2019) [2] and Wing (2008) [3]. It is a cognitive ability to analyze a problem and its details to define or create a workflow to develop or solve problems with computers. And then test the system, fixing all errors. It consists of three processes, as follows: 1) Problem Specification, the process of determining the details of the problem that analyzes the problem and the details of the problem; it is divided into three sub-processes: (1) Abstraction, this is the process of gathering all of the information required to solve a problem. (2) Decomposition, this is the process of separating the elements of a problem and breaking a large problem or system into smaller components to make problem solving easier. (3) Pattern Recognition, this is the process of finding a pattern of similar or repetitive problems to find patterns or characteristics of things that frequently occur the same to be analyzed for the cause solution 2) Algorithmic Expression and coding, this process is defining or creating a sequence of steps to solve problems and write a set of instructions. It is made up of four sub-processes: (1) Algorithm Design, this process involves creating a flowchart, that shows series of steps to solve problems. (2) Pseudocode, this is the process of writing informal code in English. (3) Revision algorithm [4], this is the process that identifies the target concept, starting from an initial concept. (4) Coding, this is the activity of creating computer programs. 3) Solution Implementation and Evaluation, this process involves testing and debugging the system until it is error-free and stable. It is made up of two sub-processes: (1) Systematic Testing, this process involves testing and modifying the program while connected to an IoT device. (2) Generalization, involves implementing a program that is linked to an IoT device.

Mobile learning [5] is a concept based on devices using wireless technologies such as smartphones, iPads, tablets and etc. Students can take it with them and use it to manage their learning through the Internet network. Learning can be managed in ways that encourage learners to learn on their own using the learning management model. Allowing learners to research and seek knowledge from a variety of sources at any time and from any location based on their availability. In addition, learning how to encourage student collaboration The foundation is the most important aspect of mobile learning. Prioritize learning management at all times and in all places, not just in the classroom. Learners can access information such as still images, audio, and video, as well as information that is easily accessible. There is immediate interaction between learners and teachers, or learners with learners, and when mobile communication devices are brought. Teachers use the Internet network system to organize learning and promote interaction between students and teachers, as well as between learners, through conversation, knowledge sharing, and problem solving. As a result, mobile learning is an environment that caters to today's learners' needs.

Based on the importance and issues raised above, the researcher used a theoretical framework to investigate the synthesis of designing a framework for the model of a mobile based learning environment to enhance computational problem solving in programming for high school students, and to design and develop it as a learning environment that focuses on how important it is for students to understand the subject. while also developing learner's computational problem solving abilities.

2 Methodology

The purpose of this study was to design and develop the model of a mobile based learning environment to enhance computational problem solving in programming for high school students.

2.1 Target Group

1. 12 experts which are three content experts, three instructional designers, three mobile based learning designers, and three measurement and evaluation experts reviewed the efficiency of a mobile based learning environment to enhance computational problem solving in programming.
2. 35 high schools students in Surathampitak School, Muang district, Nakhonratchasima province, Thailand.

2.2 Research Instruments

The instruments consisted of experimental instruments: the mobile based learning environment to enhance computational problem solving in programming and data collection instruments.

1. 1) The experiment's instrument was a mobile based learning environment to enhance computational problem solving in programming. The design and development process was as follows: (1) examine the principles and theories, (2) synthesize the designing framework, (3) design and develop the mobile based learning environment, and (4) evaluate the mobile based learning environment's efficiency.
2. 2) The data collection instruments include: (1) the document analysis record form, (2) the expert evaluation form, (3) the learner's opinionnaire for the mobile based learning environment to enhance computational problem solving in programming, and (4) the learner's computational problem solving in programming tests.

2.3 Data Collecting and Analysis

Based on the theoretical framework and designing framework, the researchers designed and developed a model of a mobile based learning environment to enhance computational problem solving in programming for the high school students. The model was tested during this phase. The quantitative and qualitative data were collected and analyzed as follows:

2.3.1 The expert reviews cover a variety of topics, including content, media, and technology, instructional design, computational problem solving in programming, mobile based learning environments, and measurement and evaluation. The researchers collected the data and analyzed it using descriptive statistics, interpretation, and summarization.

2.3.2 The learners' perspectives on the model of a mobile-based learning environment to enhance computational problem solving in programming for the high school students. The researchers collected the data and analyzed it using descriptive statistics, interpretation, and summarization.

2.3.3 The test of learner's computational problem solving ability. The quantitative data were collected and analyzed using descriptive statistics such as mean, standard deviation, and percentage. Descriptive statistics, interpretation, and summarization were used to collect and analyze qualitative data.

3 Result

The design and development of the mobile based learning environment to enhance computational problem solving in programming for high school students as follows:

3.1 Synthesis of Theoretical Framework

The constructivism theory [6], cognitive theories [7], the mobile based learning environment, multimedia learning [8], media attribution, media symbol system, and computational problem solving were studied and analyzed to create the theoretical framework. The theoretical framework displays the following five important theoretical categories: (1) Psychology base, (2) Pedagogy base, (3) Technology and Media base (4) Computational problem solving base, and (5) Contextual base.

3.2 Synthesis of the Designing Framework

The following details describe how the designing framework of the mobile based learning environment was synthesized based on the mentioned theoretical framework: 1) The cognitive structure activation and computational problem solving were designed with enabling context (Hanafin, 1999) [9], and computational problem solving (Ricky J. Sethi. (2019), Wing (2008)) as the problem base. 2) The supporting cognitive equilibrium was created using cognitive theories such as Resources (Hanafin, 1999) and Related case (Jonassen, 1999). 3) The enhancement in constructing knowledge and computational problem solving were designed based on both Social Constructivist (Vygotsky, 1925) [10] as Collaboration and Cognitive tools (Jonassen, 1999) as Cognitive tools, and Manipulating tools (Hanafin, 1999) and Computational problem solving (Ricky J. Sethi. (2019), Wing (2008)) as Computational problem solving lab, and 4) The support and enhancement for constructing knowledge were designed as Scaffolding (Hanafin, 1999), and Modelling and Coaching (Jonassen, 1999) as Coaching.

3.3 Model Components of Learning Environments

The designing framework was used to create the mobile based learning environment to enhance computational problem solving in programming for high school students. It is made up of the following eight elements: 1) Problem base, 2) Resources, 3) Related case, 4) Cognitive tools, 5) Computational problem solving lab, 6) Collaboration, 7) Scaffolding, and 8) Coaching center derived from various major theories: (1) Psychology foundation, (2) Pedagogy foundation, (3) Technology and Media foundation, (4) Computational problem solving foundation, and (5) Contextual foundation, as shown in Fig. 1, 2, 3, 4, 5, 6, 7 and 8.

Fig. 1. Problem base.

Figure 1. Problem base: It was demonstrated as the problem's foundation. Problem base for improving learners' ability to construct knowledge and solve computational problems.

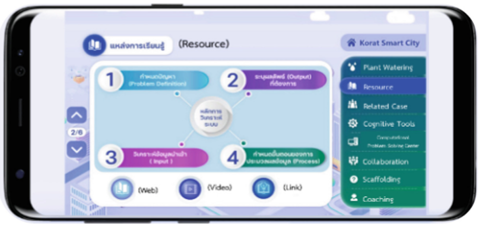


Fig. 2. Resources.

Figure 2. Resources: It was demonstrated Resources provide just-in-time information to assist learners in comprehending and solving the problem.

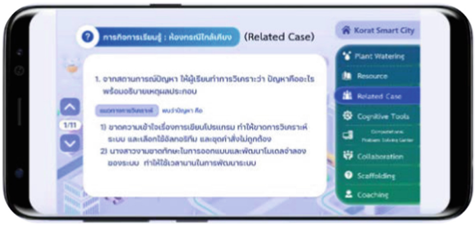


Fig. 3. Related case.

Figure 3. Related case: It was shown the Related case for representing a collection of related experiences and providing various perspectives.

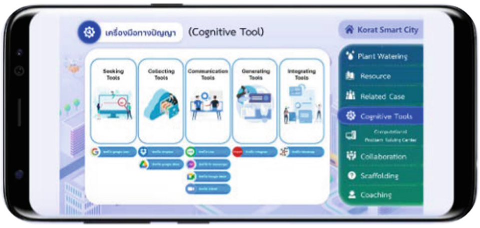


Fig. 4. Cognitive tools.

Figure 4. Cognitive tools: It was shown Cognitive tools for knowledge construction and computational problem solving were demonstrated. The learners were assisted in completing their learning tasks.

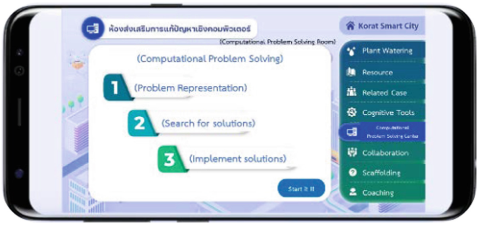


Fig. 5. Computational problem solving room.

Figure 5. Computational problem solving room: It was shown a section on computational problem solving to improve Problem solving through computational problem solving based on Ricky J. Sethi. (2019), Wing (2008);

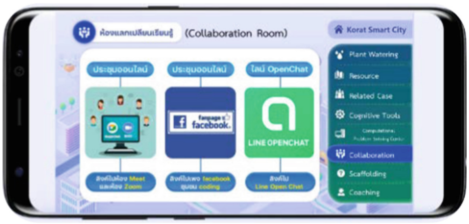


Fig. 6. Collaboration room.

Figure 6. Collaboration: It was shown Collaboration in assisting learners to share their experiences with experts by using Facebook, Google Meet, and Line Openchat, and chatbot to broaden their multiple perspectives.

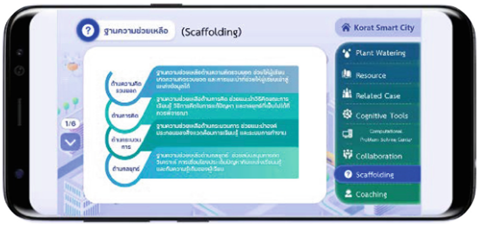


Fig. 7. Scaffolding

Figure 7. Scaffolding: It was shown Scaffolding to help students solve problems, learn, and construct knowledge on their own.

Fig. 8. Coaching

Figure 8. Coaching: It was shown a Coaching Center by teachers and experts in computational problem solving with the best advice that can help students become programming experts.

3.4 The Model of Learning Environments' Efficiency

The effectiveness of a mobile based learning environment to enhance computational problem solving in programming for high school students

1. The experts' review determined that the learning content, technology and media, instructional design, computational problem solving in programming, mobile based learning environments, and measurement and evaluation experts were all appropriate.
2. According to the learners' opinions, this mobile-based learning environment is appropriate for learning and supporting computational problem solving, using both content media and mobile technology as the foundation and design.3) The Learners' computational problem solving in programming skills.
3. The learners' computational problem solving abilities in programming. As shown in Table 1, the learners understand the concept of computational problem solving in programming.

Table 1. The computational problem solving ability of the learners in programming.

	Problem Specification		Algorithmic Expression and coding		Solution Implementation and Evaluation		Average
	Score	Percentage	Score	Percentage	Score	Percentage	
Pre-Test	10.60	35.33	11.03	36.77	12.14	40.47	11.26
Post-test	24.26	80.87	25.03	83.43	26.40	88.80	25.23
Summary							
	Total of Learners						35
	Number of learners with a passing score of 70 percent						31
	Percentage of learners with a passing score of 70 percent (21 point)						88.57
	Average student grades						25.8
	standard deviation (S.D.)						1.27

According to the data in Table 1, the computational problem solving skills of students who used a one-group pre-test post-test design resulted in a score of 11.26 points for the pre-test and 25.23 points for the post-test, and the number of learners who passed the specified criteria with 70% of students having a passing average score of 70% of 31 people or 88.57%.

4 Conclusion

This study's findings were supported by the findings of Kay Dennis Boom [11], who discovered that in order to increase the abilities of their software programs, it is more important for the students to have applied computational thinking procedural skills than generalized computational thinking abilities.

There are several potential research directions based on the findings of this study. Visual programming environments, such as microbit, are commonly used to teach computational problem solving and programming concepts to people who do not know how to code, as was the case in this study. The level of computational problem solving in programming for experienced programmers and novices may differ.

The findings of this study provide preliminary evidence for improving computational problem solving in programming. Future research should look into whether teachers can use the model effectively in their classroom activities. Other intervention hypotheses must also be investigated and tested in order to demonstrate the model's broader validity.

Acknowledgement. This study was supported by the Academic and Research Affairs, Innovation and Cognitive Technology Research Group, Faculty of Education, and the Research and Technology Transfer Affairs Division, Faculty of Education, Khon Kaen University.

References

1. World Economic Forum: The future of jobs: employment, skills and workforce strategy for the fourth industrial revolution. http://www3.weforum.org/docs/WEF_Future_of_Jobs.pdf. Accessed 13 July 2022
2. Sethi, R.: Essential Computational Thinking: Computer Science from Scratch, 1st edn. Cognella Academic Publishing, California (2020)
3. Wing, J.M.: Computational thinking and thinking about computing. Philos. Trans. Roy. Soc. **366**(July), 3717–3725 (2008)
4. Goldsmith, J., Sloan, R.H., Szörényi, B., Turán, G.: New revision algorithms. In: Ben-David, S., Case, J., Maruoka, A. (eds.) ALT 2004. LNCS (LNAI), vol. 3244, pp. 395–409. Springer, Heidelberg (2004). https://doi.org/10.1007/978-3-540-30215-5_30
5. Sarrab, M., Elgamel, L., Aldabbas, H.: Mobile learning (M-learning) and educational environments. Int. J. Distrib. Parallel Syst. **3**(4(July)), 31–38 (2012)
6. Jonassen, D.: Designing constructivist learning environments. In: Reigeluth, C. (ed.) Instructional-Design Theories and Models: A New Paradigm of Instructional Theory, pp. 215–239. Pennsylvania State University, University Park (1999)
7. Klausmeier, H.J.: Educational Psychology, 5th edn. Harper & Row, New York (1985)
8. Salomon, G.: Communication and Education: Social and Psychological Interactions. Sage Publication, California (1981)
9. Hannafin, M., Land, S., Oliver, K.: Open learning environments: foundations, methods, and models. In: Reigeluth, C.M. (ed.) Instructional Design Theories And Models: A New Paradigm of Instructional Theory, vol. II, pp. 115–140. Lawrence Erlbaum Associates, Mahlway (1999)
10. Vygotsky, L.S.: Mind in Society: The Development of Higher Psychological Processes. Harvard University Press, Cambridge (1978)
11. Boom, K.-D., Bower, M., Siemon, J., Arguel, A.: Relationships between computational thinking and the quality of computer programs. Educ. Inf. Technol. (in press). https://doi.org/10.1007/s10639-022-10921-z. hal-03596834. Accessed 13 July 2022

Challenges and Opportunities of Education in the COVID-19 Pandemic: Teacher Perception on Applying AI Chatbot for Online Language Learning

Pham My Linh, Andreja Istenič Starčič, and Ting-Ting Wu(✉)

National Yunlin University of Science and Technology, Yunlin County 64002, Taiwan, R. O. C.
ttwu@yuntech.edu.tw

Abstract. Education has been considerably hindered or interrupted as a result of restrictive regulations and the building of social distance, making it one of the major sectors of COVID-19. In the past, it was suggested that chatbots may be utilized to assist individuals in learning more independently and in a variety of virtual learning contexts. The goal of this study was to evaluate the potential hurdles posed by the COVID-19 outbreak to online learning, as well as teachers' perspectives on the use of AI chatbots for online language learning. An online interview has been conducted with six interviewees in verifying the proposed questions from the teachers' perspectives. The result shows that there are common themes of challenges for online learning and online teaching: (1) Infrastructure; (2) Accessibility and Technology; (3) Readiness; (4) Assessment and Examinations; (5) Socioeconomic factors; (6) Mental health and personal well-being; (7) Online Security Issues and human and pet intrusions; and (8) Digital competence. The finding also indicates that the proposed technology, an AI chatbot, is anticipated to help the learning process to achieve the course's objectives more effectively than traditional methods.

Keywords: Online teaching · AI chatbot · COVID-19 pandemic

1 Introduction

A novel coronavirus started to spread in late December 2019 in Wuhan, China and rapidly spread to neighboring regions. The World Health Organization classified the epidemic as a pandemic on March 11, 2020. On September 22, 2020, the number of instances of infection worldwide surpassed 31 million, with the virus affecting more than 215 countries. The virus disrupted many people's daily lives, which had negative effects on all facets of human life—repercussions that most people had never experienced before.

Southeast Asia is one of the oldest civilizations in the world and it occupies a dominant position economically, socially, and politically. They are developing countries, and their common objective is to promote economic growth, education, health, cultural development, social progress, and prosperity globally. During the COVID-19 pandemic, they fell into one of the most vulnerable groups that got affected.

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 501–513, 2022.
https://doi.org/10.1007/978-3-031-15273-3_55

Southeast Asia, as one of the first regions to be hit by the coronavirus (COVID-19) outbreak, is seeing a rapid increase in the number of confirmed cases. As a result of domestic containment measures and global disruptions to trade, tourism, and production, the region, which has the majority of its members classified as developing countries, is now facing the prospect of a worldwide financial shock and recession.

One of the most afflicted areas by the virus is education, which has been significantly slowed or halted as a result of restrictive legislation and the formation of social distance. As a result, several governments around the world, including those in ASEAN, have made public assemblies illegal, closed educational institutions, and suspended schools and colleges. In 182 countries, educational institutions have closed, and traditional university education has been hampered. Furthermore, the virus has afflicted more than 90% of the world's student population, putting further pressure on higher education systems to modify their approaches to distance learning (e-learning). Due to the COVID-19 pandemic, school and university closures affect over one billion students worldwide (UNESCO, 2020). The government prohibits face-to-face instruction and mandates that all educational institutions transition from traditional learning to online learning via digital platforms. As a result of this threat, all educational institutions and professionals are attempting to respond correctly by devising effective ways to reduce the pandemic's negative effects on the field of education. In underdeveloped nations, a shortage of network equipment, computers, and Internet connections hinder distant learning [1]. The COVID-19 pandemic could affect a lot of people, and poor people are expected to be the hardest hit [2].

The COVID-19 pandemic is not the first time a pandemic has disrupted education, particularly online education; the SARS epidemic in 2003 also had an influence on education but to a lesser extent. The COVID-19 pandemic, on the other hand, will have far-reaching and long-lasting consequences. As a result, examining the problems and opportunities presented by the current epidemic in online education might assist us in better adapting to the new circumstances and ensuring the continuance of education. It will also help us keep online education from being interrupted in the event of an emergency. As a result, in addition to identifying difficulties that must be addressed immediately to limit harm, such crises also present a chance for faculties to experiment with new technologies in online learning. As a result, the current study looks at the challenges and opportunities that the COVID-19 epidemic has caused in online learning.

On the other hand, when people talk or write to machines, they can interact with them through chatbots, also known as "conversational bots." These artificial intelligence-based systems let people communicate with machines through written or spoken code [3–6]. In the past, research suggested that chatbots could be used to help people learn more on their own and in a variety of virtual learning environments.

Therefore, the purpose of this study was to investigate the obstacles potentially created by the COVID-19 epidemic in online learning, as well as teachers' perceptions of using AI chatbots for online language learning.

2 Literature Review

2.1 AI Chatbot

Although the first chatbots arose in the 1960s [7], they did not garner the attention of scholars and businesses until the early twenty-first century. Now, firms such as Apple (Siri), Amazon (Alexa), and Microsoft (Cortana) have developed voice assistance to assist users in completing personal tasks and gaining access to resources or consumer items. A virtual assistant is a collection of computer programs that can communicate with humans in natural language. They are classified as on-screen characters that aid in training [8]. Natural language processing, autonomous deep learning and other services such as inference, recommendation, and contextualized reasoning underpin chat technology [9, 10]. Chatbots are programmed using natural language processing and decision tree approaches.

2.2 AI Chatbot for Learning

Although the educational usage of chatbots is still in its infancy, some recent studies demonstrate that chatbots can successfully enhance the teaching-learning process across several subjects. While these studies are primarily concerned with the design and functionality of chatbots [3, 4, 11–15], there is little research on their didactic potential and application to student assessment and feedback processes regarding content and curricular competencies. Chatbots are defined by four central characteristics [16]: (1) they attempt to mimic human speech; (2) they initially interacted via written messages [17], though subsequent advancements enabled the appearance of spoken interaction; (3), unlike robots or similar devices, chatbots lack a physical presence [18]; and (4), unlike avatars, they do not represent a human being in a virtual world. Another study was conducted with graduate students' participation in an online course at a national university in southern Taiwan, according to [19], and the findings showed that students' reflective and creative abilities were enhanced, and the students held positive emotions toward the multimethod approach.

In addition to instant messaging, chatbots and pedagogical agents have inspired educators to integrate messaging tools into teaching and learning in recent years. Coniam evaluated several well-known language chatbots and concluded that, while they are not yet reliable conversation partners, they have made significant progress, with three of the five performings satisfactorily at the grammar level [20].

These broad proposals generate several specific questions that will be examined in this paper, including the prospects for using AI chatbots for online learning in the COVID-19 pandemic period, as well as the obstacles that the COVID-19 epidemic has posed to online learning.

RQ1. What is the teacher's perception of the challenges learners might encounter when learning online?

RQ2. What is the teacher's perception of the challenges teachers might encounter when teaching online?

RQ3. What is the teacher's perception of the opportunities for applying AI chatbots in online learning?

3 Methodology

3.1 Proposed Participants

COVID-19 outbreak period online teachers at Vietnamese universities, including one or more teachers from the same university, will be among the recommended participants. The ideas of novel AI chatbot approaches were introduced and demonstrated in these online interviews with those participants to avoid misunderstanding or miscommunication between both parties in which the author gives the interviews.

3.2 Procedure Design

The online classroom requires teachers to prepare digital teaching materials in advance. Teachers organize class management through online platforms to distribute teaching materials to the students outside the class. This study conducted interviews with the teachers who were using this teaching approach during the COVID-19 outbreak. An online interview was held by the author, and each interview's response was recorded by an application for the further coding process. Interview questions are open-ended questions so that in-depth information could be collected. After the interviews, the author reorganized the responses and coded them into common themes for further analysis.

4 Result and Discussion

An online interview has been conducted to verify the proposed research questions. Six interviewees participated in the interview, as described in Table 1.

4.1 Challenges for Online Learning and Online Teaching

Many institutions around the world, in both developing and wealthy countries, are having difficulty implementing and adopting e-learning technologies. However, the problem is not as severe in industrialized nations because most of their students have embraced and are eager to use e-learning systems, and a significant step has already been taken toward the deployment of online learning and e-learning [21]. Eltahir (2019) [22] claims that the digital gap is a major impediment to the adoption and implementation of e-learning in underdeveloped nations.

About previous related research (e.g., [23–29]), the current studies have supplemented their findings on the pedagogical, logistical, socioeconomic, technological, and psychosocial online learn-ing challenges that students experience within the context of the COVID-19 pandemic.

The following challenges for Online learning and Online teaching were listed after screening all of the responses from the online interview (see Fig. 1: Common themes of Challenges for Online learning and Online teaching):

1. Lack of infrastructure
2. Accessibility and Technology

3. Lack of Readiness
4. Assessment & Examinations
5. Socioeconomic factors
6. Mental Health and personal wellbeing
7. Online Security Issues and Human and pets intrusions
8. Digital competence;

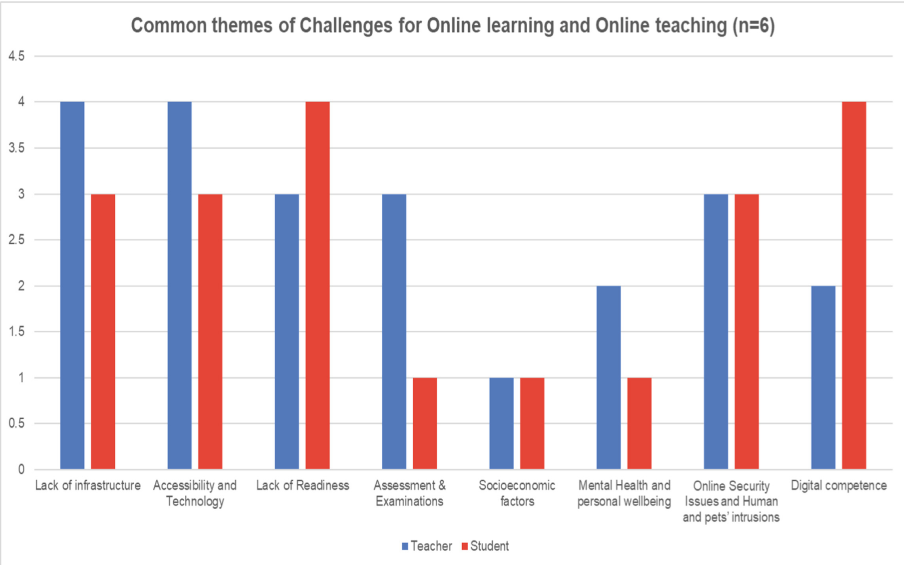


Fig. 1. Common themes of challenges for online learning and online teaching

Lack of Infrastructure

Poor infrastructural networks, a shortage of produced material, and a lack of ICT skills, according to [30], have all hampered the adoption of e-learning in developing nations. Digital infrastructure, bandwidth, and licensed software applications are all major challenges for academic institutions [31]. Schools and universities in poor nations, such as Vietnam, confront numerous obstacles, including a lack of infrastructure, materials, and adequate facilities, to take full use of online education. Infrastructure and online access are necessary for the transition from physical to virtual classes [32].

Accessibility and Technology

Internet Speed in ASEAN in 2021

The website Speedtest published the Speedtest Global Index (March 2021) as follows (Fig. 2):

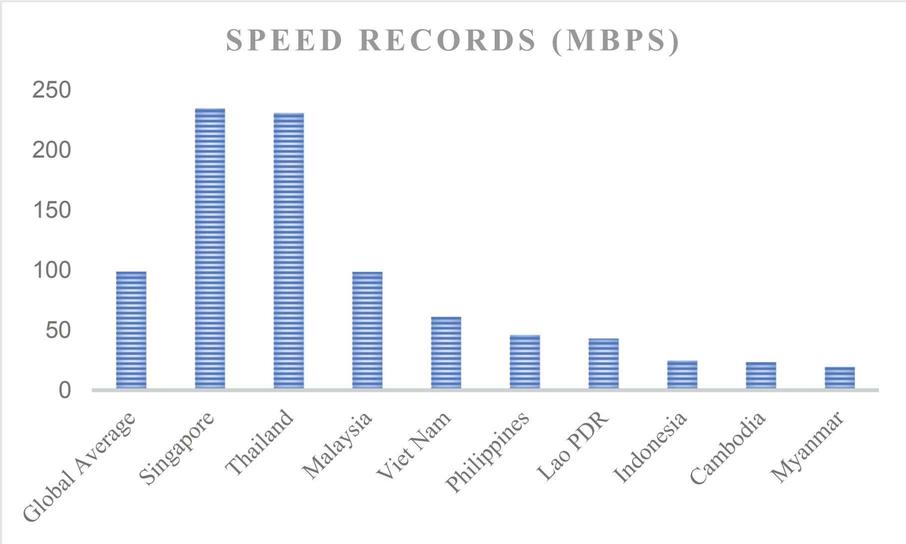


Fig. 2. Broadband internet speed

** There was no Broadband Internet Speed data in Brunei (Fig. 3).

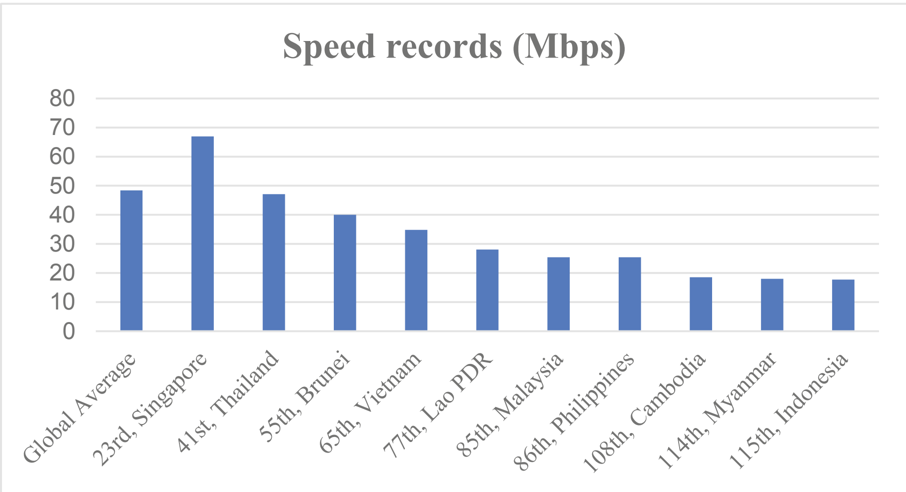


Fig. 3. Mobile internet speed

As we can see on the datasets of Internet Speed in ASEAN in 2021, there are only two countries that have Broadband Internet Speeds faster than the Global Average Speed of 98.67 Mbps (Singapore and Thailand) and only Singapore has Mobile Internet Speeds faster than the Global Average Speed of 48.40 Mbps. In poor nations, not everyone may be able to afford access to technology, and approximately 80% of students may continue to lack access to computers and the internet, as well as the need for inexpensive, durable equipment for rural students. Online learning in its entirety is dependent on technological devices and the internet, instructors, so as the result, those students with bad internet connections are liable to be denied access to online learning.

Thus, some technical criteria of online learning may be difficult to meet for students with obsolete technology gadgets. Students with accessibility issues may have trouble following directions. For example, When the instructor stated on the course announcement page that there will be no class on a particular date, a student nonetheless emailed to inquire whether the class would be held on that date.

Lack of Readiness

It was found that teachers were not immediately prepared for this massive shift in the educational landscape, as they faced unequal access to technological tools, digital resources, internet connectivity issues, and distractions and the majority of teachers lacked the digital skills required for online education, which was quite in line with Musfasa 's findings [33]. Students believe that faculty and the institution were not prepared for the online environment into which they have been thrown, and this has led to an uncomfortable situation for everyone involved [34]. For example, the survey indicated that most students had a favorable opinion of e-learning [35]. In addition to Alison, the UCC Moodle platform and Google Classroom are all well-known e-learning tools to them. It is also important to note that they prefer to use social media platforms like WhatsApp and Zoom as well as their smartphones and laptops as e-learning equipment for university-sponsored remote learning or teaching. There was a strong unfavorable reaction from them to online education. It was difficult for them to adapt because they had never had any experience with online learning or teaching (lacked training and experience).

Teachers have to build their lessons on the assumption that students would enroll in an online course and be fully prepared to profit from the materials [36–38]. A significant amount of work is being placed on schools' and universities' ICT departments as a result of the abrupt and dramatic shift to digital platforms and integration of external applications.

Assessment and Examinations

Assessment problems and ethical concerns are possible outcomes of online assessments of traditional exams. It is possible that this is due to a lack of adequate technical infrastructure, particularly in developing countries; students' unfamiliarity with hardware and software and the assessment process in general; scoring challenges; and difficulty in assessing group projects in particular. In online learning, evaluations are frequently administered online, limiting educators to proxy monitoring of students and making it impossible to supervise and manage to cheat.

Socio-economic Factors

As a result of inequality in the socioeconomic status of students, some rely on the computer and free internet in school [39], it is undeniable that students with a low socioeconomic background will find it difficult to migrate as quickly as anticipated given that they cannot attend school because of the pandemic. As the amount of poverty in a community rises, the rate of internet connectivity plummets, and as a result, students without or with limited socioeconomic resources to afford an internet connection are most susceptible to falling behind in online learning. Faculty from low- and middle-income countries are often hesitant to teach online courses because they lack expertise and training in remote instruction, not to mention the ability to produce high-quality online courses [40].

Digital competence is the combination of abilities, knowledge, and attitudes required while utilizing ICT and digital devices to carry out tasks, such as problem-solving, information management, and collaboration about effectiveness, efficiency, and ethics [41]. Students and teachers with inadequate digital skills are likely to fall behind in online learning.

Otherwise, faculty members and instructional designers must implement creative pedagogical strategies and practices to improve student learning to better prepare our students for the increasing complexity of digitization (study, work, teach, language, volunteer abroad, international student services, and career services). When utilizing ICTs in the classroom, students must adopt and apply new learning skills and capabilities [42].

Mental Health and Personal Well-Being

The Covid-19 pandemic has greatly impacted the well-being and mental health of instructors and students around the world, including an increase in the risk of burnout. The analysis of the current studies' data revealed several additional issues. One of these issues was that some participants struggled with excitement during online classes [43]. In a global survey, COVID-19 affected the mental health of 90% of trainees, while Ashry et al. calculated that over 60% of Egyptians suffered burnout symptoms during the epidemic. The delay in reopening educational institutions negatively affected the emotional health and academic performance of students [44]. During online learning, students encountered numerous issues, such as mental health, anxiety, and loneliness. According to [43], some participants claimed that they lacked sufficient self-motivation for a variety of reasons ranging from personal to financial to professional, even though self-motivation is an essential component for successful learning whether in an online or traditional classroom.

Online Security Issues and Human and Pets Intrusions

Platforms, software, and apps utilized by online academics are equally susceptible to security breaches. Human and pet intrusion, on the other hand, refers to the unexpected appearance or interruption of family members, friends, and/or pets that may disrupt or divert the focus of online learning participants during the online teaching or learning process.

According to the results of the online interview, several teachers indicated that they and their students are frequently distracted by noise, family members, or pets. Moreover, Vietnam is notorious for its severe light pollution and sound pollution, especially during the day, when individuals join the traffic in their cars or scooters and may honk more than those in nations like Taiwan. In this situation, both the teacher and the student found it extremely difficult to concentrate during online classes.

4.2 AI Chatbot for Learning

Table 1. General information of the interviewee.

No.	Participant	Teaching institution	Teaching period	Current teaching subject
1	A	Industrial University of Ho Chi Minh city	3 yrs	Foreign Languages
2	B	Industrial University of Ho Chi Minh city	3 yrs	Foreign Languages
3	C	Industrial University of Ho Chi Minh city	10 yrs	Foreign Languages
4	D	Industrial University of Ho Chi Minh city	3 yrs	Business Administration
5	E	Ho Chi Minh City University of Food Industry	6 yrs	Marketing Management
6	F	Viet Nam Maritime University	4 yrs	Finance and Accounting

The first session of the interview is intended to acquire general information about the interviewees. While the second and third sessions collect the respondents' perspectives on the difficulties they encountered throughout the online teaching process, the issues their pupils encountered while online learning, and their ideas on the implementation of AI chatbot approaches in education.

The results of the interview indicate that five interviewees have never used an AI chatbot in their classroom, whereas one interviewee has used an AI chatbot during a lockout for their online language lesson. Moreover, all six interviewees believed that implementing AI chatbots in the online learning process is a smart strategy. They believe that accommodating learning activities and encouraging higher-order thinking, student autonomy, and learning effectiveness will benefit both teachers and students. The contextual learning environment based on the LINE ChatBot greatly enhanced the learners' English speaking and listening skills, according to a study by Chien et al. (2022) [45]. Furthermore, the study by Shadiev et al. (2020) [46] revealed that the SELT group outperformed the STR group, this study was conducted to investigate whether speech-to-text recognition (STR)-texts versus speech-enabled language translation (SELT)-texts impose any cognitive load on the students. In the study in 2020, the authors used speech-enabled language translation (SELT) during lectures in a foreign language and discovered that the SELT texts were the most helpful for student learning in comparison to other approaches, according to Shadiev et al. (2020) [47]. In the study by Cheng et al. (2022) [48], the authors created a dynamic associative concept map (DACM) and Internet article retrieval agent. They then experimented to compare students' learning behaviors while using this system and the Google search engine, and the results revealed that students using the agent made significantly more progress in their learning than students using the search engine.

According to interview B, who has experience with AI chatbots in their online English class, their class was designed with two sections: lecture and practice. In the lecture section, the teacher introduced briefly to the students in the online class the contents of that day, and students could share their homework with the class. After that, the teacher began delivering the vocabulary and grammar of the day. Furthermore, in the practice section, after the instructions of the teacher, the students tried to complete the tasks on time. And at the end of the class, they have to share their feedback with the class. Normally, the students have the following tasks: (1) interacting with Replika, an AI chatbot, while learning new vocabulary and grammar; (2) practicing reading skills by reading "the diary section" and writing skills by writing their own; (3) using the Andy App for vocabulary tasks, with 5 new words added daily; and (4) students must prepare five new words to present in class using Andy.

If they can utilize the applications, it can be helpful to solve the lack of infrastructure, accessibility, and technology; lack of readiness; mental health and personal wellbeing; and lack of infrastructure, as well as digital competence. With the help of the AI chatbot in the online class, students can practice with the chatbot before giving feedback to the class, so their anxiety could be reduced and they could be more well-prepared. Furthermore, the applications provide both website and mobile app versions, giving students a variety of options for easily accessing the applications regardless of an unstable connection or a lack of devices. Overall, the students could improve their performance in general.

In addition, they intend to implement these exciting ways because the learning processes of kids will vary. However, they stress the additional effort teachers must perform to build suitable chatbot apps for the courses, the training for students before usage, and the possibility that the efficacy of this strategy may depend on the engagement and readiness of both teachers and students.

5 Conclusions

Following a thorough analysis of the literature, this study determined that Pandemic COVID-19 has a considerable impact on online education as well as students in developing countries, particularly those in Southeast Asia. Lockdowns of learning centers around the globe have wreaked havoc on academia, but the unequal disruption of learning, with significant disruptions in internal assessments and qualification examinations in developing countries like ASEAN, compounded by a compromised educational system, as evidenced by the preference for even questionable foreign degrees, has affected everyone equally. On the other hand, COVID-19 is boosting the case for online academics, and developing nations, such as those in Southeast Asia, are well-positioned to construct trustworthy, cost-effective, and secure online academic systems. Time, the availability of money, and the combined efforts of influential parties can determine whether something will be a blessing or a disaster. Overall, COVID-19 has challenged education systems and threatened to reverse the hard-earned improvements in learning across the region. And it has also challenged us to re-imagine and innovate.

Acknowledgements. This research is partially supported by the Ministry of Science and Technology, Taiwan, R.O.C. under Grant No. MOST 108-2628-H-224-001-MY3, MOST 110-2511-H-224-003-MY3 and MOST 110-2622-H-224-001-CC2.

References

1. Tadesse, S., Muluye, W.: The impact of COVID-19 pandemic on education system in developing countries: a review. Open J. Soc. Sci. **8**, 159–170 (2020)
2. Gupta, S., Jawanda, M.K.: The impacts of COVID-19 on children. Acta Paediatr. **109**, 2181–2183 (2020)
3. Bailey, D.: Chatbots as conversational agents in the context of language learning. In: Proceedings of the fourth Industrial Revolution and Education, pp. 32–41 (2019)
4. Clarizia, F., Colace, F., Lombardi, M., Pascale, F., Santaniello, D.: Chatbot: an education support system for student. In: Castiglione, A., Pop, F., Ficco, M., Palmieri, F. (eds.) CSS 2018. LNCS, vol. 11161, pp. 291–302. Springer, Cham (2018). https://doi.org/10.1007/978-3-030-01689-0_23
5. Fryer, L.K., Nakao, K., Thompson, A.: Chatbot learning partners: connecting learning experiences, interest and competence. Comput. Human Behav. **93**, 279–289 (2019)
6. Ho, A., Hancock, J., Miner, A.S.: Psychological, relational, and emotional effects of self-disclosure after conversations with a chatbot. J. Commun. **68**, 712–733 (2018)
7. Weizenbaum, J.: ELIZA—A computer program for the study of natural language communication between man and machine. Commun. ACM. **9**, 36–45 (1966)
8. Schroeder, J.I., et al.: Using membrane transporters to improve crops for sustainable food production. Nature **497**, 60–66 (2013)
9. Sheth, A., Yip, H.Y., Iyengar, A., Tepper, P.: Cognitive services and intelligent chatbots: current perspectives and special issue introduction. IEEE Internet Comput. **23**, 6–12 (2019)
10. Vázquez-Cano, E., Fombona, J., Fernández, A.: Virtual attendance: analysis of an audiovisual over IP system for distance learning in the Spanish Open University (UNED). Int. Rev. Res. Open Distrib. Learn. **14**, 402–426 (2013)
11. Grossman, J., Lin, Z., Sheng, H., Wei, J.T.-Z., Williams, J.J., Goel, S.: MathBot: transforming online resources for learning math into conversational interactions. In: AAAI 2019 Story-Enabled Intelligence (2019)
12. Ruan, S., et al.: QuizBot: a dialogue-based adaptive learning system for factual knowledge. In: Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems, pp. 1–13 (2019)
13. Huang, W., Hew, K.F., Fryer, L.K.: Chatbots for language learning—Are they really useful? A systematic review of chatbot-supported language learning. J. Comput. Assist. Learn. **38**, 237–257 (2022)
14. Gu, J.-C., Ling, Z.-H., Liu, Q.: Interactive matching network for multi-turn response selection in retrieval-based chatbots. In: Proceedings of the 28th ACM International Conference on Information and Knowledge Management, pp. 2321–2324 (2019)

15. Parentela, G.M., Vargas, D.S.: Pandemic Era (Covid-19) and Higher Education in the Philippines Against the World Perspective: a Literature Survey Analysis
16. Vázquez-Cano, E., Mengual-Andrés, S., López-Meneses, E.: Chatbot to improve learning punctuation in Spanish and to enhance open and flexible learning environments. Int. J. Educ. Technol. High. Educ. **18**(1), 1–20 (2021). https://doi.org/10.1186/s41239-021-00269-8
17. Io, H.N., Lee, C.B.: Understanding the adoption of chatbot. In: Arai, K., Kapoor, S., Bhatia, R. (eds.) FICC 2018. AISC, vol. 886, pp. 632–643. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-03402-3_44
18. Araujo, T.: Living up to the chatbot hype: the influence of anthropomorphic design cues and communicative agency framing on conversational agent and company perceptions. Comput. Hum. Behav. **85**, 183–189 (2018)
19. Wang, T.-H., Lin, H.-C.K., Wu, T.-T., Huang, Y.-M.: A multimethod approach for supporting reflection and creativity in online collaborative courses. J. Internet Technol. **21**, 1097–1106 (2020)
20. Coniam, D.: The linguistic accuracy of chatbots: usability from an ESL perspective. Text Talk **34**, 545–567 (2014)
21. Almaiah, M.A., Jalil, M.A., Man, M.: Extending the TAM to examine the effects of quality features on mobile learning acceptance. J. Comput. Educ. **3**(4), 453–485 (2016). https://doi.org/10.1007/s40692-016-0074-1
22. Eltahir, M., Al-Qatawneh, S., Al-Ramahi, N., Alsalhi, N.: The perspective of students and faculty members on the efficiency and usability of e-learning courses at Ajman university: a case study. J. Technol. Sci. Educ. **9**, 388–403 (2019)
23. Barrot, J.S., Llenares, I.I., del Rosario, L.S.: Students' online learning challenges during the pandemic and how they cope with them: the case of the Philippines. Educ. Inf. Technol. **26**(6), 7321–7338 (2021). https://doi.org/10.1007/s10639-021-10589-x
24. Adarkwah, M.A.: "I'm not against online teaching, but what about us?": ICT in Ghana post Covid-19. Educ. Inf. Technol. **26**(2), 1665–1685 (2020). https://doi.org/10.1007/s10639-020-10331-z
25. Copeland, W.E., et al.: Impact of COVID-19 pandemic on college student mental health and wellness. J. Am. Acad. Child Adolesc. Psychiatry **60**, 134–141 (2021)
26. Fawaz, M., Samaha, A.: E-learning: depression, anxiety, and stress symptomatology among Lebanese university students during COVID-19 quarantine. In: Nursing Forum, pp. 52–57. Wiley Online Library (2021)
27. Kapasia, N., et al.: Impact of lockdown on learning status of undergraduate and postgraduate students during COVID-19 pandemic in West Bengal, India. Child. Youth Serv. Rev. **116**, 105194 (2020)
28. Khalil, R., et al.: The sudden transition to synchronized online learning during the COVID-19 pandemic in Saudi Arabia: a qualitative study exploring medical students' perspectives. BMC Med. Educ. **20**, 1–10 (2020)
29. Grover, S., et al.: Psychological impact of COVID-19 lockdown: an online survey from India. Indian J. Psychiatry **62**, 354 (2020)
30. Aung, T.N., Khaing, S.S.: Challenges of implementing e-learning in developing countries: a review. In: Zin, T.T., Lin, J.-W., Pan, J.-S., Tin, P., Yokota, M. (eds.) GEC 2015. AISC, vol. 388, pp. 405–411. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-23207-2_41
31. Mumtaz, N., Saqulain, G., Mumtaz, N.: Online academics in Pakistan: COVID-19 and beyond. Pak. J. Med. Sci. **37**, 1–5 (2021). https://doi.org/10.12669/pjms.37.1.2894
32. Hamdan, K.M., Al-Bashaireh, A.M., Zahran, Z., Al-Daghestani, A., Samira, A.-H., Shaheen, A.M.: University students' interaction, Internet self-efficacy, self-regulation and satisfaction with online education during pandemic crises of COVID-19 (SARS-CoV-2). Int. J. Educ. Manag. (2021)

33. Ashraf, N., Mustafa, R., Sidorov, G., Gelbukh, A.: Individual vs. group violent threats classification in online discussions. In: Companion Proceedings of the Web Conference 2020, pp. 629–633 (2020)
34. Mumtaz, N., Saqulain, G., Mumtaz, N.: Online academics in Pakistan: COVID-19 and beyond. Pak. J. Med. Sci. **37**, 283 (2021)
35. Hagan, J.E., Jr., et al.: Linking COVID-19-related awareness and anxiety as determinants of coping strategies' utilization among senior high school teachers in cape coast Metropolis, Ghana. Soc. Sci. **11**, 137 (2022)
36. Altameemi, A.F., Al-Slehat, Z.A.F.: Exploring the students' behavior intentions to adopt e-learning technology: a survey study based on COVID-19 crisis. Int. J. Bus. Manag. **16**, 31–41 (2021)
37. Rapanta, C., Botturi, L., Goodyear, P., Guàrdia, L., Koole, M.: Online university teaching during and after the Covid-19 crisis: refocusing teacher presence and learning activity. Postdigit. Sci. Educ. **2**, 923–945 (2020)
38. Zitouni, R., Bezine, H., Arous, N.: Online handwritten Arabic script recognition using stroke-based class labeling scheme. Int. J. Comput. Intell. Syst. **14**, 187–198 (2021)
39. Demirbilek, M.: The 'digital natives' debate: an investigation of the digital propensities of university students. Eurasia J. Math. Sci. Technol. Educ. **10**, 115–123 (2014)
40. Altbach, P., de Wit, H.: COVID-19: the internationalization revolution that isn't. Int. High. Educ. 16–18 (2020)
41. Ferrari, A.: Digital competence in practice: an analysis of frameworks. Sevilla JRC IPTS. **10**, 82116 (2012)
42. ElSaheli-Elhage, R.: Access to students and parents and levels of preparedness of educators during the COVID-19 emergency transition to e-learning. Int. J. Stud. Educ. **3**, 61–69 (2021)
43. AlTameemy, F.A., Alrefaee, Y.: Impact of Covid-19 on English Language Teaching in Yemen: Challenges and Opportunities. Available SSRN 3856436 (2021)
44. Dong, C., Cao, S., Li, H.: Young children's online learning during COVID-19 pandemic: Chinese parents' beliefs and attitudes. Child. Youth Serv. Rev. **118**, 105440 (2020)
45. Chien, Y.-C., Wu, T.-T., Lai, C.-H., Huang, Y.-M.: Investigation of the influence of AIML-based Line Chatbot in contextual English learning. Front. Psychol. 322 (2022)
46. Shadiev, R., Chien, Y.-C., Huang, Y.-M.: Enhancing comprehension of lecture content in a foreign language as the medium of instruction: comparing speech-to-text recognition with speech-enabled language translation. SAGE Open **10**, 2158244020953177 (2020)
47. Shadiev, R., Huang, Y.-M.: Investigating student attention, meditation, cognitive load, and satisfaction during lectures in a foreign language supported by speech-enabled language translation. Comput. Assist. Lang. Learn. **33**, 301–326 (2020)
48. Cheng, Y.-P., Cheng, S.-C., Huang, Y.-M.: An internet articles retrieval agent combined with dynamic associative concept maps to implement online learning in an artificial intelligence course. Int. Rev. Res. Open Distrib. Learn. **23**, 63–81 (2022)

Effect of Learning Computational Thinking Using Board Games in Different Learning Styles on Programming Learning

Han-Chi Liu[1], Hong-Ren Chen[1](✉), Sen-Chi Yu[2], and Yu-Ting Shih[1]

[1] Department of Digital Content and Technology, National Taichung University of Education, Taichung 403, Taiwan
bit107103@gm.ntcu.edu.tw, hrchen@mail.ntcu.edu.tw, ytshih0121@gmail.com

[2] Department of Counseling and Applied Psychology, National Taichung University of Education, Taichung 403, Taiwan
rhine@gm.ntcu.edu.tw

Abstract. The popularization of the internet and the rapid development of intelligent technologies have inspired new directions in education policies. In the curriculum guidelines, the technological education field had included exploration, creative thinking, logic, computational thinking, and problem-solving skills. The study utilized board games, Kolb learning styles scale, and computational thinking test as experimental tools. Incorporating easy board games into teaching programming skills such as "loop" and "conditionals", the study aimed to explore the effects of board game-based learning methods have on students of different learning styles learning computational thinking. The study will discuss Kolb Learning style scales and examine learners' styles, dividing them into diverger, assimilator, converger, and accommodator while conducting test and quantitative analysis after the experiment. The study concludes the following findings: (1) The use of board games in teaching has a significant effect on the learning units of "loops" and "condition" in the learning of computational thinking, indicating that the use of board game for learning the concepts of "loops" and "condition" in programming can enhance computational thinking. (2) Students of different learning styles did not have a significant effect in learning the units of "loop" and "condition" concepts regarding computational thinking. However, students of the assimilator type have greater learning efficiency than other types.

Keywords: Board games · Learning styles · Computational thinking · Programming learning

1 Introduction

As a citizen of the modern society, it is our responsibility to adapt to the living of the new age and master the ability to control, analyze and apply technology [1]. Every child needs to be educated in the field of technology, enabling them to have a basic

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, pp. 514–521, 2022.
https://doi.org/10.1007/978-3-031-15273-3_56

understanding of technology and further cultivate their practical usage and creativity of technological tools through practice while enhancing students' creative thinking, logic, computational thinking and problem solving skills. Thus, though establishing the field of technology, combining technology and engineering into a single field to create curriculums, enhancing students' hands-on experiences and integrating knowledge of other fields, such as science, technology, engineering, mathematics, etc. [2].

The courses of the technology field aims to assist students to: (1) acquire basic technological knowledge and skills and cultivate a correct attitude and work habits. (2) Apply technological knowledge to create, design, criticize, logicize and compute. (3) Integrate theory and practical application to solve problems. (4) Understand the tech industry and its future trends. (5) Inspire interests in technological R&D, regardless of gender, and preparing them for future careers. (6) Understand the interactions between technology, individuals, society, environment and culture while reflecting upon its relationship and issues [2]. Board game-based research has an increasing trend in recent years, many studies alluded to their edutainment properties, hoping that when teaching professional knowledge, teachers can utilize this kind of method to help students understand different principles and facts, as if playing a board game. An example is the Law of the lever, through understanding fulcrums, points of forces, and pivot, students can understand what methods they can use to exert less force and apply them to mechanical tools and daily life experiences. Besides learning, many theories proposed that playing board games can aid emotional management, social and work performances while also developing creativity in children.

The questions of this study are as follows: (1) Does the use of board games in programming teaching have any learning effectiveness of the concept of "general", "loop" and "condition" in computational thinking? (2) Do students with different learning styles have any influence on the learning effectiveness of the concept of "general", "loop" and "condition" in computational thinking?

2 Literature Review

Learning style meant the habitual behavior of an individual during the learning process. The [3] also referred to learning style as learning preference, which meant students' needs of their study goals and the learning methods they use for acquiring knowledge in fields such as science, arts, and skills. Learning styles encompassed many aspects, from the preference for the abstract culture of texts, language, architecture, food, tools, skills, knowledge, traditions and arts to the physical environment of sound, light, electricity and heat, even as far as the differences in the fundamental differences in personality traits. The [4] proposed that wen learners would develop unique learning styles when exposed to the elements around them when they were young. Learners will then develop habits from practice and will continue using the same method to learn. There are many ways to interpret learning styles, from the perspective of a researcher or teacher to which method or environment does the learning take place so that they can benefit learners. It is even possible to discover more ways to explain learning styles. However, it is ultimately up to teachers and educators to adapt and decide which method can achieve the desired outcome for the students.

The [5] divided learning styles into four different categories: diverger, assimilator, converger and accommodator. Divergers have greater imagination and comprehension abilities, they are more perceptive and better at observing the context to facilitate their learning. Assimilators can reason better, they prefer a simple and logical way of thinking. Convergers prefer practical hands-on experiences, acquiring knowledge through experiments. Accommodators can adapt easily, they enjoy accomplishing objectives through cooperation and learn from their mistakes. Kolb's experiential learning theory emphasized that learning is not a result, but a process of educational meaning. It reflects the purpose of education is to encourage the use of all types of learning so that they can be applied in different scenarios [6].

The [7] considered computational thinking is equally important as listening, speaking, reading and writing, and applicable to not just computer scientists but everyone. Computational thinking can transform a difficult problem to one resolvable through reduction, embedding, transformation or simulation. The [8] proposed computational thinking as a way to analyze thinking, such as how mathematical thinking is used to solve calculations, or the application of engineering thinking in solving a big and complex systematic problem and even the use of scientific thinking in explaining human behavior and thinking. The [9] researched the effects of robotic programming on learners' computational thinking abilities and learning attitudes towards STEM. The study reported results that indicated experimental group learners had great improvements over the control group in computational thinking grades.

3 Research Method

The study utilized a one-group pretest-posttest experimental design. Incorporating board games into teaching "loop" and "conditionals" on programming courses, the study discussed their effects on the learning efficiency of computational thinking and further explored its effects on students of different learning styles. The subject of this experiment were 37 students of one university in central of Taiwan who took the programming learning on computer network courses. The study designed learning activities and course material based on the coding card game Potato Pirates. The game contained programming languages such as "for, while, if..else", capable of enhancing learning efficiency of college students regarding computational thinking. Prior to the game-based activity, learners will first take basic courses to understand the programs. Combining board games with the university's computer network course, the activity will last 3 classes, a total of 150 min. Prior to the activity, researchers and teachers will explain the rules and content of the upcoming activity and have the students take a 15 min pretest and learning style test to categorize students into divergent, assimilative, convergent and accommodative. The introduction of the board game takes around 15 min; the students will spend 110 min playing the game. Each group will contain 3–6 players while each game takes around 20–30 min. This translates to each player being able to play 3–6 rounds. After the learning activity has been concluded, the 10-min posttest will commence, then the study will collect the tests and scales to process and analyze (Fig. 1).

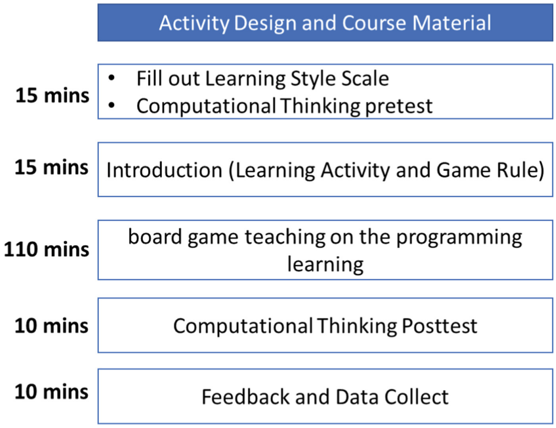


Fig. 1. Experimental process

The aspects and features that determine the choice of board games are: (1) The game itself is interesting. (2) The game is not overly expensive. (3) The game is modifiable in its mechanics and difficulty to suit newer players. This board game contained programming language such as "for, while, if..else" while also providing other cards, accessories and tutorial pictures. The study chose Potato Pirates, an American programming board game developed by Thinkfun after considering the price and difficulty of the game as shown in. Established in 1985, Thinkfun put all of its focus on creating educational games. They have provided the market with many educational products, giving children different games on learning different abilities while establishing themselves as a famous brand in the market (Fig. 2).

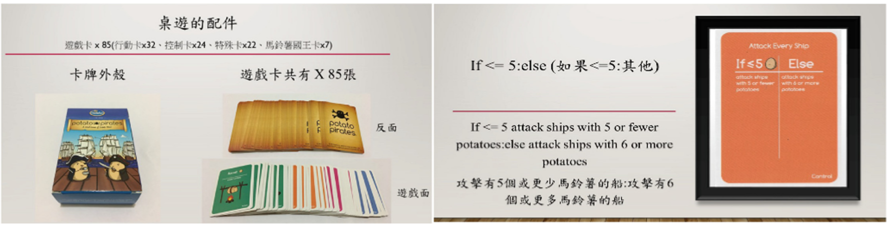


Fig. 2. Board game of "Potato Pirates"

4 Experimental Analysis and Results

To determine whether different learning styles will affect the learning of computational thinking, the study will have students fill in Kolb learning styles scale and divide students into diverger, assimilator, converger and accommodator based on the results. The present study set board game-based learning as independent variable, learning styles as moderation and posttest scores as dependent variable to perform one-way ANOVA, discussing how using board games can affect students of different learning styles on learning computational thinking.

4.1 Discuss the Learning Effect of "General" Unit in Learning Styles

According to Table 1, there are 9 accommodators, 9 divergers, 10 assimilators ad 9 convergers in this analysis. Accommodators' general scores averaged at 76.67, SD = 21.21. Divergers' general scores averaged at 74.44, SD = 18.10. Assimilators' general scores averaged at 78.00, SD = 18.14. Convergers' general scores averaged at 67.78, SD = 24.38. According to Table 2, "General" ANOVA reported no significant difference, hence exists a possibility for null hypothesis, F = .450, p = 0.719 > 0.05. Divergent, assimilative, convergent and accommodative all did not exhibit significant difference in terms of "general" computational thinking, hence no need for post hoc analysis.

Table 1. Descriptive statistics of "General" unit in learning styles

Learning style	N	Average	S.D.	S.E.
Accommodative	9	76.67	21.21	7.071
Divergent	9	74.44	18.10	6.03
Assimilative	10	78.00	18.14	5.73
Convergent	9	67.78	24.38	8.13
Total	37	74.33	20.07	3.30

Table 2. ANOVA summary table of different teaching styles' learning efficiencies on "General" unit

Source	SS	df	MS	F	Significance
Between groups	570.33	3	190.11	.450	.719
In groups	13937.78	33	422.36		
Total	14508.11	36	Ss		

$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .000$

4.2 Discuss the Learning Effect of "Loop" Unit in Learning Styles

According to Table 3, there are 9 accommodators, 9 divergers, 10 assimilators ad 9 convergers in this analysis. Accommodators' "loop" scores averaged at 86.67, SD = 18.54. Divergers' "loop" scores averaged at 81.11, SD = 22.05. Assimilators' "loop" scores averaged at 77.50, SD = 26.38. Convergers' "loop" scores averaged at 77.78, SD = 24.64. According to Table 4, "Loop" ANOVA reported no significant difference, hence exists a possibility for null hypothesis, F = .310, $p = 0.818 > 0.05$. Divergent, assimilative, convergent and accommodative all did not exhibit significant difference in terms of "loop" computational thinking, hence no need sfor post hoc analysis.

Table 3. Descriptive statistics of "Loop" unit in learning styles

Learning style	N	Average	S.D.	S.E.
Accommodative	9	86.67	18.54	6.18
Divergent	9	81.11	22.05	7.35
Assimilative	10	77.50	26.38	8.34
Convergent	9	77.78	24.64	8.21
Total	37	80.68	22.52	3.70

Table 4. ANOVA summary table of different teaching styles' learning efficiencies on "Loop" unit

Source	SS	df	MS	F	Significance
Between groups	501.164	3	167.055	.310	.818
In groups	17756.944	33	538.089		
Total	18258.108	36			

$*p < .05$, $**p < .01$, $***p < .000$

4.3 Discuss the Learning Effect of "Condition" Unit in Learning Styles

According to Table 5, there are 9 accommodators, 9 divergers, 10 assimilators ad 9 convergers in this analysis. Accommodators' conditionals scores averaged at 83.33, SD = 25.00. Divergers' conditionals scores averaged at 77.78, SD = 15.02. Assimilators' conditionals scores averaged at 90.00, SD = 17.48. Convergers' conditionals scores averaged at 66.67, SD = 25.00. According to Table 6, "Condition" ANOVA reported no significant difference, hence exists a possibility for null hypothesis, F = 2.072, $p = 0.123 > 0.05$. Divergent, assimilative, convergent and accommodative all did not exhibit significant difference in terms of "conditionals" computational thinking, hence no need for post hoc analysis.

Table 5. Descriptive statistics of "Condition" unit in learning styles

Learning style	N	Average	S.D.	S.E.
Accommodative	9	83.33	25.00	8.33
Divergent	9	77.78	15.02	5.01
Assimilative	10	90.00	17.48	5.53
Convergent	9	66.67	25.00	8.33
Total	37	79.73	21.92	3.60

Table 6. ANOVA summary table of different teaching styles' learning efficiencies on "Condition" unit

Source	SS	df	MS	F	Significance
Between groups	2741.742	3	913.914	2.072	.123
In groups	14555.556	33	441.077		
Total	17297.297	36			

$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .000$

5 Conclusions

Effects of different learning styles had on the "general" concept of computational thinking judging from the foregoing data, it can be inferred that all four styles of learning did not have significant differences on the game-based computational thinking learning, this however did not exempt them from having any influences. Due to ANOVA results, post hoc analysis can be ignored. Even while examining post hoc analysis, the data suggested no significant differences exist between all four styles. Nevertheless, when viewed in terms of learning the "general" concept, convergers performed better than the other three types. Effects of different learning styles had on the "loop" concept of computational thinking. It can be inferred from the data analysis that all four styles did not have significant differences. However, even when examining the post-hoc analysis, all four styles also did not have differences in terms of learning the "loop" concept. Effects of different learning styles had on the "conditionals" concept of computational thinking. It can be inferred from the data analysis that all four styles did not have significant differences, this however did not exempt them from having any influences. Even while examining post hoc analysis, the data suggested no significant differences exist between all four styles. Nevertheless, when viewed in terms of learning the "conditionals" concept, convergers performed better than the other three types.

References

1. Zhao, L., Liu, X., Wang, C., Su, Y.-S.: Effect of different mind mapping approaches on primary school students' computational thinking skills during visual programming learning. Comput. Educ. **181**, 104445 (2022)

2. K12 Education Administration, Advanced Secondary School, National Secondary School 12-Year National Basic Education Curriculum Outline in the Field of Science and Technology. https://www.k12ea.gov.tw/Tw/Common/SinglePage?filter=11C2C6C1-D64E-475E-916B-D20C83896343. Accessed 30 Apr 2022
3. Sternberg, R.J., Willams, W.M.: Educational Psychology, 2nd edn. Pearson (2010)
4. Gibson, J.T., Chandler, L.A.: Educational Psychology Mastering Principles and Applications. Allyn and Bacon, London (1988)
5. Kolb, D.A.: Experiential Learning: Experience as the Source of Learning and Development. Prentice-Hall, Englewood Cliffs (1984)
6. Shih, H.-J.: The study on the combination of learning style and approach for examining learning performance-based on interactive or non-interactive. Unpublished Master Thesis, Chung Yuan Christian University, Taiwan (2003)
7. Wing, J.M.: Computational thinking. Commun. ACM **49**(3), 33–35 (2006). https://doi.org/10.1145/1118178.1118215
8. Wing, J.M.: Computational thinking and thinking about computing. Philos. Trans. Roy. Soc. A-Math. Phys. Eng. Sci. **366**(1881), 3717–3725 (2008). https://doi.org/10.1098/rsta.2008.0118
9. Huang, Y.-L.: The Effects of Robotic Programming Courses on Children's Computational Thinking Ability and Attitude toward to STEM Learning. National Taipei University of Education, Taiwan (2019)

Correction to: Familiarization Strategies to Facilitate Mobile-Assisted Language Learning in Unfamiliar Learning Environments: A Study of Strategies Development and Their Validation

Rustam Shadiev, Meng-Ke Yang, Dilshod Atamuratov,
Narzikul Shadiev, Mirzaali Fayziev, Elena Gaevskaia,
Anna Kalizhanova, and Nurzhamal Oshanova

Correction to:
Chapter "Familiarization Strategies to Facilitate Mobile-Assisted Language Learning in Unfamiliar Learning Environments: A Study of Strategies Development and Their Validation" in: Y.-M. Huang et al. (Eds.): *Innovative Technologies and Learning*, LNCS 13449,
https://doi.org/10.1007/978-3-031-15273-3_24

In an older version of this paper, there was error in the author name, "Fayziev Mirzaali" was incorrect. This has been corrected to "Mirzaali Fayziev".

The updated original version of this chapter can be found at
https://doi.org/10.1007/978-3-031-15273-3_24

Y.-M. Huang et al. (Eds.): ICITL 2022, LNCS 13449, p. C1, 2022.
https://doi.org/10.1007/978-3-031-15273-3_57

Author Index