A

Aboriginal

▶ Safe Frames, Essential Determinant for Educational Technology Implementation in an Indigenous Context

Acceleration

▶ Assistive Technology and the Gifted Learner

Access

▶ Assisting Elderly Non-computer-Literate People with Computer-Based Communications

Accessibility

▶ Assisting People with Physical Disabilities Through Technology

Accountability

▶ Support for School and Institutional Improvement and Accountability

Action Plan

▶ Open Educational Resources and Distance Learning, Challenges and the Way Forward in Higher Education

Active Aging

▶ Assisting Elderly Non-computer-Literate People with Computer-Based Communications

Active Learning

▶ Digital Technologies in Higher Education, Learning Challenges

Actor-Network Theory

▶ Assisting Students with Learning Disabilities Through Technology

Actor-Network Theory (ANT)

▶ Technological Innovation in ICT for Education

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Adapting to New Software and Hardware

► Sustaining Digital Technology Use in Professional Communities

Adaptive Learning

► Artificial Intelligence in Education

Adoption of Innovative ICT-Enabled Systems for Analysis- and Intuition-Styled Teachers in Primary Schools

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Synonyms

Cognition; Innovation diffusion; Teaching/learning system; Technology acceptance

Introduction

The effects of technology acceptance and innovation diffusion behaviors on information and communications technology-enabled teaching/learning systems (ITLS) adoption attract increasing attention among primary school teachers (Wu and Liu 2015). In particular, Internet-based e-learning has been considered one of the important ICT tools for knowledge providers and receivers to create an exchange process in cyberspace for knowledge development. The system adoption is generally a multidimensional issue that needs to consider such issues as providers' teaching behaviors (e.g., teaching cognition and ICT use preference), characteristics of ITLS (e.g., material presentation, diversity, and adaptability), and receiver's learning behavior (e.g., learning cognition and ICT adoption propensity) (Bertacchini et al. 2012).

In particular, the provider's teaching behavior based on his or her cognitive system is one of the major determinants of the ITLS utilization (Mampadi et al. 2011). When ITLS providers attempt to describe how effective their tools will be in assisting teachers to develop their ITLS programs, the characteristics of their cognitive system are important to the system design characteristics. For example, a few teachers may need an online community to ease mutual socialization for knowledge exchange and development, whereas others prefer teaching materials developed using multimedia technologies. Certain teachers in a secondary school are unlikely to participate in an online community because of the various cognitions of ICT applications, which need strategies and policies to deal with this issue (Wang and Lu 2012).

One of the relevant methods to motivate preservice teachers to utilize ICT-enabled tools in teaching is to narrate the existing offerings in the training courses to ITLS available in schools and the methods of using them. This process signifies that the ITLS use perception of teachers varies and should be retreated to maximize the ITLS use with respect to teaching performance. As such, instructors in the current educational environment are required to assume such diverse roles in education as mentors, lifetime learners, curriculum designers, curriculum implementers, teaching assistants, student motivators, peer counselors, teaching consultants, and learning partners. Liaw et al. (2007) conducted a survey and indicated that the teacher-led feature is one of the major determinants that substantially influence the learners' attitude toward e-learning as an effective learning tool. This result implies that teacher roles considerably influence the learning performance under ITLS.

Considerable effort has been exerted to the research, development, adoption, and evaluation of ITLS. In general, emphasis focused on the learner side to enhance the learning performance without considering the personality style of the instructors with respect to the adoption of the cognition-relevant ITLS. As an initiator or facilitator of learner e-learning use, the propensity of a teacher in using ITLS is crucial for learner use of e-learning. The e-learning critical success factors can be generally grouped into four facets, namely, instructor, student, ICT, and university support (Selim 2007). In particular, the instructors' use of e-learning environments is actually affected by their opinions and propensity to perceive web-based activities and computer-assisted learning. Therefore, the understanding of teachers' adoption intention of ITLS should be deepened to determine the relationship between their cognitive style and propensity to adopt. Accordingly, this study analyzes the factors that explain teachers' willingness or unwillingness to adopt an e-learning system and determine the role of the instructor cognitive styles.

The features of the cognitive style are mainly thinking styles, problem solving, individual perception, and the role of memory and other cognition shown by typical personal traits (Allinson and Hayes 1996). The intuitive and analytical styles, which are called cognitive style index (CSI), are among the many differentiating cognitive styles. The intuitive style prefers free and less-structured thinking behavior, whereas the analytical style is to think with further logic and structure. For example, "People think that I prefer rapidly browsing learning materials" is an intuitive style. By contrast, "People think I usually analyze learning materials with logics" is analytical.

A specific ITLS has been developing its own characteristics that often involve the technology perception and cognitive behavior of users. Its adoption propensity is strongly related to the technology acceptance behavior (e.g., perceived usefulness and perceived ease of use) and technology use behavior (e.g., perceived compatibility) of instructors. The study in the chapter incorporates the behavior of technology acceptance (Davis 1989) and innovation diffusion (Rogers 2003) to derive the research model. An empirical study is conducted on elementary school teachers to analyze the determinants of the adoption intention of ITLS. The moderation effect of the cognitive style on the adoption attitude of ITLS is also presented.

Literature Review

Behavior of Technology Acceptance

The intention of technology acceptance is linked mainly to perceived usefulness and perceived ease of use (Davis 1989) and has been broadly used to analyze the willingness of innovative technology. This idea argues that individuals believe that using a particular technology or system will improve their performance level. When a system is useful and easy to use, it will produce positive intention conducive to adoption. Teachers often consider ITLS as a beneficial tool because they think it can reduce the cost of teaching materials and of teaching itself, enhance the personal accomplishment of information and professional knowledge, and improve teaching performance. The perceived usefulness is related to the course performance in the analysis of the factors that contribute to a successful e-learning environment. The perceived ease of use refers to the extent of personal needs to use a specific technology or system. This study attempts to evaluate whether these factors are also the determinants related to the adoption willingness of ITLS for teachers in primary schools and whether they are moderated by the cognitive styles. The first and second hypotheses are as follows:

H1: Perceived usefulness will significantly and positively influence the attitude toward the adoption of ITLS.

H2: Perceived ease of use will significantly and positively influence the attitude toward the adoption of ITLS.

Innovation Diffusion

Innovation diffusion theory is proposed to explain the attitude toward the behavior of technology use, including cognition, persuasion, decision, implementation, and confirmation (Rogers 2003). The behavior of innovation diffusion is linked to five major factors, namely, (1) comparative advantage, (2) compatibility, (3) complexity, (4) to try, and (5) observability. Comparative advantage and complexity factors are considerably similar to perceived usefulness and perceived ease of use, respectively. Compatibility refers to the similarity between teachers' behaviors in teaching and their original teaching methods if the use of ITLS is considered. This factor is positively related to behavioral intention and perceived education quality to use ITLS that offers online learning courses. Adopting ITLS to assist in teaching is not simply an issue of using ICT tools or their integration. Such issues as similarity of learning and teaching behavior (e.g., pull strategy) and educational policy set (e.g., push strategy) may also need to be considered.

For example, if teachers want to make the materials available in ITLS, then they probably should prepare based on their preferences for and perception of the required software, hardware, and e-materials. Thus, behavior and concept conflicts may occur, thereby probably decreasing the willingness to use the e-learning system. However, if the ITLS education is a set educational policy wherein a teacher has to adapt to using ITLS, then the relationship between perceived compatibility and adoption attitude may change because compatibility may not be an issue for a teacher to adopt. In this case, theory of technology acceptance behavior may explain the situation that behavior is occasionally not self-controllable.

When ITLS enables teachers or students to attempt only part of it, the uncertainty of potential adopters is reduced. Understanding the willingness to attempt an ITLS is highly important to the adoption attitude of ITLS. The advanced ICT has already developed innovative tools and strategies, such as the game-based learning system for learning educational materials in a playful manner, thereby facilitating the educational process. The experience of human–computer interaction frequently marks the playfulness as a predictor of innovation technology use. The effect of edutainment (education plus entertainment) on the increase in motivation was linked to interest/enjoyment and competence (Bertacchini et al. 2012). The playfulness is likely a predictor of the adoption attitude of ITLS for elementary school teachers.

H3: Perceived compatibility will substantially influence the positive attitude toward the adoption of ITLS.

H4: Trialability will substantially influence the positive attitude toward the adoption of ITLS.

H5: Perceived playfulness will substantially influence the positive attitude toward the adoption of ITLS.

H6: A positive attitude will substantially influence the ICT adoption intention.

Cognitive Behavior

Social cognitive theory that is used in explaining learning processes is central to understanding the personality of the learners and instructors (Bandura 1986). Learning is explained in terms of a model, in which behavior, cognition, and environment combine as interacting determinants of one another. Such process is affected by the students' own thoughts, self-beliefs, and interpretation of learning subjects. However, training is believed to be shaped continuously by factors within the environment and thinking behavior of trainers, particularly the technology use perceived by instructors. In general, the stock knowledge of instructors probably interacts with design manipulations when they adopt technology-based learning materials. Teachers use their prior knowledge as basis to possibly prefer ITLS with media-enriched tools to assist in externalizing their knowledge, such that their students can efficiently obtain, relate, and restructure knowledge elements to develop their own knowledge structure. Accordingly, an instructor may argue that reading additional texts (e.g., ICT-based Wiki) can improve performance better than talking to people often (e.g., ICT-based Google talk) based on his or her cognition or experience. This argument may substantially influence the use propensity of ITLS.

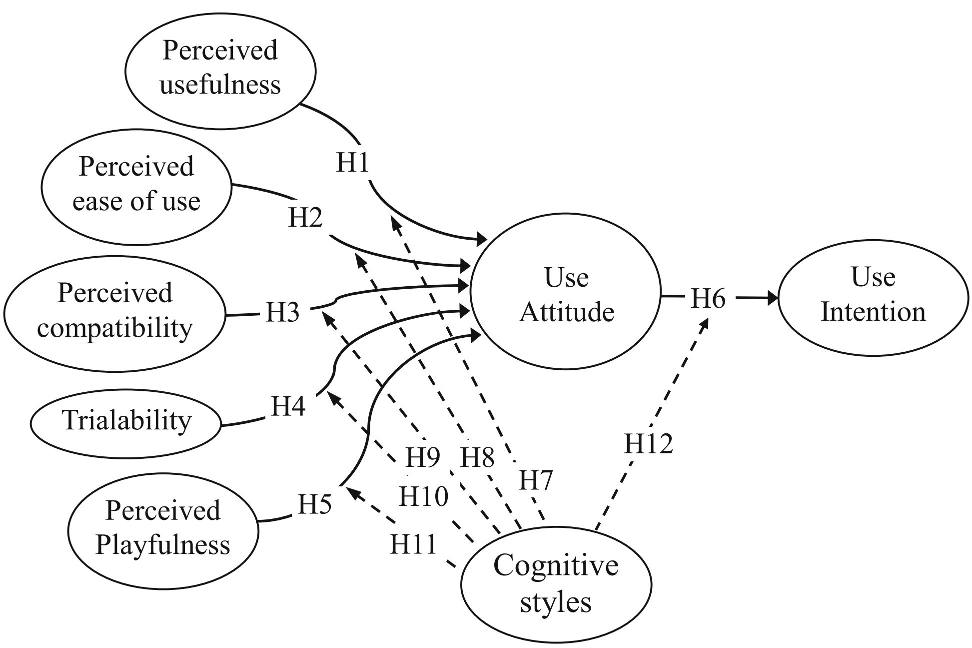
The role of cognitive style varies but generally centers on the impact on learners. Research had limited focus in considering the instructor viewpoint by concentrating on the cognitive characteristics that may be linked to the design and adoption preferences. Thus, instructor perception with respect to the cognitive characteristics on the use of ICT tools will likely be related to learning performance. The basic classification of cognitive style is based on the viewpoint of human perception, which can be divided into intuitive and analytical perceptions (Allinson and Hayes 1996). The analytical type has characteristics in the method of organizing information and messages, such as concise thinking, logical reasoning, analytical functions, and further attention to detail, structured problem-solving style, and methodical approach. The intuitive type tends to involve imagination, understanding, metaphor, rhythm, attitudes, and emotions. This type often changes over time. Problems are preferably solved without any restriction. Cognitive style may influence the teacher adoption intention of ITLS. Thus, the following six hypotheses are formulated:

H7: Cognitive style substantially moderates the effect of perceived usefulness on the adoption of ITLS.
H8: Cognitive style substantially moderates the effect of perceived ease of use on the adoption attitude of ITLS.
H9: Cognitive style substantially moderates the effect of perceived compatibility on the adoption attitude of ITLS.
H10: Cognitive style significantly moderates the effect of trialability on the adoption attitude of ITLS.
H11: Cognitive style significantly moderates the effect of perceived playfulness on the adoption attitude of ITLS.
H12: Cognitive style significantly moderates the effect of adoption attitude and intention of ITLS.

Method

Model

Technology acceptance and innovation diffusion theories are employed to describe the ITLS adoption behavior. The research model presented in Fig. 1 is developed based on the formulated hypotheses. The moderating role of cognitive styles is also analyzed. The independent variables are perceived usefulness, perceived ease of use, perceived compatibility, trialability, and perceived playfulness. By contrast, the dependent variable is



Adoption of Innovative ICT-Enabled Systems for Analysis- and Intuition-Styled Teachers in Primary Schools, Fig. 1 Research Framework

Adoption of Innovative ICT-Enabled Systems for Analysis- and Intuition-Styled Teachers in Primary Schools, Table 1 Descriptive statistics

Data items	Category	Subjects ($N = 340$)			Percentage		
		All	Intuitive	Analytical	All	Intuitive	Analytical
Gender	Male	66	31	35	19.41%	46.97%	53.03%
	Female	274	153	121	80.59%	55.84%	44.16%
Teaching age	1–5 years	46	23	23	13.53%	50.00%	50.00%
	6–15 years	178	106	72	52.35%	59.55%	40.45%
	16–25 years	92	46	46	27.06%	50.00%	50.00%
	Over 26 years	24	8	16	7.06%	33.33%	66.67%
Education degree	Specialist	43	20	23	12.65%	46.51%	53.49%
	College	176	92	84	51.76%	52.27%	47.73%
	Graduate or above	121	72	49	35.59%	59.50%	40.50%
Weekly hours to use ICT in teaching	0–5 h	178	106	72	52.35%	59.55%	40.45%
	6–10 h	65	32	33	19.12%	49.23%	50.77%
	11–15 h	63	31	32	18.53%	49.21%	50.79%
	16–20 h	24	12	12	7.09%	50.00%	50.00%
	20 h or above	10	3	7	2.91%	30.00%	70.00%

attitude conducive to the intention of ITLS adoption.

Sample

The research population comprised the primary school teachers in a municipality that agreed to participate in the research. The subjects were encouraged to follow the city government's education policy to develop advanced teaching models in primary schools, particularly the ITLS adoption. The city has 49 primary schools and a total number of 2645 teachers. The number of samples for each school was based on the proportion of school teachers to the total number of teachers. Random sampling was conducted to distribute the questionnaires to the class teachers, subject teachers, and administrators. A total of 420 questionnaires were mailed or delivered personally to the schools that accepted participation. The data collection period was 4 weeks. The basic information of the subjects includes gender, teaching age, educational level, and average number of hours per week they use ITLS in teaching.

A total of 340 valid samples were returned (80.95% valid return rate). Of the 340 respondents, 184 were intuitive style and 156 were analytical. Table 1 shows the descriptive statistics. The majority of the respondents were female teachers (80.59%) and most have been teaching for at least 6 years. For the proportion of basic information of the intuitive and analytical types, teachers generally had teaching experiences "within 6 to 15 years" in both styles. Those who teach using the intuitive style account for 58%, whereas 46% employ the analytical style. For the weekly hours using ICT-enabled systems in teaching, most subjects were in the range of "0 to 5 hours," 54% and 45.5% of which were of the intuitive and analytical types, respectively.

Measure

A questionnaire was designed as the data collection instrument (see Table 2). First, nine items were developed for two variables in the technology acceptance composite. For example, the item "I think ITLS can improve my teaching efficiency" is used for the variable of usefulness. Second, for the innovation diffusion composite, three items were developed for perceived compatibility and three for trialability. For example, the

Adoption of Innovative ICT-Enabled Systems for Analysis- and Intuition-Styled Teachers in Primary Schools, Table 2 Questionnaire design

Composites	Factors	Items
Perception of technology acceptance	Perceived usefulness (PU): subjects perceive that ITLS is useful for their teaching work	PU1: I think ITLS can improve my teaching efficiency
		PU2: I think ITLS can improve the quality of my teaching
		PU3: I think ITLS can ease my teaching work load
		PU4: Overall, I think ITLS is useful
	Perceived ease of use (PEU): subjects perceive that ITLS for teaching work is easy to use	PEU1: I think ITLS is not difficult to use
		PEU2: I think learning how to use ITLS does not need too much effort
		PEU3: I think learning how to use ITLS does not need much time
		PEU4: Overall, I think ITLS is easy to learn
Perception of innovation diffusion	Perceived compatibility (PCOM): subjects perceive that they do not have to change too much of their existing behavior or skills while using ITLS	PCOM1: I think using ITLS to teach is similar to the existing tools
		PCOM2: I think the way to use ITLS in teaching is similar to the way I use other tools
		PCOM3: Overall, I think using ITLS is consistent with my current teaching behavior
	Trialability: subjects perceive that trying ITLS is necessary before using it	TRI1: I think it is better to try ITLS before actually adopting it
		TRI2: I think I am willing to adopt ITLS if I am allowed to try it
		TRI3: Overall, I think ITLS should be triable
	Perceived playfulness (PP): subjects perceive that using ITLS is playful and enjoyable	PP1: I think ITLS is interesting.
		PP2: I am happy when I use ITLS
		PP3: I think using ITLS is playful
		PP4: I think using ITLS is enjoyable
		PP5: I think using ITLS can help me explore new things
		PP6: Overall, I think ITLS can enhance teaching playfulness
Attitude	Attitude (ATT): subjects perceive that using ITLS is a positive idea	ATT1: I think using ITLS is a good idea
		ATT2: I think I have a positive attitude toward the use of ITLS
Intention	Intention (INT): users perceive that they will continue (or intend) to use ITLS	INT1: I will be willing to continue using ITLS
		INT2: I am happy to use ITLS now and in the future
		INT3: Overall, I am (will be) sure to use ITLS in teaching

Do you have any comments or opinions on the ITLS adoption? Additional information on your school regarding the use of ITLS is particularly welcome (e.g., policy and strategy) item "I think the way to use ITLS in teaching is similar to the way I use other tools" is used for the variable of perceived compatibility. Six items were used for the variable of playfulness. For example, the item "I am happy when I use ITLS" is used for this variable. Lastly, two items for attitude and three items for intention were used.

Each variable was measured based on the five-digit Likert rating scale (from 1 to 5) using bipolar descriptors for each question. An open question was also provided at the end of the questionnaire for subjects if they have additional information to provide (e.g., policy, training programs). The CSI questionnaire was used to differentiate the analytical subjects from the intuitive ones. For example, "When I make a decision, I will think calmly then carry out and complete all relevant factors" is used for the analytical style. By contrast, "I am better in generating ideas rather than handling data of precise information" is used for the intuitive style.

Results and Discussion

Reliability

Table 3 shows the reliability test results. The Cronbach's α of the overall model was 0.906. The exploratory factor analysis (EFA) using principle component analysis (PCA) was conducted to measure the concepts because the proposed model contained several factors. The PCA and varimax of the orthogonal rotation to derive the factors were utilized. The explained total variance was 79.46%, which is above 60%. Table 4 lists the

Adoption of Innovative ICT-Enabled Systems for Analysis- and Intuition-Styled Teachers in Primary Schools, Table 3 Research variables of cronbach's α coefficient

Factors	Items	Mean	S.d.	Item to total	Cronbach's α
Perceived usefulness (PU)	PU1	4.41	0.78	0.633	0.836
	PU2	4.34	0.80	0.694	
	PU3	4.55	0.64	0.654	
	PU4	4.55	0.64	0.707	
Perceived ease of use (PEU)	PEU1	4.26	0.81	0.711	0.914
	PEU2	4.04	0.96	0.856	
	PEU3	3.96	0.98	0.820	
	PEU4	4.09	0.92	0.839	
Perceived compatibility (PCOM)	PCOM1	4.08	0.86	0.828	0.897
	PCOM2	4.12	0.82	0.861	
	PCOM3	4.44	0.91	0.711	
Trialability (TRI)	TRI1	4.48	0.73	0.698	0.882
	TRI2	4.53	0.72	0.863	
	TRI3	4.50	0.69	0.759	
Perceived playfulness (PP)	PP1	4.40	0.76	0.662	0.843
	PP2	4.23	0.79	0.708	
	PP3	3.27	1.31	0.335	
	PP4	4.06	0.89	0.793	
	PP5	4.12	0.83	0.790	
	PP6	4.09	0.85	0.702	
Attitude (ATT)	ATT1	4.40	0.70	0.813	0.895
	ATT2	4.26	0.78	0.813	
Intention (INT)	INT1	4.34	0.76	0.903	0.963
	INT2	4.32	0.78	0.937	
	INT3	4.30	0.83	0.928	
Overall Cronbach's α					0.906

Adoption of Innovative ICT-Enabled Systems for Analysis- and Intuition-Styled Teachers in Primary Schools, Table 4 Factor analysis results

	Factors						
Item	PU	PEU	PCOM	TRI	PP	ATT	INT
PU 2	**0.795**	0.281	0.109	0.027	0.151	0.021	0.023
PU 1	**0.783**	0.129	−0.009	0.247	0.094	0.016	0.198
PU 4	**0.743**	0.127	0.254	0.172	0.227	0.092	0.214
PU 3	**0.692**	0.035	0.310	0.167	0.267	0.213	0.089
PEU 2	0.129	**0.858**	0.232	0.175	0.156	0.301	0.032
PEU 3	0.143	**0.835**	0.259	0.117	0.188	0.056	0.134
PEU 4	0.127	**0.777**	0.336	0.245	0.202	0.124	0.176
PEU 1	0.259	**0.697**	0.142	0.246	0.235	0.202	0.142
PCOM 2	0.196	0.390	**0.789**	0.219	0.173	0.312	0.302
PCOM 1	0.225	0.385	**0.760**	0.256	0.126	0.213	0.111
PCOM 3	0.214	0.322	**0.662**	0.233	0.313	0.010	0.105
TRI 2	0.189	0.226	0.219	**0.853**	0.186	0.104	0.179
TRI 1	0.107	0.188	0.193	**0.799**	0.131	0.189	0.152
TRI 3	0.267	0.194	0.134	**0.790**	0.229	0.234	0.165
PP 5	0.220	0.211	0.165	0.168	**0.858**	0.316	0.211
PP 6	0.222	0.193	0.138	0.129	**0.834**	0.165	0.079
PP 4	0.186	0.223	0.156	0.249	**0.807**	0.099	0.103
ATT 1	0.201	0.302	0.133	0.221	0.144	**0.889**	0.342
ATT 2	0.214	0.207	0.154	0.187	0.231	**0.884**	0.302
INT 2	0.230	0.198	0.231	0.126	0.244	0.323	**0.919**
INT 3	0.067	0.099	0.199	0.097	0.306	0.362	**0.898**
INT 1	0.091	0.087	0.318	0.213	0.292	0.378	**0.878**

1. KMO = 0.892; Bartlett's test of sphericity: ***$p < 0.01$
2. *PU* perceived usefulness, *PEU* perceived ease of use, *PCOM* perceived compatibility, *TRI* trialability, *PP* perceived playfulness, *ATT* adoption attitude, *INT* adoption intention

details. Factor loading was between 0.662 and 0.919, which is above 0.5.

The model validity test and significance of path coefficient were conducted. For the validity, the model satisfied three requirements, namely, (1) composite reliability (CR) (Cronbach's α) above 0.7, (2) average variance extracted (AVE) above 0.5, and (3) square root of AVE for a factor higher than the correlation coefficient of the other factors. Table 4 presents the test results. The CR value of PU (0.893) was above 0.7. The AVE of PU (0.822 * 0.822 = 0.676) was above 0.5, and its square root (0.822) in Table 5 was higher than the correlation coefficient of other factors. Table 6 presents the results of path significance. The explained variance of the independent variables and the dependent variables were 0.659 and 0.463, respectively, and were considered acceptable. Table 7 presents the test result of the moderation effect. The discussion and implications are provided as follows.

Discussion

Research findings provide several contributions to research theory and practice. The current study describes the research arguments via a basic and rigorous review of literature. This research considers previous theoretical concepts and findings obtained for TAM, IDT, and cognitive styles. The ITLS characteristics are also considered to derive the potential factors that affect adoption attitude, including perceived usefulness, perceived ease of use, perceived compatibility, trialability, and perceived playfulness. This study confirms that perceived usefulness, perceived ease of use, trialability, and perceived playfulness

Adoption of Innovative ICT-Enabled Systems for Analysis- and Intuition-Styled Teachers in Primary Schools, Table 5 Model validation

	CR	PU	PEU	PCOM	TRI	PP	ATT	INT
PU	0.893	**0.822**						
PEU	0.939	0.467	**0.892**					
PCOM	0.938	0.534	0.716	**0.913**				
TRI	0.927	0.482	0.531	0.579	**0.899**			
PP	0.942	0.518	0.525	0.539	0.495	**0.918**		
ATT	0.951	0.634	0.610	0.584	0.624	0.690	**0.952**	
INT	0.976	0.562	0.494	0.547	0.593	0.588	0.681	**0.966**

1. The number in the bold diagonal course is the square root of AVE
2. *CR* composite reliability
3. *PU* perceived usefulness, *PEU* perceived ease of use, *PCOM* perceived compatibility, *TRI* trialability, *PP* perceived playfulness, *ATT* adoption attitude, *INT* adoption intention

Adoption of Innovative ICT-Enabled Systems for Analysis- and Intuition-Styled Teachers in Primary Schools, Table 6 Results of hypothesis test for all subjects

	Dependent variables					
	Attitude toward ICT adoption			Intention toward ICT adoption		
Independent variables	β	t value	p-value	β	t value	p-value
PU (H1)	0.259	6.357***	0.000	–	–	–
PEU (H2)	0.193	4.030***	0.000	–	–	–
PCOM (H3)	−0.015	−0.290	0.772	–	–	–
TRI (H4)	0.234	5.587***	0.000	–	–	–
PP (H5)	0.346	8.306***	0.000	–	–	–
	$R^2 = 0.659$					
	Adjusted $R^2 = 0.653$					
	$F = 128.09^{***}$; $p = 0.000$					
	Attitude toward ICT adoption (H6)			0.681	17.034***	0.000
				$R^2 = 0.463$		
				Adjusted $R^2 = 0.462$		
				$F = 290.16$***; $p = 0.000$		

*$p \leqq 0.1$; **$p \leqq 0.05$; ***$p \leqq 0.001$
PU perceived usefulness, *PEU* perceived ease of use, *PCOM* perceived compatibility, *TRI* trialability, *PP* perceived playfulness

substantially affect the ITLS adoption attitude conducive to adoption intention.

First, the perceived usefulness does have a substantial effect on adoption attitude (see Table 6). Education-supported tools or strategies need multiple channels and media-rich presentation to efficiently bring materials and knowledge into situations where teaching/learning occurs. Although ITLS in cyberspace is increasingly changing the way teachers are pursuing education, the analytical- and intuitive-styled teachers in primary schools likely accept ITLS as one of the important tools to satisfy their teaching needs and wants.

Second, the perceived ease of use for the entire subject is significantly related to the adoption attitude toward adoption intention. However, the moderation test shows that analysis-styled subjects do not support this situation, thereby signifying that these subjects are more unlikely to care whether ITLS is easy to use. On the one hand, the type of analysis style has characteristics in the method of organizing teaching materials, such as concise thinking, logical

Adoption of Innovative ICT-Enabled Systems for Analysis- and Intuition-Styled Teachers in Primary Schools, Table 7 Results of moderation test for the analytical and intuitive styles

Independent variables	Dependent variables					
	Analytical style ($N = 184$)			Intuitive style ($N = 156$)		
	β	t value	p-value	β	t value	p-value
	Attitude toward ICT adoption					
PU (H7)	0.148	2.660***	0.009	0.340	5.899***	0.000
PEU (H8)	0.048	0.539	0.590	0.238	4.168***	0.000
COMP (H9)	0.112	1.288	0.200	−0.052	−0.832	0.406
TRI (H10)	0.203	2.907***	0.004	0.232	4.292***	0.000
PP (H11)	0.466	7.039***	0.000	0.292	5.445***	0.000
	$R^2 = 0.676$			$R^2 = 0.664$		
	Adjusted $R^2 = 0.665$			Adjusted $R^2 = 0.655$		
	$F = 62.61; p = 0.000$			$F = 69.63; p = 0.000$		
	Intention toward ICT adoption					
Attitude toward ICT adoption (H12)	0.743	12.144***	0.000	0.755	12.661***	0.000
	$R^2 = 0.489$			$R^2 = 0.468$		
	Adjusted $R^2 = 0.486$			Adjusted $R^2 = 0.465$		
	$F = 146.472; p = 0.000$			$F = 160.298; p = 0.000$		

*$p \leqq 0.1$; **$p \leqq 0.05$; ***$p \leqq 0.001$
PU perceived usefulness, *PEU* perceived ease of use, *PCOM* perceived compatibility, *TRI* trialability, *PP* perceived playfulness

reasoning, analytical functions, additional attention to detail, structured problem-solving style, and methodical approaches. These teachers tend to be considerably confident in analyzing and organizing teaching materials based on their own perceptions and preferences. However, these observations do not imply that the subjects with this cognition style completely ignore whether ITLS is easy to use. They are likely to be involved in the development of ITLS based on their preferences and may disregard ease of use as an adoption barrier.

On the other hand, intuitive people prefer diverse and less-structured thinking behavior. They tend to be substantially imaginative, empathic, and emotional with respect to the characteristics of the ITLS that they can use (e.g., online talk and animation). This view implies that they prefer teaching with substantial freedom or without excessive involvement in developing or using the ITLS and prefer ICT tools that are easy to use. Therefore, to promote ITLS in teaching, vendors, agents, and consultants should first understand the users' cognitive style. If the intuitive style is substantially dominant, then additional attention should be focused on designing ICT tools that are easy to use.

Third, perceived compatibility is an insignificant factor for the intuitive and analytical groups. Accordingly, the compatibility of perception of the intuitive and analytical styles to the use of ITLS with the existing teaching behaviors is insignificantly linked to their ITLS adoption attitude. A response from a few subjects and their questionnaire responses showed a major reason. The subjects realized that they have to directly accept ITLS for their teaching endeavor because of the school policy. In general, the research subjects of the analytical and intuitive styles are not ICT professionals. ICT is merely a teaching aid. To date, the general use of the ICT experience or personal habits in teaching endeavors may be different for individuals. They have to change their existing teaching concepts and behaviors to adapt to the needs. Therefore, compatibility perception may be quite different with respect to its influence on the adoption attitude of ITLS.

Fourth, the subjects are significantly willing to attempt a teaching tool before they adopt it. Thus, trialability is important to the enhancement of the adoption willingness of ITLS. In general, most elementary school teachers have non-IT-related professional backgrounds. They often have to train frequently and continuously use new technologies to ensure they know how to considerably operate these technologies.

Fifth, perceived playfulness shows a significant effect on the adoption attitude of ITLS. The ITLS or educational strategies need innovative technologies to satisfy the teaching/learning needs of the "e-generation." Accordingly, responding to the needs may require varied media-rich materials to efficiently present educational information and knowledge in general and enjoyment-based learning process to motivate learning attitude in particular. Edutainment that combines education theory and entertainment may be one of the solutions that researchers, vendors, consultants, and government agencies consider for the development of ITLS. Lastly, adoption attitude is substantially related to adoption intention, which is a result that is also true for the analytical and intuitive subjects.

Moreover, the overall results imply that emphasis should be placed particularly on usefulness, trialability, and playfulness to attract the attention of school teachers. Toward this aim, primary teachers can explain that ITLS assists in presenting teaching materials in a media-rich manner, ease the communication with learners, develop an immersive environment, and enhance learning enjoyment, among others. In addition, the intuitive subjects prefer the easy-to-use ITLS, whereas the analytical subjects are unlikely to be concerned with the ease of use but do need involvement in the development of ITLS tools. These findings will be useful for ITLS providers and consultants to analyze the requirements of their school teachers, particularly the consideration for cognition characteristics. Moreover, the result discloses that the analytical and intuitive subjects are not excessively concerned with the issue of compatibility with respect to the effect of adoption attitude. Under the established education policy and strategy as well as the removal of the adoption barrier, this finding can serve as an aid for researchers, vendors, consultants, and government agencies to persuade primary school teachers to adopt ITLS.

Conclusion

Primary school teachers are concerned with technology acceptance and innovation diffusion behaviors as the major determinants of ITLS adoption. Communication between instructors and learners via ITLS is a requirement in knowledge development because connections are established through externalization (instructor side) and internalization (learner side), thereby involving such variables as behavior, cognition, and technology-mediated environment. The cognitive styles were utilized to classify the sampled subjects and the moderation effect was tested to provide additional information on the adoption willingness of ITLS. Additional focus on the result limitations and implications should be provided with respect to the school level and cognition differentiation base.

A transition gap exists in the literature. Such issues as virtual instruction for the knowledge-provider side (e.g., online structural materials based on instructor cognition), ITLS for knowledge development platforms (game-based teaching/learning systems), and virtual self-learning process for the knowledge-receiver side (e.g., personalized materials based on learner cognition) should be considered in future research. Furthermore, the current research conducted a quantitative study without in-depth investigation on cognitive issues from a qualitative perspective. Therefore, a research direction may be a case or multi-case study to report additional findings on ITLS adoption and performance and offer suggestions thereafter for the ITLS vendors and agencies.

Cross-References

- ▶ Leadership on Information Technology in Education
- ▶ Qualitative Methods, Lesson for Information Systems Researchers
- ▶ Teacher Education, Thinking About ICT

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Adoption of Virtual Laboratories in India, Learning Assessments and Roles of ICT Skill Learning Tools

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Synonyms

ICT; Learning tools; Pedagogies; University education; Virtual labs

Introduction

In developing countries, literacy is crucial key for socioeconomic growth, and for achieving sustainable development goals, education platforms enabling remote or classroom didactic education must impact millions of students and teachers irrespective of geographic or infrastructure barriers. With the use of ICT in didactic laboratories, over the last three decades, several online educational tools have promoted enhanced learning and teaching experiences across communities of users (Youssef and Dahmani 2008; White 2008). Addressing the challenges of inquiry-based science learning, some of these ICT tools focus on augmenting skill training and supporting lecture courses with easily accessible online tools that can deliver laboratory skills through computer-based interfaces (Chu 1999; Harward et al. 2008; Diwakar et al. 2011; Heradio 2016). Virtual laboratories have also been presented as complementary education tools and as ICT platforms for sustainable education (Bocconi et al. 2013; Srivastava et al. 2013; Radhamani et al. 2016; Kumar et al. 2017). Besides, in biology, virtualization of wet-lab techniques have improved individualized education and increased the scope for flexible tools for students in remote areas in developing nations (Nair et al. 2012).

In India, government programs (MHRD 2016) for exploring e-learning were initiated for facilitating education for the masses and towards connecting teachers and students in formats including recorded lectures, smart boards, audio and visual tools (Bijlani et al. 2012) and education tools, and mobile applications. Through such projects, there have been a significant number of online laboratories reported for high school education (Nedungadi et al. 2015) and University-level education (Raman et al. 2011; Achuthan et al. 2011; Srivastava et al. 2013; Diwakar et al. 2015; Radhamani et al. 2015). With an entire nation in focus, Virtual Labs project, launched by Ministry of Human Resources Development (MHRD), under National Mission on Education through ICT, Government of India, was set up jointly by top-tier engineering institutes with the focus of developing and providing advanced training environment aimed at solving issues faced classroom laboratory education. This team had designed, developed, and deployed experiments in biological sciences, physical sciences, chemical sciences, mechanical engineering, computer science engineering, and cybersecurity systems.

Virtual laboratories have been developed as multiple content and media models including animations (McClean et al. 2005; Radhamani et al. 2014), mathematical simulations (Parasuram et al. 2011; Murray 2002; Diwakar et al. 2014), remotely controlled hardware models (Ma and Nickerson 2006; Kumar et al. 2014), and analogue equivalents of realistic dynamics (Sridharan et al. 2016). Development (McClean et al. 2005; Diwakar et al. 2014) and deployment of virtual laboratories (Diwakar et al. 2014, 2016a) relate multiple elements connecting didactic education (Sajid et al. 2013; Herga et al. 2016), educators (Donovan et al. 1999; Houts et al. 2006; Diwakar et al. 2011; Svoboda and Passmore 2013), content (Eggen and Kauchak 1988; Sheorey and Gupta 2011), and access modalities (Youssef and Dahmani 2008; Noor-Ul-Amin 2013; Kumar et al. 2015; Alkhaldi et al. 2016).

Virtual Laboratories as an E-Learning Platform in India

Since 2009, we were involved in the development and deployment of virtual laboratories (www.vlab.amrita.edu) to complement classroom courses and accessible freely over the internet. As a consortium, India's Virtual Labs project had developed over 1000+ experiments for undergraduate and postgraduate students and as tools for teachers (Diwakar et al. 2015, 2016b). The target of development of such laboratories was handling insufficiency in numbers of trained experts for educating millions of graduating STEM students, unavailability of expensive hardware or experimental setups, and ability to enable extended access unrestricted by geographical or time constraints (Huang 2003; Diwakar et al. 2012).

The development of content was based on syllabi in most universities and modified to suit teacher-independent education in and outside classrooms (Diwakar et al. 2010; Raman et al. 2011, 2014). India's virtual labs were also developed to cater towards resource or content unavailability and to help teachers and institutions who faced regression in student interests in science and technology experimentation (Diwakar et al. 2011; Achuthan et al. 2011).

Virtual labs were deployed in three modalities. Animation-style labs involved non-interactive or interactive graphical emulations capturing an experiment in terms of manipulating materials and equipment, or the temporal procedure including critical to-dos and do-nots (Radhamani et al. 2014). Simulation-based virtual labs employed mathematical approximations to generate realistic yet computationally feasible emulations of real-world conditions. Simpler mathematical models like logistic growth, predator-prey equation, spiking neuron models help resolve complex biological properties with equivalents for pedagogical benefits (Parasuram et al. 2011; Diwakar et al. 2016a). Remotely controlled experiments enable access to remote equipment and serve as an interface to perform real experimentation or with analogue equivalents serve to virtualize real experiment practice and data collection. Such experiments serve to help reduce accessibility or lab usage issues (Freeman et al. 2012; Kumar et al. 2014, 2015; Vijayan et al. 2017). The national platform consortia had established more than 1000 online experiments and are freely available via http://vlab.co.in.

Comparative Analysis of Virtual Labs

The cost–benefit analysis was estimated by comparing direct and indirect costs of laboratory skill training with and without virtual laboratories (Achuthan and Murali 2015). With an increase in student performance higher than 80% (Achuthan et al. 2014; Achuthan and Murali 2015) in over 40% students using physical lab to around 70% in students using both platforms, evaluations related the efficacy of virtual labs in classroom education.

The study related learning outcomes, time for learning, setup cost, safety, and facility requirements and assumed 800 square feet classroom for laboratory education and appraised 48% savings in tangible costs with virtual laboratories instead of physical laboratories suggesting additional training hours could be cost-effective, if performed on virtual platforms rather than physical laboratories. A cost order of Indian rupees 3 million was shown as a comparison for physical laboratories and virtual laboratories performing chemistry experiments being used in resource-restrained environments. The study also suggests selection of experiments could be based on cost, facilities, safety, time, and learning modalities relating physical laboratory, virtual laboratory, expensive physical laboratory, or remotely controlled laboratory choices. Physical labs and expensive physical labs (with equipment or resources being more uncommon) were not feasible for situations involving large number of student learners. Our study suggested low maintenance yet scalable labs were significantly cost-effective.

Evaluating Virtual Laboratory Usage

Learning outcomes have been shown to be improved by content consumption in addition to quality of learning material (Collis and Moonen 2001; Anderson 2007). Analyzing teacher-student interactions (Chu 1999; Sousa et al. 2010) and the usability of ICT tools (Bocconi et al. 2007; Vilaseca-Requena et al. 2007; Nair et al. 2012; Fathima 2013) such as virtual laboratories have been done across several case studies in multiple modalities (Guma et al. 2013; Achuthan et al. 2014; Kumar et al. 2015).

Another study had taken animations and simulations-based virtual laboratory and had evaluated the relative advantage, ease of use, and perceived usefulness among students and teachers (Diwakar et al. 2014). In technology acceptance model (TAM), usefulness is a criterion representing acceptance by users. The increase in usage also related to representation of general curriculum (Diwakar et al. 2011). Usage/design scalability, deliverability efficiency, network connectivity issues, security issues in developing and implementation online laboratories in biotechnology courses were perceived critical in initial development and deployment of curriculum-specific virtual laboratories in India.

A previous paper (Diwakar et al. 2016a) had focused on the development, deployment, and implementation of 20 web-based virtual laboratories involving more than 170+ online experiments in Biotechnology and Biomedical engineering disciplines on students across villages in India. Pedagogical studies on didactic undergraduate and post-graduate classrooms involving remote labs reported the usage trend beyond scheduled classroom hours and the effective use of remote labs as a learning material towards laboratory examinations. Perceived relative advantage for remote lab users indicated the use of online labs as a next-gen interactive textbook for teachers and students in practical skill education. A small percentage of users reported learning issues in connection with poor internet connectivity and device failures. This implied several practical issues need to be resolved before deploying virtual and remote labs as a massive online course. A study on neurophysiology virtual labs suggested employing ICT-based skill training complemented as a cost-effective methodology for enhancing neuroscience education especially, in financially and geographically challenged nations like India (Diwakar et al. 2014). Remote labs have also been assessed as a self-learning material for robotic education (Vijayan et al. 2017). Using metacognition, analytical thinking, and transfer of knowledge, virtual laboratories in chemistry indicated students showed augmented reflective learning and information retention when virtual labs were introduced before physical laboratory training (Achuthan et al. 2017). Alternate concepts of chemistry students on molecular symmetry were evaluated after students used virtual laboratories (Achuthan et al. 2018). The virtual lab-based study had suggested identifying concept-based learning as relevant for perceiving alternate concepts among learners.

Technology Adoption: Criteria and Design Restraints

Several diffusion-of-innovations theories and models have emerged in order to study community members' acceptance and assimilation of these innovations (Venkatesh et al. 2003). Understanding technology adoption and diffusion of innovation play a vital role in outreach extent of new technologies by determining acceptance factors and new adopters' behaviors. A general framework on the social impact of technologies on people can also provide insight into the characteristics of technology that may influence specific groups to adopt them (Chuttur 2009). Research on innovative technologies in education has recommended several factors including technology design, instructional methods, and students' characteristics contribute to the effectiveness of technologies (Raman et al. 2014).

Laboratory exercises in STEM (Science, Technology, Engineering, and Mathematics) areas often require effective skill acquisition and hands-on roles for sustained skill training. In such scenarios, a virtual laboratory has to be modelled to meet the user requirements, namely: data collection, data measurement, data analysis, equipment handling, discarding biological hazards, use of explosive chemicals, among others. With design of effective learning tools, online laboratories have improved better understanding, facilitated problem-solving skills, and facilitated observation quality in a class of students. This has allowed overcoming challenging aspects of traditional classroom education in geographically and economically backward institutes such as time-constrains and scarcity of laboratory resources for delivering a high-quality education (Radhamani et al. 2016; Diwakar et al. 2016a; Nutakki et al. 2017). Although technology platforms need to account usage time to assess behavioral patterns, there is no significant indication in the literature regarding time users need to spend with an innovation prior to making the decision to adopt it into regular practice.

Dissemination of Virtual Laboratories: An India-Based Model Approach

In 2011, a nodal center program was conceptualized for dissemination and involved induction of science and engineering education institutes partnering to become early adopters of innovation in their regional areas. The induction of nodal centers was based on an institute's interest to join the program and were ensured support and assessment tools. Classroom integration of content and virtual lab methods were introduced to teachers who were part of the nodal center. Workshop-based hands-on training to faculty members was a part of the nodal center program. Assessment tools involved multiple choice questionnaires and descriptive questions for institutions and teachers to assess student's perception of technical concepts and to report the user experience. An annual conference allowed attendees to have hands-on training and opportunities to interact and provide feedback. Nodal centers and its associated students and teachers have been supported periodically with training sessions online and/or onsite. Today, we see a 25-fold increase in nodal centers compared to 2011 and more than a million active usages.

An analysis of technology adoption using Roger's model (Lee et al. 2011) suggests five types of adopters: Innovators (2.5%) were developer universities and institutes of national importance and ranked research intensive private universities. Early adopters (13.5%) included top colleges, large public or state universities and private universities (who became the nodal centers) tending to be opinion leaders in the social system and influenced the decisions of others. Combining the innovators and early adopters gets 16% and these two groups typically gives all the information of the product system. Early majority (34%) included colleges affiliated to universities that were rarely leaders but adopted new ideas and implemented them. Late majority (34%) were institutions that tried innovation after many had already incorporated and tested them. Both early majority and late majority comprise 68% of the adopter categories and their characteristics tend to be similar. Laggards (16%) were a few institutions that were most difficult to be persuaded to adopt innovations and were insignificant diffusers of innovation.

User's Role in Autonomous Learning via Virtual Laboratories

Through feedback-based analysis, studies show students who performed virtual laboratories were able to learn concepts of experiments in an instructor-independent manner implying augmented self-organization abilities among students, facilitating reduced student-teacher interaction within crowded classrooms. Biology and biotechnology students preferred virtual laboratories as a pre-lab material to acquaint the basics of each experiment before practicing it in a wet lab. Workshop participants from India's rural and geographically remote non-city regions perceived remote labs as a distant education tool for equipment training and as a platform that allowed repeated usage of devices beyond scheduled classroom hours. Some issues related to poor usability of the remote labs were correlated to technical issues and inconsistent network connectivity. Deployments suggested low-cost and feasible FOSS-based implementation augmented student-teacher interaction and usage adaptability with remote labs.

Usage data from direct feedback suggested 82% users were able to use and adapted to self-organized learning through an ICT environment. Towards developing a more substantiated assessment of virtual labs, online feedback from 300,000 users received till January 31, 2018, were processed. Around 49,800 valid feedback inputs were evaluated for testing the virtual lab adaptability and its usage in the curriculum of university education in science and engineering disciplines all over the world. Fifty-eight percentage (28,884) of users rated virtual laboratories as an excellent tool for ease of use, 20% (9960) of users rated it as very good, and 18% (8964) indicated as it as a good platform for laboratory education.

A small percentage of users found it difficult to work with the virtual lab experiment and thus they rated the technical support of virtual laboratories as average (2%, 996) or poor (2%, 996). This was related to students who faced connectivity or computer-usage issues while working with virtual lab experiments. Statistics showed that 62% (30,876) users supported the use of virtual laboratories as a complement to classroom education, 15% (7470) rated as very good, and 10% (4980) each suggested it as a good or an average tool after performing the virtual laboratories experiments. A small percentage of users (3%, 1494) rated it as a poor online material.

Among university-level teachers who participated in the remote lab workshop, 84% suggested that advanced technologies like remote controlling of lab equipment were helpful in their classroom scenario, whereas 16% did not favor use of such tools in blended learning. A participating college teacher commented: "Although the remote lab did not feel as real as the actual lab, remote labs allow students (to) practice the experiment many times and compare the results in order to have a better idea. This reduces our efforts in teaching the experimental concepts in the classroom so many times."

Virtual Labs and Extensions

While animation and simulation-based virtual laboratories were apt for most classroom-related practical courses, complementing remote student education may need specific design and deployment considerations while translating usage across regions and disciplines. Assessing trends of usage seem crucial to make such tools reliable for student learners in daily education. Biology students expect media-rich translations for higher usage and engineering students rely on content and interaction-rich environments. Remote laboratories with setup handling were not the most favorite among students in rural India. Such outcomes may also need more extensive testing. Effective learning strategies are yet to be perceived while major focusses have been on assessment of usage and use-related scoring. Our deployment and usage-based studies suggests nodal center outreach as early adopters was effective for curriculum-related laboratory skill enhancement. Although continuous development and constant upgrades and new content are needed, statistics indicates steady increase of new users on virtual laboratory platform suggesting a general acceptance by teachers and students as a complementing laboratory skill-training resource.

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Advanced Computer Human Interactions

► Games, Simulations, Immersive Environments, and Emerging Technologies

Affordances

► Affordances of Technological Connectivist Tools in Higher Education

Affordances of Technological Connectivist Tools in Higher Education

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Synonyms

Affordances; Connectivist tools; Higher education; Social media

Introduction

Connectivism is a learning theory which has been gaining ground in higher education in recent years. Its currency could be attributed to the rapid development of emerging technologies, which has impacted on the ways in which knowledge is produced and accessed (Downes 2005; Siemens 2004, 2009). As a theory, connectivism is often referred to as *networked learning* involving more than just the technology used to achieve the end result (Darrow 2009). Connectivism assumes that “knowledge is distributed across a network of connections and knowledge nodes” (Downes 2012). Social media can be used to connect to some of these nodes of knowledge and facilitate further knowledge development on the premise of collaboration and sharing.

Although much has been written about connectivism since it was first coined by Siemens (2004) and Downes (2005) as a new learning theory, not much has been written about the affordances of connectivist tools for educational purposes. One of the problems with introducing connectivist tools into higher education is that academics are often not au fait with their use for educational purposes (Johnson et al. 2014; Seaman and Tinti-Kane 2013). In order to use these tools for educative purposes, higher educators would have to be inducted into their use in teaching and learning (Johnson et al. 2014; Stevenson and Hedberg 2011). To disseminate knowledge about connectivist tools, it is necessary to provide professional development for academics on the use of these tools for pedagogical purposes (Ng'ambi et al. 2013) and in reporting on how the academics experience these endeavors. As Anderson and Garrison (in press) note, the support needed to help teachers access and organize instructional content through the www is very important. "Teaching in a global, information-rich environment is a very different experience from teaching in a closed classroom." Unfortunately, academics remain uncertain and even fearful about the use of connectivist tools such as social media in their pedagogical practice as doing so requires them to abandon many conventional teaching and learning practices (Adria and Rose 2004). There is thus a need to investigate the use of connectivist tools such as Google Drive, WhatsApp, and Skype from the learner's perspective (Rambe and Nel 2014; Stevenson and Hedberg 2011).

This entry reports on the experiences of a group of university lecturers who were enrolled in an interinstitutional Postgraduate Diploma in Higher Education Teaching and Learning. The group of participants in the study was involved in an assessment task which entailed investigating a specific learning theory and developing a collaborative assignment on this theory. Our particular group was allocated "connectivism" as their learning theory. During the process of completing the task, the group researched on connectivism as a learning theory and used connectivist tools such as Google Docs, Google Slides, Google Forms, WhatsApp, and Skype to investigate and develop their assignment. It was decided during the course of completing this assignment that group members were interested in disseminating their experiences of doing this task and their views on the pros and cons of connectivist tools. Toward this end, auto-ethnographic data were collected through a Google Forms where the participants shared their experiences and perceptions of connectivist tools and their various affordances.

This entry provides a brief overview of connectivism, connectivist tools, and the affordances of the specific tools which are considered in this entry. This is followed by a description of the methodology used, after which the findings are presented and discussed, as well as their implications for the higher education context.

Connectivism

In proposing connectivism as a learning theory for the digital age, Siemens (2004) characterizes it as a successor to behaviorism, cognitivism, and constructivism (Bell 2011). These antecedents to connectivism had their limitations in the form in which they viewed intrapersonal learning; their failure to address the learning that is located within technology and organizations; and their lack of contribution to the value judgments that needs to be made in knowledge-rich environments (Siemens 2004). Connectivism offers the platforms to shift teaching and learning practices in the twenty-first century.

In connectivism, learning takes place when learners make connections between ideas located throughout their personal learning networks, which are composed of numerous information resources and technologies (Dunaway 2011). One of the underlying principles of connectivism is that the capacity to know is more critical than what is currently known (Siemens 2008; Wang et al. 2014). Connectivism is driven by the understanding that decisions are based on rapidly altering foundations, where new information is continually being acquired and shared (Siemens

2004). From an epistemological point of view, learning in connectivism takes place by connecting to different nodes of knowledge across cyberspace, objectively analyzing and reviewing the gained knowledge. This process is aided through critical discussions and social interactions using social media. Technology used was blended in the form of cloud, social network, online voice integration, in this entry enhanced real time communication among participants and provided a platform for social creation of knowledge (Callaghan and Bower 2009; Rowe et al. 2013).

Connectivist Tools

Connectivist tools are used for learners to interact by creating and sharing knowledge, and are based on emerging or Web 2.0 technologies, made possible through the social web (del Moral et al. 2013). Shared working spaces for collaborative projects such as Google Drive and its various tools, such as Google Slides, Chat, Docs, Forms, etc., and WhatsApp and Skype for communication are some examples of connectivist tools which can be used for teaching and learning purposes. Through these connectivist tools, the learner is able to become an active and visible node in the learning network, contributing resources and ideas and participating in the collaborative creative process (Pettenati and Cigognini 2007). A clear implication of using connectivist tools and other social media is that the learners should be "active co-producers" of knowledge rather than "passive consumers" of content and subsequently that learning should be participatory (Selwyn 2012). Establishing how higher educators and learners perceive connectivist tools and how they understand the affordances of these tools is important for enhancing their use for educational purposes (Rambe and Nel 2014).

Affordances and Connectivist Tools

In recent years, the term "affordance" has increasingly appeared in educational literature, especially related to the use of online technologies in education (Bower 2008; Conole and Dyke 2004; Day and Lloyd 2007; Gee 2014). In order to understand how attributes of online technologies interact with other elements of a learning context, including learners, teachers or educational practitioner, and the physical environment, it is necessary to understand affordance theories (Day and Lloyd 2007).

"'Affordance' refers to the perceived and actual properties of a thing, primarily those functional properties that determine just how the thing could possibly be used" (Salomon 1993 cited in Conole and Dyke 2004). When considering how to match learning tasks with technologies, it is useful to have a knowledge of the affordances of the technologies (Bower 2008). The term "affordance" was coined by the ecological psychologist Gibson (1977) and adapted by Norman (1988) for the design of everyday objects who distinguished between "real" and "perceived" affordances (Day and Lloyd 2007). In the original description that Gibson provides, an "affordance" is present as long as the organism is physically able to undertake the required action and as long as the possibility of executing that action is present (Bower 2008). In other words, affordances relate to the *action possibilities* (Gee 2014) that exist for connectivist tools. Affordances are therefore relational in that they concern the opportunities a connectivist tool offers and provides for action and how these qualities are taken up by the person using it.

Real affordances are not nearly as important as perceived affordances which signal to the user which actions can be performed and how they may be accomplished (Bower 2008). Gibson (1979) and James Paul Gee (2014) take this important point on perception of affordances forward by observing that unless an individual can *perceive* the possibilities connectivist tools provide, these tools are unlikely to be used effectively. In order to take advantage of the affordances or possibilities of a connectivist tool, "*effectivities*" are necessary (Gee 2014; Gibson 1979). Effectivities are "the set of capacities for action that the individual has for transforming affordances into action" (Gee 2014). These effectivities are thus necessary for academics and students using connectivist tools in educational contexts so that they can be used in ways which take the learning forward. This is why it is important to engage with academics and students around the use of these tools for pedagogical purposes. Thus, the concepts "affordances" and "effectivities" are relational in that they are dependent on both connectivist tool and the ability and perception of the academic or student to use the tool for educational purposes.

This study sought to investigate was how the affordances of connectivist tools for teaching and learning were perceived by a group of learners who were educators in institutions of tertiary education. Specifically, the tools under examination were Google Drive, WhatsApp, and Skype.

During the course of engaging with the task, the group members became interested in the efficacy of utilizing connectivist tools to prepare and complete their assignment, particularly since they were located in geographically disparate spaces. The formal work of the assignment was conducted on Google Slides presentation, with collaborative writing and posting of graphics from group members and feedback to each other in the comments and chat boxes on the side. A Google folder for readings was uploaded for any useful texts that group members and the facilitator were able to source. In order to gather data for the study, a Google Forms questionnaire was sent to all group members, including the facilitator. At the same time, through the narrative, the participants were able to reflect on the experience. Auto-ethnography is defined as a qualitative research method that uses data about self and its context to gain an understanding of the connectivity between self and others within the same context (Ngunjiriet al. 2010). The auto-ethnographic researcher strives to examine his or her experiences in relation to others who have encountered similar circumstances as a way to identify a pattern, theory, or thread inherent to the group (Raab 2013).

The responses from the participants resulted in the close scrutiny of the affordances of the connectivist tools used in the assessment task, in terms of what the possibilities that various tools were able to provide or not provide for the purposes of completing the assessment task given to the group.

Collaboration

The use of social media was perceived as enabling group collaboration and the ability to complete tasks assigned to group members, particularly since members were geographically separated. Rambe and Nel (2014) also noted that educators in the South African context reported on the opportunities that social media present for collaborative purposes. One of the participants commented, "from my experience, the use of these social media (i.e., WhatsApp, Google Docs) was an important aspect for the successful completion of the assignments (1&3)."

Familiarity with Connectivist Tools

One of the participants, who came from fields such as Information Sciences, indicated his familiarity with the use of social media: "Exposure and deep knowledge of IT made it easy for me to use social media." Another participant found Google applications to be well designed from a technical viewpoint and was able to express this eloquently:

> Google drive, presentation and docs are very user friendly. Google has been great by not attempting to redesign the interface, but rather use an interface that is familiar to most users. This makes all google applications easy to figure out and follow. The use of a great, simple intuitive interface is in my mind the key to their success and why I like using those platforms.

Participants found the use of tools for educational purposes to be more conducive when they were familiar with them, "WhatsApp was easy as I am familiar with it." Conversely, when participants had not used the tool before or were unfamiliar with it, they found that their participation in the group activities was impeded, "Google presentations was not as easy to use as PowerPoint (which I am used to) as it was a bit slow and froze at times which was frustrating and it was unfamiliar."

The Personal and Professional Boundaries with WhatsApp

The fact that participants found WhatsApp an easy connectivist tool to use did not mean that there were no problems with its application for educational purposes. Because participants were used to using this tool for social and personal purposes, participants found it more difficult to confine the discussion to educational matters. Rambe & Bere (2013) and Madge et al. (2009) have also noted the difficulties in traversing personal and professional boundaries in relation to mobile learning, similarly with Facebook for learning. One participant observed:

> When it comes to WhatsApp use, it was the easiest of the tools as most people who own smartphones would utilise it on a day to day basis. That being said, the fact that it was easy to use, does not mean that it was not challenging to control what was being discussed.

Google Docs and Presentations, on the other hand, were not familiar to all participants, and they related these tools more with the tasks at hand than with socializing with their peers:

> Google Docs and Presentations were new media platforms for me. I truly enjoyed learning about their potential use. Between the two I would say that Google Presentation was the most challenging as there are many options one could make use of.

Skype was also a familiar tool to most participants who had used it to communicate with others across geographical distances. Skype is a familiar social media platform for me, although I rarely use it.

Uneven Communication Through Social Media

Participant 1 and Participant 2 were great at communicating and interacting and drove our group assignments – I am grateful for this. Due to the distance, it was not easy to interact with Participant 3.

> As can be seen in the above quote, some participants took more responsibility than others and made far more use of the connectivist tools to work on the task, 'I tend to take the reins of group work when things are not going according to the original plan.' Two group members took a leading position when working on the assignment - as one of them noted:
>
> We had frank conversations about the course and the assignments. I always felt we had a good synergy. The other two members were a bit more distant in terms of the way we engaged but towards the end of Assignment 3 we had managed to establish a good rapport

Affordances of Tools as Perceived by Participants

The affordances of the different connectivist tools which were used regarding matching the teaching and learning tasks which the group members had to complete, and the processes involved in doing them, were commented on by the participants. They examined the attributes of the connectivist tools and what they made possible in terms of the group communication and abilities to collaborate on the course assignments.

Social Media

Group members were working academics who had little time to meet face-to-face with their work and family responsibilities, and social media provided a flexible platform for communication under these circumstances.

> We only met face-to-face a few times, most communication was done via WhatsApp and the Google drive. There were times I realise I could have been better at communicating, this was due to pressures relating to work, home responsibilities and the course and having to prioritise each of these at different times.

WhatsApp

WhatsApp was seen as providing group members with immediate notification (Church and De Oliviera 2013) and coordination of upcoming deadlines: "With WhatsApp, the messages are instant although there is no face to face." Another member commented on the fact that WhatsApp was not used to engage with the task but to arrange meetings and alert people to what was happening currently and what was being planned in the group:

> WhatsApp was mainly used as an organizational tool with little to no interaction about the topic or task at hand. This I mainly ascribe to the laborious nature of entering text on a cellphone. But WhatsApp did provide social interaction promoting motivation and group coherence.

Google Drive

The Google Drive was used for working collaboratively on the task at hand both synchronously and asynchronously. The Google platform provided a much better platform for task-oriented interaction. The interaction taking place while all simultaneously working on the same project was amazing as interaction and comments in real time. However, our interaction was also asynchronous via comments and replies. Similar affordances of Google Drive were found by Rowe et al. (2013). Participants were highly enthusiastic about the affordances of Google Drive for the educational task:

> The best platform for interaction was Google presentation with the built-in chat facility for task orientated learner-learner interaction. The reason it is so effective is because it has the chat function which allowed real-time chats, input, I think the true reason it was the most effective tool is because we were actually working on the task, thereby the conversations were guided to be task orientated and generally didn't shift into the social paradigm like WhatsApp for example. In addition, Google presentation allows for the asynchronous communication in the form of comments and input to which one can respond to at any time removing the time constraints. Furthermore, the comments are left directly on the task, making it easy to follow the meaning. Often in emails it becomes difficult to figure out exactly to what the comment pertains in particular if its attempting to address issues of formatting.

Google Drive was seen as the most useful tool for a number of different aspects of the task. In the participants' descriptions below, the accessibility, view-ability, read-ability, write-ability, share-ability, collaboration, move-ability, large size-ability, upload-ability, dialogue-ability, accessibility, synchronicity, revision-ability, browse-ability, search-ability, build-ability, communicability, and interaction-ability are mapped out:

> We could access the material from any location as well as share information among the rest of the peers.
>
> Google drive allowed for uploading of large file sizes and instant feedback that involved commenting electronically. There was online collaboration of work activities among the group members involved in the project.
>
> I think Google Drive was great to build and develop learner-content interaction. We could access the material from any location as well as share information among the rest of the peers
>
> Google Drive was great to build and develop learner-content interaction. We could access the material from any location as well as share information among the rest of the peers.

For some participants, while Google Drive had many affordances, it was not sufficient altogether to accomplish what needed to be done. Some participants noted that they needed to do individual work to prepare for the collaborative work in groups:

> group engagement with the content occurred in the creation phase on Google presentation, but it was often not in depth. The more in depth discussions occurred face-to-face.
>
> Some form of content interaction occurred on Google presentation, but I think the majority of interaction with the content in my case occurred by reading and analysing pdf and word documents myself, in other words individual content engagement.
>
> Google drive was where we could access useful and relevant content. I did however find a lot of articles and papers through my own searches online.

Skype

Skype was the choice of tool to have more extended conversations between group members who were distantly located geographically: "I used Skype for conferencing with group members at a distant away from the physical venue." However, Skype was not perceived by participants as being reliable in its communicative affordances:

> Skype is a platform I find least useful. There are always problems with connection particular when

> more than two people want to engage in the conversation. Often it is difficult to hear and there is always someone that is not sure on how to connect. Therefore, I rate Skype as being a difficult platform and avoid using it as a tool unless there is no other option.

Participants perceived connectivist tools used in this study, viz., WhatsApp, Google Drive, and Skype, to have various media, spatial, temporal, navigational, and accessible affordances for the task they were required to complete. These tools provided different affordances needed to complete the task – WhatsApp for alerting members to what was happening, Google Drive for collaborative work on the task, and Skype for verbal conversation and planning regarding the task.

Conclusion

This entry aimed to explore the perceived affordances of connectivist tools for a Higher Education Postgraduate Diploma course. The auto-ethnographic data of the author of this entry corroborate Bryant et al.'s (2014) observation that the use of connectivist tools can make a significant contribution to learning through their affordances which enable social interaction, connectivity, and support of collaborative practices. However, the adoption of connectivist tools may be thwarted on both an institutional and individual level if the perceived affordances of these tools are not made explicit and if personal and professional boundaries become too blurred (Bryant et al. 2014; Madge et al. 2009). The core assignment on this course was designed in such a way as to encourage the creation of a product by the group of higher educators who were part of the interinstitutional PG Dip teaching and learning course through the use of social media platforms such as Google Drive. However, if the affordances of connectivist tools such as WhatsApp, Google Drive, and Skype are to be actualized for educational purposes, they must be accompanied by effectivities of academics and students in terms of their abilities to recognize and use the tools for teaching and learning.

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Agile Methodology

► Agile Methodology in Education of IT Students, Application of

Agile Methodology in Education of IT Students, Application of

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Synonyms

Agile methodology; IT education; Kanban; Project work; Scrum

Introduction

In recent years, the world has become much more complex and unpredictable. A special acronym "VUCA," meaning "volatile," "unknown," "complex," and "ambiguous," has even appeared to describe it. The situation changes unexpectedly and rapidly, the crisis becomes the norm of life, and the rate of change inexorably increases. In modern management, the implementation of projects that respond flexibly to the demands of a volatile market is receiving increasing demand.

This VUCA world requires employees able to apply Agile principles to their work. Training in the Agile approach has become common for employees and leaders of large companies but also the governments such as Norway and New Zealand. Agile method education has been introduced at many universities including Cornell University and Northern Arizona universities.

Definition

The word "Agile" has many meanings. The English dictionary definitions include:

- Quick management (Gaponova and Kulin 2016)
- Flexible management (Evseev et al. 2016.
- Active, surviving (Chernykh 2008)
- Agile, lively, fast, moving (Babaev 2016)

By studying the current literature on the Agile topic and opinions of professional experts, it is concluded that there is no precise definition of "Agile" methodology in project management. So it is necessary to consider the most vivid variants of the term "Agile."

Gaponova and Kulin write that Agile represents flexible management that reacts quickly to changing meso-, macro-, and mega-changes and adjusting economic policy in accordance with changing conditions (Gaponova and Kulin 2016).

Talking about Agile software development, it is a range of different incremental and iterative software engineering methods that are advocated based on an "Agile philosophy" mentioned in the Agile Manifesto (Fowler and Highsmith 2001).

The iterative approach involves splitting the project lifecycle into a series of iterations, each of which resembles a "mini project," including all phases of the software lifecycle in application to creating smaller fragments of functionality, compared to the project as a whole. The goal of each iteration is to get a working version (release) of the software, including the functionality of all previous and current iterations. The final iteration result contains all the required functionality of the product. Thus, with the completion of each iteration, the product develops incrementally.

Lifecycle of this model allows to classify this model as iterative and in terms of product development – incremental (Defazio et al. 2014).

It is worth noting that Agile software development methods first appeared in the early 1990s, and IT companies were the first to show interest in this methodology. Many of these companies were interested in Agile methods and its application in the companies (Jovanovic et al. 2017).

The use of Agile software development led to changes in the project work in companies, as well as in the results of project implementation, which is a significant advantage of this approach in comparison with traditional (Dingsoyr et al. 2012; Stettina and Hörz 2014).

Considering the various tools of project management, Agile methodology emerged as the first of them, and other tools were formulated on the basis of it.

The most famous for this philosophy was after the adoption of the "Manifesto of a flexible methodology for software development" (Agile Manifesto). This document contains the basic principles that are characteristic of Agile philosophy in project management.

The main ideas of the Agile Manifesto are as follows:

- Individuals and their interactions are more important than processes and tools. In other words, the project team in the Agile philosophy is much more important than the formalization of the processes, because the results of the project depend on it.
- Running software is more important than full documentation. This principle suggests that it is more important to create a working product that fully meets the needs of the client than simply perform a number of works under the contract, not paying attention to the result itself.
- Cooperation with the customer is more important than contractual obligations. It is more important to communicate with the customer and clarify the contentious issues, than work under the contract.
- Responding to change is more important than following a plan. This is also an important principle, because Agile philosophy is a flexible methodology that allows for easy changes to the project, despite formal requirements (documentation, contracts, etc.). During the project, the customer can make adjustments to the product, and the project team accepts these changes.

The Agile Manifesto was written in 2001 even though the start of Agile methods can be traced back to 1957 (Larman and Basili 2003). In the mid-1990s, the so-called "light methods" of project management appeared as an alternative to "heavy methods," such as the V-model, the cascade model (Waterfall), and various variants of the stage-gate models. Such models were called "heavy" because of a large number of necessary project documentation, a lot of formal control procedures, and verification of project implementation, which significantly complicated the design work and extended the implementation period. Therefore, the authors of the Agile Manifesto decided to fix the principles of work on Agile flexible methodology in one general document (Grimheden 2013).

Evseev et al. in their article note that Agile defines the basic values, rules, and principles on which flexible project management methodologies are built, such as Scrum, Kanban, Lean, and others. The presented methodologies can be used both together and independently of each other. Refactoring, iteration table, sprints, retrospective, quick meetings, division into roles, etc. are all tools that can be implemented in any project team where the Agile approach will be applied (Evseev et al. 2016).

Speaking about the application of Agile in the IT field, a flexible development methodology is implied as a series of approaches to software development based on the use of iterative development and the dynamic formation of requirements and ensuring their implementation as a result of constant interaction within self-organizing working groups consisting of specialists from different fields (Lopatin 2012; Ildemenov 2016).

Akmaeva et al. argue that the Agile methodology is a set of approaches to software development that is built on the principles of teamwork, speed, lack of formalism in communicating with the customer, and flexibility in changing the initial plan of action (Akmaeva et al. 2017).

Agile is a time-boxed, iterative approach to software delivery that builds software incrementally from the start of the project, instead of trying to deliver it all at once near the end (http://www.agilenutshell.com/).

Martin Christopher says that Agile is a system of building work in the company, which makes changes in organizational structures, in information systems, in logistics processes, and in the way of thinking of employees. Flexibility is the main characteristic of such businesses. Indeed, the origin of flexibility as a business concept lies in flexible production systems (FMS) (Christopher 2000).

Another significant definition was given by Fowler and Highsmith that Agile software development is a set of iterative and incremental methods of software development that are promoted on the basis of the "Agile philosophy" captured in Agile Manifesto (Fowler and Highsmith 2001).

Despite the fact that in the main repacking and re-branding used to be well proven in the development of good software, flexible movement can be considered as an alternative to the so-called traditional methods of software development. Traditional methods focus on pre-planning and strict change management, but flexible methods have been developed for adoption and effective change management (Highsmith and Cockburn 2001).

The Need for Agile Methodologies

The two most popular Agile methods are Extreme Programming (XP) and Scrum (Hamed and Abushama 2013). Scrum is a method focused on the point of view of project management on flexible development (Schwaber and Beedle 2002), appointment of time, continuous tracking of project progress, and customer focus. The XP development method is a set of practices to ensure effective gradual development. In practice, many flexible development projects combine them in two ways (Dikert et al. 2016).

There are several methodologies for project management. The most widely known and long used is the cascade model (waterflow approach). It is defined as the work flow, passing the successive phases of analysis, design, implementation, testing, integration, and support (Evseev et al. 2016).

This model is more suitable for large projects that are performed for a long time with the involvement of a large number of employees of different positions and functions. It is important to note that the distinctive feature of the cascade model is the execution of each next stage after the previous one has been performed.

Consider the main advantages of using the waterflow approach. Such a project is easily controlled by the customer due to the rigid formalization of all processes, where each type of work is transparent and consistent. In addition, such transparency leads to more cohesive teamwork due to the fact that each team member knows his area of responsibility and the task pool, which also positively affects the success of the whole project. Such rigid management of the project allows you to accurately estimate the cost of the project and each of its individual stages and determine the timing of each task. This allows you to forecast the necessary costs and financial benefits from this project.

Each methodology of project management is not ideal and has its drawbacks. The main negative point in the cascade model is the lack of flexibility when making changes to the project. Hard formalization of all processes does not allow to quickly changing the elements of the project, which negatively affects the time of its implementation. Even the slightest changes require the whole project or part of it to stop before making the necessary changes to the project documentation. Many project management experts criticize this cascading approach for excessively formal project management, which adversely affects the timing of its implementation, the budget spent, and the quality of the finished product (Evseev et al. 2016).

History of Agile Methodologies

Approximately 10–15 years ago in IT sphere, there appeared another methodology of project management – Agile methodology or spiral model.

Initially, it was thought that the way to production flexibility was provided by automation in order to ensure a rapid change and, thus, greater responsiveness to changes in the range or product volume. Later, this idea of production flexibility was expanded in the broader business context, and a concept of flexibility as an organizational orientation emerged (Christopher 2000).

Agile methods were originally intended for usage in small projects with a single team (Boehm and Turner 2005). However, its demonstrated and potential benefits made them attractive beyond this context, especially for large projects and in large companies. This is despite the fact that they are more difficult to implement in big projects. Compared with small projects that are ideally suited for rapid development, larger ones are characterized by the need for additional coordination. A particular problem with large projects is how to handle coordination between teams. Large-scale flexibility is associated with additional problems in dealing with other organizational units, such as human resources, marketing and sales, as well as product management. In addition, large scale can lead to the fact that users and other interested parties will be removed from the developers. Despite these known problems associated with large-scale flexibility, there is an industry trend toward the introduction of flexible methodologies in general (Dikert et al. 2016).

An important question is raised by many researchers as to what benefits the team or company receives from the use of flexible technologies. According to the 11th Annual State of Agile Survey, the companies get the following benefits from Agile application:

- Ability to manage changing priorities. In today's rapidly changing world, this characteristic is one of the keys for these companies.
- Quickly make changes in the business processes in the company according to the new data from the market. Agile allows flexible companies to remain on the market and be ahead of competitors.
- Increased team productivity.
- Improved project visibility.

Agile methods become the most commonly used in the software industry. Annual surveys have shown that the use of Scrum has increased over the past few years. According to the Annual State of Agile Survey, in 2016, the percentage of respondents' organizations that practice Agile amounted to 94%.

Knowledge of Scrum is critical for most companies, as it emphasizes the importance of team effort and social activity in software development. Scrum is often used in project management projects and includes monitoring and support, which provides transparency (Mahnic 2011; Coupal and Boechler 2005). This advantages allow the use of Scrum reducing the gap between the skills taught in academic contexts and the requirements imposed on the software industry (Rodriguez et al. 2015).

With the growing popularity of Agile software development methods, the software community has faced a new challenge. Most Agile methods "pay very little attention to overall architectural activity" (Babar 2014). For example, Kent Beck views architecture as emerging and evolving in everyday design (Beck 1999). Kruchten et al. predict that "the software architecture will be recognized as a key basis for Agile software" (Kruchten et al. 2006). The question of how much architectural effort is required in flexible projects was rated as "the second, burning issue facing Agile practices" (Freudenberg and Sharp 2010).

The relationship between Agile methods and the software architecture in education has not been sufficiently studied in the literature. Cleland-Huang et al. represent an approach to the study of software architectures in Agile projects in education (Cleland-Huang et al. 2014). This approach focuses on the design phase of the architecture in Agile projects and, in particular, on the role of stakeholders, but does not affect the actual dynamics of this Agile project (Angelov and Beer 2017).

Angelov and Beer (2017) present an approach to the implementation of software architecture in Agile education projects and share our experience with two successive application approaches. The strategies chosen for the implementation of architectural measures proved to be mostly effective. Using our approach, students perceive the value of architectural actions and view the access as an addition to the Agile software. They appreciate the avant-garde activity in building architecture, although they perceive it as a slight deviation from flexibility. The realism of this approach requires additional attention. It was applied mainly to architecturally savvy software, while in practice, the software often does not understand or appreciate the architecture activities performed in the projects. In the future work, it is necessary to study the types of problems that an architect and Agile teams face when working with architecturally uncoordinated software and the approaches they can perform to facilitate them (Angelov and Beer 2017).

Teamwork is one of the key competencies that students must acquire to be competitive in the labor market, as enshrined by the European Higher Education Association (EHEA) (Noguera et al. 2018). The ability to work in groups is of particular importance, since today many tasks are too complex and too large to be performed by one person. Many studies show that the use of teamwork in learning increases students' motivation to gain new knowledge and experience (Laux et al. 2016). Students have to learn to cooperate fruitfully with each other and to independently organize work in group (Miller and Hadwin 2015; Tseng and Yeh 2013).

The flexible methodology of Agile project management is becoming very common in tertiary education. Lecturers advance Agile methodology, especially a scrum in educational process that will allow students to use the gained knowledge in practice in the real companies (Scott et al. 2014).

Many large companies note importance of training in Agile methods at various business schools. The strategy of large companies such as British Telecom and IBM is directed to use of flexible technologies in all business (Grout and Bonham 2012). This is also true of many companies not in the IT sphere who also actively apply Agile principles of work in the business. It is possible to give the Government of Great Britain (the review of the NAO 2012), the US Government (the report of GAO 2012), the banking sector as examples (Sarran 2012), the pharmacological industry (Fitzgerald 2012), and many other branches (Cubric 2013).

Agile Methodologies Course Example

Kropp and Meier have conducted survey of 103 students to understand the efforts they spent in projects for project management, programming of a product, and drawing up necessary documentation (Kropp and Meier 2013). The result of the poll has shown that a lot of time and work has been spent for management and documentation preparation. Also students have noted that during implementation of student's projects, they have gained much more knowledge and competences, than at ordinary lectures that has also positive effect in educational process.

Besides these competences, flexible values which are sounded in the Agile Manifesto (http://agilemanifesto.org/) are important. The mutual respect, openness, and courage are examples of such flexible values (Kropp and Meier 2013).

The course on program engineering on Agile methodology which is submitted in the work of Kropp and Meier can be an example of the application of Agile education. This discipline was carried out for students of a bachelor degree and lasted one semester (16 weeks) with a total of 120 h. The number of students was 27 people. Within the course, a 2-h lecture for all students and a program seminar for a half of students were given every week. Work is implied in teams from six to eight people. The complete project of programming Java created with the use of flexible methodologies was the result of the development of a course.

In the part one titled application engineering the practical – at the first two lectures has been given to students' introduction to extreme programming (XP). The extreme programming and Agile Manifesto methods were discussed. In seminars, each student has finished assessment of coding and has received comments.

While the students were working individually or in small groups in part one, part two was different – the Agile game was played in the classroom. The students must be members of a "real" scrum team to really understand how scrum works. Since this is not possible in the classroom, the scrum team was simulated in the student project. The student project purpose was to develop a 2D computer game applying all needed engineering practices. The students worked in four scrum teams of six to eight. Each team was free to decide what kind of computer game they wanted to develop. One student was voted scrum master; the lecturer was the product owner. The teams completed six 1-week sprints. Every week during the workshops, each team did the sprint planning, sprint review, and retrospective coached by the lecturer. During self-study, the students developed the actual game. In the last week, all the teams could demonstrate a working game.

Agile values (Agile Manifesto) are difficult to teach. The approach in this course was to present to the students that these values are not just something the developers of the Agile Manifesto intended to give lip service to and then forget. They are working values. The Agile value concepts were introduced in the first part. Usage of the values was propagated in the second iteration through means like retrospectives, common code ownership, or pair programming. Many discussions during the lectures and workshops tried to transport that message (Kropp and Meier 2013).

Development of an Agile training course is also important process in the higher education since depends on competently built course knowledge and skills of this approach gained by students.

Ingrid Noguera et al. describe creation process of such subject matter in the work. Two online and three personal meetings have been held for construction of the new training course. An important point is Google Drive usage and the Dropbox instrument for sharing the files in the course of creation of documentation of a new Agile course. After definition of the new scenario, the introduction process has begun in autumn and spring semester of academic year 2015–2016. The new course has been tested during two consecutive semesters. After each iteration, the design was estimated on the basis of notes and opinions of the teacher (collected through two interviews) and opinions of the students (who are brought together through two polls held at the end of both semesters). Based on assessment, minor changes have been applied to design which have been simply directed to providing more accurate recommendations for students (Noguera et al. 2018).

In 2011, in KTH Royal Institute of Technology, Switzerland, it was offered to five student's projects on mechatronics to use a scrum in implementation of projects. 37 students, 5 companies, and 10 teachers have participated in this experiment. In total, five design teams have been organized. The working product prototype has acted as a result of project work of college teams. The application of an Agile methodology in project work of students teaches bigger flexibility to cope with a difficult task when developing a product in the sphere of mechatronics. Besides, flexible methodologies allow carrying out IT projects quicker and more qualitatively. Universal introduction of an Agile and scrum at the university is complicated by complexity of refusal of the traditional work principles of design team and the fact that mainly flexible methodologies are used when developing IT projects today (Grimheden 2013).

Cubric in the entry gives an example of Hertfordshire Business School where since 2007 the discipline “Flexible project management” within training of masters in the sphere of project management has been entered. The main course objective is providing to students practical experience of application of flexible technologies. Within this discipline to students offered to create the Internet the page on training in flexible approaches, using the Wikipedia platform. In total, the project has included five iterations (sprints), and each sprint lasted 2 weeks. In each design team are cast as follows: one student carries out a role the master’s scrum (scrum master is appointed by other team participants), and the others are performers. The scrum master’s role consists in ensuring effective teamwork, carrying out regular sprints, and preparing reports on the done work at the end of each sprint.

Within the next 3 years, students gave feedback about this course specified by positive sides of discipline – regular and operational feedback about the project implementation, the interest of the teacher in a subject, and a practical orientation. One of course problem is unavailability and inability of some students to work in team that is implied by flexible approaches (Cubric 2013).

Erturk and Mac Callum (2015) have presented in their article interesting ways of flexible technology application in the educational program of IT specialties in a higher educational institution in New Zealand. In the first case it is described how students acquainted with flexible practice within discipline the system analysis at which more than 30 students studied.

The second research was directed to applying of practice within discipline the user interface where flexible Agile methodology has been used for assessment of course passing.

The main motivation of such experiments is to acquaint students with flexible approaches and to show that they can face them in practice, in the real company. Therefore, it is necessary in advance to study and try to use what will be applied in future work of students.

Therefore, the lecturer used this course as an opportunity to acquaint students with some concepts and approaches of flexible development in branch. The purpose was not in completely to imitate Agile, and it is rather to give to students the chance to see how these methods can be built in system development. The main attention was concentrated on studying and use of the UX/UI methods, while they have also tested how flexible approaches can support its work (Erturk and Mac Callum 2015).

Kamat and Sardessai present the principles to the Agile Manifesto adapted for use for flexible approaches in education in the article. Their option of the principles of this code looks as follows:

- Teachers and students are much more important than administration and infrastructure.
- The competence of the team and their cooperation are more important than observance of regulations and the competition.
- The involvement into work and competitiveness of a product are more important than the plan of work and the set indicators.
- The relation to the project and skills of training are more important than abilities and education (academic degrees).

The flexible manifesto in education can be applied in all main spheres of educational activity with assistance of ICT. It is expedient to teach some disciplines to students of different specialties. For example, the course on geometrical modeling could be taught in common in the field of computer sciences, mathematics, and mechanical engineering faculty. All cooperation has to be facilitated by means of a learning management system (LMS). At the same time, students can find all training materials on available free resources in the Internet that unifies a discipline course. It is promoted by appearance of the Web 2.0. In that case, teachers can spend more time for practice.

Also Kamat and Sardessai declare in their article that it is necessary to approach modern information technologies in the training course, for instance, to suggest students to pass the small test on the passable material on their phones at the beginning of the occupation. Thereby, the student's motivation to digestion of material increases. In general, authors say that it is important to transfer all system of the higher education to the flexible half-courses and to take modern IT tools (Kamat and Sardessai 2012).

Pozenel and Mahnic describe how the checklist was used for design of empirical studies with students (ESWS) at computer and information sciences faculty at the University of Ljubljana, Slovenia, for the purpose of assessment of two most widespread methods of flexible assessment, that is, planning poker (PP) and team estimation game (TEG). The research is conducted within a training course on the development of the software in which students have to work in teams to develop the project, strictly following Scrum.

The capstone course at the University of Ljubljana teaches students to the software flexible development, in particular scrum, on the basis of practical command projects. The course lasts 15 weeks and is accepted by student's information scientists in the last (sixth) semester. Students have to work in groups to develop the real project on the basis of requirements of the users provided by the expert of the domain playing a role of the product owner.

The course design is based on scrum structure and consists of four sprints. The first sprint (which is also called by Sprint 0) lasts 3 weeks and serves as preparatory sprint prior to the project beginning. Other part of a course is divided into three regular sprinters of scrum sprint (Sprint 1, Sprint 2, and Sprint 3), each of which lasts 4 weeks.

During Sprint 0, there take place official lectures to teach students of scrum and how to apply the user stories to the requirement specification and project planning. These 3 weeks are also used for acquaintance of students with the initial product lag containing a set of priority user stories for the project which they are going to develop. At the end of Sprint 0, each team estimates the efforts necessary for realization of each history of users and prepares the plan of release.

Sprinters 1, 2, and 3 are regular sprints which have identical structure. Each sprint begins with a meeting on planning of sprint in which students report about the content of the following iteration with the product owner and develop the initial sprint backlog version. During the sprint, every team should get together at meetings of daily scrum regularly and to support their lag from sprint, while at the end of each sprint, reviews of parley and retrospective meetings of sprint are held. At a general appointment, students present the results to the heads, and at a retrospective meeting, students and heads forgather to discuss development process in the previous sprint in which suggestions for improvement in the following are offered (Pozenel and Mahnic 2016).

If to speak about Russia, then there is no practice of application of Agile in the university environment now. Certainly, not all problems in education can be solved with the help of flexible methodologies. For example, at the university, it is possible to build work of scientific and educational groups or design and educational groups; it is possible by means of methodology Agile. Also flexible methodologies perfectly are suitable for a design seminar where students work on the projects. An important part of educational process of all students is preparation course and theses, work which can also be built with use of collaborative technologies. Also flexible methodologies can increase productivity of work on applied projects of external customers at the university thanks to harmonious work of team and continuous contact with the customer.

It is important to remember the organization of scientific activity at the university. Flexible technologies can be applied at the organization of work on preparation of the application for a grant, when carrying out joint scientific research, including with foreign colleagues. Also Agile methodology perfectly fits into the organization of work on writing of joint articles, monographs, and textbooks in co-authorship.

Impact of Agile Methodologies in the Classroom

The course to an Agile at the university especially on IT specialties is obligatory discipline in the modern world. Before development of a new Agile course for program engineering, it is important to define competences which need to be developed at students in the course of studying of a course. Such competences can be divided into three categories.

First of all, it is technical skills. Their development forms a basis for development of the high-quality software. Engineering practicians who especially carefully accustom to extreme programming are also important and include modular testing, clean coding, test development, collective possession of a code, and others. Engineering practicians are competences which accustom everyone the person individually.

Also important competences are flexible management methods. Agile project management defines as projects on flexible technology are formed and started. Flexible methods of management include iterative planning, the short release periods, strong participation of clients, and highly intellectual and motivated teams. Management social competences are extremely important in the process of Agile methods development to form team and adjust work.

Summary

The cases cited in the entry show the applicability of the methodology in the educational environment and not only in the teaching of computer technologies.

Using Agile tools allows students to save time on developing a new product and improve interaction between team members, which leads to increased productivity.

Thus, the methodology should be shifted not only to teaching computer sciences but also to other educational programs, where the design type of instruction is applied.

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Agile Methods and Team Work in IT Education

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Synonyms

Collaborative practices; Project-based learning; Software development

Software Engineering and Information Technology Curricula

Information technology and software engineering education curricula incorporate training in programming and computer technologies, as well as basic science skills. As information technology is always applied in organizations, skills related to organizational understanding, business and interpersonal relationships are gaining more emphasis when the extent of systems grows. Competencies required from software developers are getting wider; developers are expected to understand the lifecycle of the products from early planning to design, implementation, and maintenance. The concept of systems development life cycle was introduced around 50 years ago, and since then information systems have evolved from individual entities to interconnected webs of technologies, data, and software. Understanding current technological and information environments is an enormous task that maybe no one fully masters any more. Educational institutions strive to provide skills and tools that help in this constantly growing and evolving challenge.

Although education standards vary from country to country, the international and global character of software development enforces certain amount of unity in training. Same tools and programming languages are used all over the world, and many large systems development projects are divided between many locations and countries at the same time. Even though there are some systematic differences in the working habits and organization of the work between cultural areas, global requirements for collaboration challenge them. Outsourcing to distant countries has become standard in software work, and differences are doomed to narrow. Organizations with low hierarchy that allow employees a good degree of self-determination will be best candidates to apply agile methods, which are becoming the new standard of software work.

Competence Requirements from Industry

What are the essential industry skills in software engineering or information technology? The UNESCO global report on the status of engineering 2010 discusses engineering education, which has developed worldwide towards similar overall practices (UNESCO 2010). According to the report, there seems to be a wide consensus on main goals of engineering education.

Accreditation bodies define information technology and software engineering competences broadly to accommodate the variation of educational institutions and programs. For example, the list of goals by ABET in the USA remains the same in the last decade (http://www.abet.org). ABET includes in the student outcome requirements for any engineering program general science and technology skills, research skills for conducting and analyzing experiments and data, and an ability to formulate engineering problems. Moreover, engineers need to be able to consider also constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability, and to act ethically. Particular working life skills are listed as an ability to function on multidisciplinary teams, and to communicate effectively. The UNESCO report on engineering mentions similar capabilities, referring to a many other organizations and accreditation bodies (UNESCO 2010). The question remains, however, how these goals are attained within various educational systems.

Dialogue with companies has revealed that ICT education had failed to fully respond to the current requirements in the software industry despite existing standards (Holvikivi et al. 2017). Demands from companies increasingly stress capabilities for collaboration, efficient team work, and professional communication. Moreover, feedback from software industry has confirmed some of the points previously mentioned, such as the ability to function on multidisciplinary teams and the ability to communicate effectively are needed, but there is also need for negotiation skills, and, specifically, a need to understand development processes. The fast changes in development practices need particular attention.

Teamwork and Group Processes

Groups play a critical role in people's lives, and in particular, in contemporary business environments, teams occupy a central role. Teamwork and groups are mainly studied by social and organizational psychology. In his review of current status of research in group processes, Levine (2013) emphasized that the amount of accumulated research is enormous, and the interest has not shown signs of decline because of the great importance of social aspects of group processes in organizations. Some of the most important findings regarding group processes that are relevant to student teamwork, agile development practices, and education are presented below.

Perhaps the most essential research finding is the importance of mutual trust in the team. Groups perform better when their members feel accepted and comfortable in the group. Certain personal factors influence this, namely interpersonal attraction, as well as individual characteristics of group members such as openness to experience. The degree to which the rest of a group agrees with each member about who he or she really is has an impact on the feeling of comfort. Moreover, mutual support and leadership improves group cohesion. The leader of the group has a crucial role in taking a visionary position and inspiring people to follow. Additionally, group performance is affected by a number of task related factors, such as the complexity or difficulty of the tasks, routineness, or autonomy.

Creative groups need to aim at internal synergy and to overcome the factors related to production loss in groups such as social loafing, evaluation apprehension, production blocking, and downward comparison. One of the means is to ensure that group members are held accountable for their individual contributions to the group. Moreover, group members should feel free to express their ideas as they occur without fear of others' criticisms, and members must be motivated to process information from other members. Diversity within group usually is beneficial for its creativity. Factors which enhance the benefits of diversity are a generally supportive social context and a longer time working together as a team. Research has proven effectively that successful real-world collaborative groups have a common vision and set of values. When the composition of a group is changing in one way or another, even when the members remain the same, it requires renegotiation of the interpersonal relations from time to time.

Student Teamwork

In case of student project groups, the composition of the group is often one-time only, and the members might not know each other previously. To ensure that a transformational leadership and mutual trust in the team are formed, instructors have to support the teams in the beginning. Establishing a leadership position and gaining authority in a team tends to be difficult for students in a peer relationship. Even later, teams require monitoring and facilitation that prevents social loafing, free-riding, and negative interactions within the team. One way to encourage equal contribution to the projects is to organize a mutual evaluation at the end of the project where students are individually requested to indicate how much each team member contributed to the project.

Teamwork and project work are more challenging to evaluate fairly than individual deliverables. Larger teams such as six or seven students are more problematic in this respect. Most often teams of four are the ideal solution also for team efficiency. Moreover, a regular presence of teachers in the classroom gives them an understanding of each student's skills. Also, virtual environments such as Trello and GitHub follow individual contributions.

Teacher Competences in Team Teaching
Multidisciplinary courses built around real-world problems provide one possible way of helping students to improve their communication and group working skills in an environment resembling actual work life situations. These kinds of courses are by definition being designed, conducted, and evaluated by a teacher team as opposed to a single subject matter teacher. At many universities, teachers are used to being the only teacher responsible for the course. Teaching staff with industry experience has learnt teamwork in practice, but for purely academic staff, the change required to work efficiently in a team of colleagues might be challenging. This change is profound as it is not just a method or single skill, but it actually changes the whole culture of teaching. Actually, this new challenge for teachers to be able to work productively in collaborative teams is similar to the requirement set by the changed working life for their students. It could be considered a legitimate requirement for teachers to follow the same practices they expect from their students (Vesikivi et al. 2018). The method requires that teachers have an open mind and are ready to face uncertainty. Teachers need to have enough professional experience and confidence when they start collaboration in this format.

Collaborative Problem-Solving and Project-Based Learning

Collaborative problem-solving and project-based learning are considered central methods to educate present day engineering students, because they simulate challenges that the students will face in professional work, such as open-ended assignments, uncertainty, and coordination of collaborative efforts. Numerous implementations of project-based learning have been reported in various countries in recent years. Even though the theoretical backgrounds of these efforts differ, the practical implementation usually follows similar patterns on applying a project development cycle to course work and concentrating on the problem and its solution instead of listed curriculum items (contents, skills, competences).

One of the well-known systematic efforts towards project-based learning is the global CDIO initiative that has united a number of engineering institutions around a common curriculum structure worldwide (Crawley et al. 2007). Another global model which extends beyond engineering to other academic fields is led by the Aalborg University in Denmark. Edström and Kolmos (2014) compared these two models and found them to be mutually complementary rather than competing. The CDIO model includes one project in each academic year, whereas the PjBL model followed in Aalborg is totally based on thematic project courses. Numerous other successful implementations of project-based learning methods have been reported in various countries in recent years, building a large body of evidence for their favor.

In the CDIO syllabus, personal, professional, and interpersonal skills include engineering reasoning and problem-solving, experimentation and knowledge discovery, system thinking, multidisciplinary teamwork, and communication (Crawley et al. 2007). When the learning is organized between members of a collaborative community combining theory, creativity, progressive inquiry, and practice, it profoundly develops student understanding (Lakkala 2010).

History of Systems Development Methods

With the increasing capacity of computer hardware, and development of high-level programming languages, application size grew fast in the 1960s. The maintenance and control of new large software modules required software development methods that were later called software development life cycle (SDLC) or systems analysis methods. The first methods were built for managing large mainframe software applications such as statistical, insurance, and banking systems, not to forget military applications. The software engineering methods emphasized structural, controlled processes, and extensive documentation, and were coupled with project management methods. The development work was divided into distinct phases, which is referred to as the waterfall model: defining business requirements, system analysis, design, coding, testing and evaluation, implementation, and training and maintenance. Each phase has fixed deliverables, milestones, and measures that mark its completion and move to the next phase (Encyclopedia of software engineering 2002).

The basic waterfall model led to development of CASE (computer-aided software engineering) tools in the 1970s to smoothen the development work, and methodologies such as UML in the 1990s, the visualized unified model that is tied with object-oriented programming. However, when systems became even more complex in networked environments, and particularly the new application types appeared in the internet, the waterfall model was used in more creative and flexible ways, including prototyping, iterative, and incremental development.

Agile and Scrum

Software engineering has encountered methodological crisis in 1960s and again in 1990s because of the complexity and long development time of large applications. In 1994, it was estimated that over 80% of the software projects encountered delays and exceeded their budgets. The Agile Manifesto in 2001 (http://agilemanifesto.org/) was a culmination of the frustration on heavy long-lasting projects. It condensed the alternative views into a list of 12 principles:

1. Customer satisfaction by early and continuous delivery of valuable software
2. Welcome changing requirements, even in late development
3. Working software is delivered frequently (weeks rather than months)
4. Close, daily cooperation between business people and developers
5. Projects are built around motivated individuals, who should be trusted
6. Face-to-face conversation is the best form of communication (co-location)
7. Working software is the primary measure of progress
8. Sustainable development, able to maintain a constant pace
9. Continuous attention to technical excellence and good design
10. Simplicity – the art of maximizing the amount of work not done – is essential
11. Best architectures, requirements, and designs emerge from self-organizing teams
12. Regularly, the team reflects on how to become more effective, and adjusts accordingly

Agile methods are based on four broad values derived from the Agile Manifesto: individuals and interactions, customer collaboration, working software, and response to change. These values are common to all major forms of agile methods such as Scrum, Extreme Programming, Lean Software Development, and Crystal. The agile way of working includes short development cycles that are called sprints and constant interaction between the development team and the customer. It is best suited for web projects where requirements tend to change quickly, and goals are not very clear in the beginning. Therefore, agile methods were first adopted by smaller companies with smaller projects. However, currently, even the largest software and ICT companies, such as Accenture, Microsoft, Nokia, and SAP, claim to apply agile practices in their work.

The various methods to apply agile development typically include sprints that last a week or two and scrum as project management method. In scrum, small stand-up meetings are held daily to check the current progress and assign new tasks. Moreover, scrum includes a few roles such as scrum master and product owner. A sprint has a task list from where team members pick their tasks after they have finished the previous one. After the sprint cycle, there should be a product prototype that can be evaluated, and further decisions made based on the delivery. Short cycles allow changes in requirements and close monitoring of costs and other resource use.

Lean and Kanban

Lean manufacturing and kanban were developed in Japan for Toyota, and their idea is to simplify manufacturing process by eliminating all waste, minimizing inventory and process time. In software development, kanban cards are used for tasks, and they will contain a backlog for the project. Use of kanban cards has exploded in all business areas with the availability of simple online products such as Trello or Asana.

Experiences Form Agile Courses

Agile software development has replaced former, highly systematic project management practices in many areas of the software industry. Software development has changed drastically during the last decades. Individual coding or testing in large projects still exist, but most developers have to be able to co-operate in diverse teams and to apply flexible working methods. Many studies have shown that agile methods are already mainstream in the industry (Kropp et al. 2016). However, the incorporation of the tremendous changes in development practices has entered academic education rather slowly.

First efforts to include agile methods to higher education were made more than a decade ago, and currently, separate courses on agile development are widely offered as part of software engineering curricula (ibid 2016, Mahnic 2012). However, actual use of agile methods as educational practice is less common even though a widespread use is presumably on the brink of breakthrough. Agile development can be applied in many kinds of project-based learning courses by replacing traditional project management with flexible practices and sprints, and by replacing formal meetings with scrum meetings. Compared to traditional project management methods, this way allows more development cycles and therefore enables the completion of a functional prototype during an academic module.

The literature on agile methods in education presents largely three different ways to approach the subject. First, as any other subject, project management can be lectured and knowledge tested through examinations. Nevertheless, this method does not address the development of interpersonal or organizational skills.

Secondly, agile methods can be introduced through a project course, where they are practiced in an application development project. There are many examples of innovation and multinational application development projects, where the agile approach and teamwork function as a backbone, even though not necessarily explicitly expressed. The EU has sponsored Erasmus intensive programs that include universities from several countries and require a preparation phase over distant education tools. In this kind of international efforts, where virtual learning environments are an essential part of the course, students and teaching staff from various universities need to adapt to changing and unexpected learning settings.

Positive experiences have been reported particularly from capstone courses where students are assumed to have already strong technical skills and involvement of real customers is possible (Mahnic 2012). Moreover, agile working methods have been studied in multicultural groups, and in courses on software business, reporting promising outcomes. However, it remains unclear whether negative cases have been reported to the same extent as positive outcomes.

A quick introduction to agile, user centered way of developing product ideas is presented by Google Ventures Sprint (http://gv.com/sprint). Even though it is mainly designed and applied for real business settings, the 1-week framework makes it a suitable way to introduce the main ideas to a student group. Because it is very much hands-on, practice centered, it gives a quick immersion to creative IT work.

The third, most immersive method extends beyond agile courses, where agile work has been expanded to the entire curriculum. Agile approach is more than a subject of study; instead, the methods in course design and implementation are based on agile ideas. In this approach, the schedules of modules are not defined in strict detail in advance; instead, the planning is flexible and done in small increments during the implementation (Holvikivi and Hjort 2018).

Case Example: Simulated Work Placement

Metropolia University of Applied Sciences offers a bachelor of engineering degree in information technology. Part of the degree is a 3 month internship in a company. Sometimes students fail to find a real employer for their work placement. A simulated workplace environment was created to give students chance to practice internship in this kind of situation. Fourteen students participated working full time as interns in a designated office space inside the school building during 3 months. They received an order from a publishing company that wanted to explore alternatives for a new product. The work was organized as an agile project, which emulated real workplace conditions. The project group held regular scrum meetings every morning where teachers participated as needed. In a scrum meeting, all participants stand up and explain briefly what they have done since the last meeting, what they intend to do next, and what kinds of problems they face.

A working life experience should teach project management and team working skills in addition to technical skills. Because of a real customer, students started understanding what making a commercial product entails, and how user needs are incorporated in design. The scrum development project was a new method for the participants. In the beginning, the group held scrum meetings every day in the morning. First, teachers were involved to show the method, set up timesheets for work, and comment on student achievements and plans. Three weeks later, teachers let the team divide into technical and user interface groups that were self-regulating. Students were allowed to decide how often they need scrum meetings and stopped holding them daily. Soon they noticed that having fewer meetings did not facilitate the process (Holvikivi and Hjort 2018).

Case Example: Software Engineering BSc Curriculum

The software engineering curriculum for bachelor of science in the Metropolia University of Applied Sciences in Finland went through a fundamental change in 2014 (Holvikivi and Hjort 2018). Project-based methods were included into most modules in the new curriculum. Additionally, the concepts of progressive inquiry and problem-based learning were applied in course design. It was assumed that it would be most efficient to start with open-ended problems immediately at the beginning of studies. Moreover, participatory online learning environments were used to support the learner's development of understanding through collaborative construction of a shared product (Lakkala 2010).

The first study year was divided into four successive 15 ECTS modules 8 weeks each. Each module had a theme that introduced the different IT subjects students could major in: networks, media and web-development, electronic devices, and software engineering. The project in each module was supported by a varying amount of basic and theoretical studies such as mathematics and physics.

In an integrated module, all professional and language content (communication skills) was integrated apart from the separate science classes. The teachers collaborated both in theoretical subjects and project work. Deliverables such as presentations and project documentation were assessed both on substance and communication aspects. Some types of lessons with practice usually had more than one teacher present. Also during student team presentations most teachers attended, gave feedback and evaluated deliverables together.

The integrated modules that applied an agile approach were Orientation and Games (programming) in the first year, Application Development Methods in the second year, and Software Business Start-up in the third year. They were largely similar in design, lead by nearly the same teacher teams who applied agile practices in the planning of instruction.

The Games module was actually an introduction to Java programming. In the beginning of the module, students attended some lectures in programming and completed a large number of programming assignments in a MOOC setting. The MOOC (massive open online course) was provided by the University of Helsinki. Additionally, students completed a game project during those 8 weeks. After the setup of teams in the second week, teams held weekly scrum meetings, and they were required to use kanban (Trello) for task management.

The Application Development Methods module in the second year consisted of a mix of Finnish and international software engineering students. As the name implies, the module concentrated on software project management skills. The lectures covered some conventional project management, a number of development tools, and user-centered design. The technical skills included setting up a Java server, creating a responsive client-side, using GitHub and REST API, and usability testing tools. Other methods that the students were already familiar with included Trello and scrum meetings. Additionally, students used a variety of free online tools that they chose themselves. The composition of teams was constrained in a way that single-nationality teams were not allowed. Diverse teams tend to be more creative, and on the other hand, multicultural teams offer important skills for the future of international students.

The Software Business Start-up module was conducted in the beginning of the third study year. The idea of the module was to practice business skills by creating a mock start-up and developing a product prototype. The module built on the skills that had been acquired earlier including Git version control, weekly scrum meetings, voluntary use of kanban and other agile tools. Some new technical skills were introduced, namely the so-called MEAN stack that contains node.js and noSQL databases. Student teams were allowed to assemble freely, but the team size was limited to four. Very obviously, student ability to tolerate uncertainty had increased from one module to the next. In the second implementation, creativity and innovation were practiced during 1 week using the Google Ventures sprint model. The generation and development of product ideas was unprecedented in the classroom.

Certain positive outcomes were obvious, such as high student satisfaction and good retention rate (Holvikivi et al. 2017). The change from large study groups, separate lectures and laboratories into smaller, tightly knit groups seemed to have been a decisive factor in improving the results in the first years. Belonging into a group and working in teams was a simple way to enhance commitment to studies and overall feeling of belonging, for students from diverse backgrounds in particular.

Nevertheless, the results of this case extend beyond agile courses, as agile work has been expanded to the entire curriculum. Not only the subject of study but also the methods of teachers in course design and implementation have applied agile ideas. The modules were not defined in much detail in advance; instead, the planning was flexible and done in small increments during the implementation. In particular, in case of heterogeneous student groups, this allowed more freedom in the realization.

Conclusion

As understanding the development process becomes more important for software developers, skills that help to master the process have to be included in software engineering curricula. New ways of teaching bring advantages to the institutions in terms of graduations and good results for courses as well, and enrich the work of faculty. Agile development is an exciting new avenue, which is not only embraced by the software industry but also applied to project work in other areas of business.

Cross-References

- ▶ Agile Methodology in Education of IT Students, Application of
- ▶ Mobile Computing and Mobile Learning
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- ▶ Teaching Software Design Techniques in University Courses

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Alerting Devices

► Assisting People Who Are Deaf or Hard of Hearing Through Technology

Algorithm

► Design in K-5 Programming Projects, Role of

Algorithmic Language

► Programming Language Selection for University Courses
► Teaching Computer Languages in Universities

Algorithmic Thinking in Primary Schools

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Technological advances have changed the ways we work, learn, and play. For today's students to take full advantage of the opportunities these technologies afford, a set of ways of thinking, that mirror how computers function, are increasingly pervasive in schools. These include a thinking skill called algorithmic thinking that can be seen to be comprised of four key areas:

- Design thinking
- Decomposition
- Pattern recognition
- Abstraction

These four skills are used in schools to engage learners in problem-solving, critical thinking, and collaboration. They offer opportunities for learning across the curriculum. Algorithmic thinking activities can be seen in written maths problems, in historical research, in text analysis, and in the evaluation of art products. Current research suggests that engaging students in algorithmic thinking in their early schooling can open doors for them as adults entering the workplace (Deloitte Access Economics 2017).

As technological change continues to infiltrate our homes and schools, it has become clear that school curricula documents must reflect the society in which they are used. Curriculum writers are therefore seeking to engage students in the key thinking and practical skills that might enable their full engagement in the world of work and life beyond schools.

What Is Algorithmic Thinking and Where Did It Come From?

With its origins in mathematics, algorithmic thinking refers to logical, sequenced processes that together create a desired outcome. Algorithmic thinking, in relation to technologies, has developed concurrently with computer programming and the microprocessor. At its simplest level, algorithmic thinking can be seen as $2 + 2 = 4$.

Although sometimes used interchangeably with the term computational thinking, algorithmic thinking is focused more on the design stage of problem-solving. Whereas, “In computational thinking, the focus is on the data and the interpretation of the data, and the algorithms are just tools available to help with that” (Gas Station Without Pumps 2010).

Algorithms, of the type discussed here, first came to the fore with computer programming breakthroughs of the 1940s. Indeed, algorithmic, mathematical, thinking can be seen to exist in the code-cracking histories of World War Two and Turing’s Enigma decryption machine.

A computer algorithm is a set of instructions that interact in a sequence to produce a desired outcome. An example is the “home” button on a mobile tablet or smartphone. When this button is clicked, it triggers a set of algorithms to complete the task, in this case, to display the home page on a device’s screen. Understanding that logic and sequencing underpin technology, and that errors or challenges with technology might be solved through a logical sequenced approach, are skills needed in a wide range of industries.

In Israel, England, the USA, and France, algorithmic thinking is already part of many school curricula documents (Deloitte Access Economics 2017).

In Israel, algorithmic thinking is presented as a core skill for successful twenty-first century life; in England, these skills are embedded with a curriculum focused on coding and computer programming.

No longer seen to be a skill unique to computer programmers, algorithmic thinking has become a new type of language and literacy in today’s world. Solving a problem using digital resources and designing logical models for implementing solutions are important skills for today’s students. While a number of definitions of algorithmic thinking are available, there are four main aspects that appear common. These are explored below.

Abstraction

This aspect of algorithmic thinking focuses on making meaning from data. Students create rules about the data they have uncovered and view the broader implications of it. This might be understanding how data fits into a larger context or to reduce a complex idea to its fundamental concepts.

Systems Thinking

Many aspects of problem-solving and computing require an ability to see the complexity of the systems within which they are embedded. Systems thinking seek to understand the interactions of people, places, objects, or ideas within a system. In a school setting, this might be exploring how predators and prey interact and impact on each other within a microcosm.

Pattern Recognition

Beginning from an early age, students are often asked to engage with pattern-making and identification. With changing demands in the workplace, these patterning skills have increased in significance. Computer programmers use patterns to simplify and replicate basic commands. Students develop patterning skills to make sense of data and to identify inconsistencies from a high-level perspective. Making and exploring patterns can help students to make sense of large sets of data and can reinforce ideas of abstraction.

Decomposition

Sometimes called “factoring,” these skills see students break large sets of data or problems into their composite parts. This connects with the ideas of systems thinking as students compartmentalize problems in order to make better sense of possible solutions. When students are able to break large problems into smaller parts, they can more easily understand the nature of complex problems or ideas.

Changing Workforce Demands

Today's workforce is increasingly engaging with digital technologies, whether that is through email, digital databases or more recently, with virtual or augmented reality. The concept of work itself is also changing with one in three US workers now identifying as a freelance worker (Weber 2014) and one in four hoping to secure new employment in the next year just to "do something different" (Weber 2014).

These should be seen as opportunities for engaging students in new and innovative learning practices, after all, today's primary school students will enter the workforce in the 2020s and 2030s. It is likely that the workforce will be even more digitally, virtual and globally focused than it is already.

With scope for such large changes, it should be asked how teachers can possibly prepare students. If we do not know what social and global changes might occur, how can we teach students to engage with them? This is a question that has been raised by educational leaders and organizations globally.

One answer has come to the fore: prepare students not to use today's technologies but instead to learn how to learn. Developing the skills to learn is seen to be a way to future-proof the learning of students, who are hoped to leave schooling with transferable and flexible skills that may support them in their adult lives.

This focus on the future needs of students in the workforce has framed educational curricular such as the Australian Curriculum (Australian Curriculum Assessment Reporting Authority 2016), the National Curriculum for England (Government Digital Service, UK 2014), and the Israeli higher education program, Ghavim (2017).

New Curriculum Demands

The Australian Curriculum is the newest of these curricula and seeks to engage students in developing core computing skills from ages 5–16. Beginning in the early years of schooling, students are asked to identify patterns and exploring basic algorithms through step-by-step written activities. These activities might include following or recording a recipe or creating treasure maps with instructions for others to follow.

The Australian Curriculum is designed to engage students in specific thinking skills. Problem-solving, creativity, and collaboration are core foci in the Australian Curriculum and by giving these areas greater prominence, there is an expectation that teachers will place a greater emphasis on helping students develop the so-called "21st century skills" in addition to content related to the various disciplinary areas. As students develop skills, they may begin to design and implement more complex algorithms that leverage technologies in reaching a solution.

Reinforcing the notion of the Australian curriculum as a thinking curriculum is the statement that up to 50% of the curriculum can be completed offline, without the use of computer technologies. Offline learning activities can be effectively used to reinforce algorithmic thinking and might include designing a board game for others to play, finding errors in a list of instructions, or identifying algorithms used in the real world.

With changing curriculum demands in a number of countries worldwide, it is important to restate that the aim of these documents is rarely to produce a generation of computer programmers. With increasing global challenges, such as climate change, unstable political environments, and catastrophic weather events, there is a growing need for individuals who can analyze, decompose, reflect on, and design solutions. The Australian Curriculum frames this interpretation of curriculum in saying, "The curriculum is designed so that students will develop and use increasingly sophisticated computational thinking skills, and processes, techniques and digital systems to create solutions to address specific problems, opportunities or needs" (Australian Curriculum Assessment Reporting Authority 2016).

This curriculum positions the skills that it seeks to develop in students as "... develop[ing] and employ[in] strategies for understanding and solving problems in ways that leverage the power of technological methods to develop and test solutions (Australian Curriculum Assessment Reporting Authority 2016)."

It is pertinent to note that many teachers already engage students in developing these skills in classrooms around the world. These teaching strategies are sometimes called inquiry learning, activity-based learning, or problem-based learning. However, today's curriculum demands ask teachers to make visible the affordances of technologies in solving complex, open-ended problems. Teachers are now asked to highlight the specific thinking skills that students are using and seek to engage them in reporting on their learning strategies as they solve problems.

Previously, teachers might have asked students to create a paper graph to record the passing traffic outside the school, and then analyze the data to inform an appeal to the local roads authority. New curricular demands would see students making informed choices about which resources and technologies they might use to record passing traffic. These might include developing an app to record traffic that students could use on computer tablets, as they left school each day, or mounting a camera by the school gate that has been programmed to take photographs at designated intervals.

Students might then use the algorithmic thinking skills of abstraction, decomposition, and systems thinking to make an informed case for solving the problem of increased traffic at certain times of day. They might implement, then review, their solution and use pattern recognition strategies to interpret the data they gather.

Although, in these two examples, students are working to solve a similar problem, it is clear that the development of algorithmic thinking skills separates the learning experiences. With a focus on visible and strategic thinking skills, students can engage in more complex, collaborative, and real-world problem-solving.

Beginning to Think Algorithmically

There are a number of online resources available to engage with algorithmic thinking skills. A number of these focus on the development of computer coding skills. Coding, or programming, can be seen as the newest component of curriculum documents. These skills, therefore, represent the most novel aspects of the curriculum for teachers and learners, and are often promoted as an entry point for beginner learners.

An online search will provide a range of beginners' guides to computer coding that will introduce concepts of algorithmic thinking. An American not-for-profit organization, called Hour of Code (https://hourofcode.com), is one of the most popular and prominent websites for beginners in this area. The Hour of Code website provides free narrated, video courses in basic coding, that walk the learner through developing and implementing computer programs using a "drag and drop" interface. As this suggests, the learner drags coding "blocks" across the screen. By connecting blocks together, a computer code is developed that can then be "run" to complete a basic task. An example might be designing a snowflake by dragging a sequence of codes together that use forwards, backwards, left, and right "blocks." When the learner clicks on "run," the code is executed and any problems or errors are revealed.

Drag and drop coding is used in a range of softwares that are freely available as online, web-based resources and as smart device apps.

Algorithmic thinking invites learners to engage in deep thinking, in rationale, sequential processes, and in solution-testing and review. Learners who develop these skills may have increased opportunities in a wide range of career fields beyond school.

Global Educational Changes

There has been a steep increase in the language of computing and computers since the year 2000. Words such as Blog, Wiki, Upload, Download, Coding, and Apps have become part of the common language of society. This is true, too, in schools where computer vocabulary continues to grow as technology changes. These swift language developments can be seen to be indicative of the pace of change in the world and the classroom.

Many teachers around the world now work in Internet-connected classrooms and schools. These teachers can now engage with students online, to support and grow their learning, use interactive resources and virtual reality to bring the world into the classroom and even solve real problems with digital solutions.

As governments around the world seek to align their curricula to shifting needs of their societies, the significance of a set of skills called “algorithmic thinking” increases. It is of note, however, these documents do not seek to develop a generation of computer programmers.

While this shift in curriculum focus can be seen to be driven by society at large, there is no expectation that every child should become a computer technician, programmer, or developer. In fact, the inclusion of algorithmic thinking in schools seeks to broaden student’s opportunities, not narrow them.

Understanding the skills of algorithmic thinking, drawing on its background in mathematics and the first computers, provides insight into how digital technologies work.

This is then can create endless possibilities for innovative, perhaps entrepreneurial, skills to be developed. The 21st century skills provide unique learning experiences that teach students how to learn in the ever-changing technology-enhanced world they will enter after school.

Take the example of a group of 10-year-old students in a rural primary school in Australia (Table 1). These students are aware of a problem in their wider community: ridesharing services are difficult to arrange and access, meaning a number of students each day are unable to get to school.

These students worked through the four aspects of algorithmic thinking to better understand the challenges of solving the problem. The table above shares the thinking of the students as they moved towards a solution.

Working through this process has helped the students develop a proposed solution: a giant map of the routes parents drive to get to school. These students might need to further investigate the problem. How can a giant map at school help them when they are at home? How could they make the map reflect last minute changes to driving routes, due to weather, cattle, accidents, and so on?

This could lead students to develop a GPS tracking app that parents could use as they drive school. This would not only go towards solving the problem but would also provide ongoing algorithmic thinking opportunities as they develop, trial, review, and maintain their new ridesharing system.

Algorithmic Thinking in Primary Schools, Table 1 Components of algorithmic thinking

Aspect of AT	Key questions	Students’ responses
Design thinking	What is happening here? Why is ridesharing hard to arrange? Which part of the “system” (in this case, the arranging of ridesharing) is causing the problem? How does each part inform the other?	We don’t always know who needs a ride When parents are unavailable at the last minute, we don’t know who could offer a ride We live far away and we could get a ride to the main road, but we don’t know when people are driving past
Decomposition	Where are the main points of challenge? Which parts work well?	Contacting people driving past is difficult. Last minute changes are hard. There are people to drive us – but we can’t always find them!
Pattern recognition	What patterns might help you solve this problem? What do you need to know?	We need to know the routes that people drive so we can find a lift to school We could ask people to map their routes to school and share it with us
Abstraction	How can we summarize the data? What should we look for in the data? How can this data help us solve the problem?	We need to collate all the maps onto one big map so we can see where people drive and whether we can find a lift to school

Using Algorithmic Thinking to Solve Problems in Primary Schools

This section presents examples of algorithmic thinking in action. These examples are framed as learning activities across the three main stages of primary schooling: early years, middle years, and senior years. Students are supported to develop increasingly complex algorithmic thinking skills as they progress through primary school. These critical skills are seen to be imperative for all students from the beginning of their schooling, “. . . it is vital that we start with algorithmic thinking early on, and help the students advance towards, ultimately, mastery of the subject” (Hromkovicˇ et al. 2017).

With this mandate for all students to learn algorithmic thinking skills, the following examples make use of both digital technologies and more traditional, off-line resources. This reflects the interpretation of algorithmic thinking as a thinking skill, not only a computer or online skill.

Algorithmic Thinking in the Early Years

In the early years, students are supported to understand sequenced events, patterns, and designing solutions. At this level, this might include drawing, discussing, and/or shared writing, rather than formal, written responses. An example is a group of 5-year-old children who are planning for a school excursion. The teacher explains that they will need to pack a picnic for the class to enjoy. As a class, the students make a list of possible foods and drinks they might like to include.

From here, the teacher points out that there is a wide variety of possible sandwich filings and asks how can we determine all the options so we know what we need to buy? In small groups, students draw ways to represent all the possible sandwich filling combinations and are then led to identify patterns between the groups’ drawings. There are a few ingredients that appear to be consistent across the groups: bread, butter, and Vegemite. Each group is asked to redesign their drawing to make this pattern clear. Some draw a giant loaf of bread, others add the word “bread” to each of the sandwich options they chose. The teacher comments that by looking for patterns they have made useful additions to their drawings. You cannot make a sandwich without bread, but we may not have realized this, if we had not searched for patterns in our data.

The teacher next asks the students to consider how they might best create one drawing or diagram to represent all the options in the class. Again, in small groups, students are supported to design a flow chart the leads students through the sandwich filling options. The flow charts are then combined into a single class flow chart, again highlighting patterns that have emerged, and this is followed by a discussion of the processes and problems they worked through to create the final flow chart.

The teacher highlights the use of patterns to simplify the initial drawings and the role of abstraction in ensuring that they all focused on sandwiches, rather than just on fillings. While the language of algorithmic thinking is likely beyond student’s comprehension at this stage, they have begun to develop concepts of patterning and algorithms as tools for problem-solving.

Algorithmic Thinking in the Middle Years

As students approach the middle years of primary schooling, they begin to engage with algorithmic thinking across a wider range of curriculum areas. This might be in an interdisciplinary project or through one specific learning area. This example engages students in geography learning (human land use) and algorithmic thinking strategies.

A class of 10-year-old students is seeking to understand why some areas of the playground are busier than others, as the footy game played at lunchtimes appears to be impacting on those who wish to engage in quiet play activities.

To begin, students have explored the geology of their school grounds and have collected a range of measurements. These include the height above sea level of five locations in the school grounds, the number of students in these five locations at recess times, and the types of play that occur in each location. The teacher sees an opportunity to engage students in complex problem-solving using algorithmic thinking strategies, namely pattern recognition and decomposition.

The teacher guides students to begin categorizing their data. Students create categories of quiet play, sports games, and noisy, running games. Each student group adds their data to these categories and the teacher leads a discussion about the patterns they identify. She leads the students to make broader, abstracted comments on each category, such as more "people play noisy running games at location three." She then asks them to assign the locations and height above sea level to each activity in the three categories.

As students complete this task using a Digital Media Board, they begin to reorganize and rename their findings to better fit the categories. Some students make comments about the relationship between height above sea level and the types of play that students undertake.

The teacher uses this comment to introduce ideas of decomposition. They break the data into parts and focus on the data from one location, for one activity. They realize that this data was gathered on a slight hill and is the highest point in the school grounds. The activities at the location are reported as mainly "quiet play."

Students use this example to generate the hypothesis that higher locations in the school grounds are better for quiet play. The groups then return to their data to validate their findings. They use the Digital Media Board to share their ideas and findings with the class and to generate a whole-class conclusion.

Their findings suggest that if sports play was limited to two main locations in the school grounds, there would be more space for noisy, running games, that would, in turn, and using systems thinking, increase the space for quiet play.

Students are led to discuss the use of pattern recognition and decomposition in understanding the complexity of the problem. Initially, students believed the footy game impacted on the quiet play areas, but their findings suggest that it was in fact the noisy, running games that were impacted by the footy players, who in turn impacted on the quiet play areas.

Algorithmic Thinking in the Senior Years

In the final years of primary schooling, students are supported to engage with technologies, computer coding, and solution design. In this example, a group of 12-year-old students are engaged in a STEM learning project focused on the exploration of Mars.

The teacher begins by providing a scenario whereby it is some time in the future and Earth's resources are running low, we are broadly overpopulated, and climate change is regularly resulting in catastrophic disasters. As one way of dealing with these issues, the global community has sent humans to Mars in the hope of colonizing the planet and making human habitation possible.

As the students and the teachers begin to work through this scenario, they move through each of the STEM disciplines. In the area of science, they must consider general requirements for the sustenance of life. Thus, how will food, water, shelter, and breathable air be provided. Quite quickly they may realize that they will need to grow plants. Not only will they provide a source of food but through photosynthesis oxygen will also be released.

Students will design the base station for the Mars settlement. This will draw on digital technologies, engineering, and mathematics. They will plan for how the inhabitants of the base station will move from location to location around the settlement. Imagining that a codable robot (for example, Sphero or Dash bot) is a Mars rover controlled remotely from the base station. This will be achieved by using grid references (or Cartesian coordinates for more advanced learners) and drag and drop coding. The input device for the code would usually be a Bluetooth enabled android or iOS tablet or smartphone. It is suggested that a large-scale map of Mars is created on the floor of the classroom. A number of landmarks or significant areas of interest are included on the map (for example Olympus Mons, the largest volcano in our solar system and Valles Marineris, a valley larger than the Grand Canyon on Earth). Students should draw on their developing understanding of abstraction, systems thinking, pattern recognition, and decomposition to plan and have the rover navigate its way around a preplanned circuit.

We suggest the teacher identify the component parts of algorithmic thinking and create formative assessment matrices to provide feedback to students about their progress and areas for future growth.

Summary

Algorithmic thinking can be seen as encompassing a range of skills including the four areas of design thinking, decomposition, pattern recognition, and abstraction. In this entry, we have described and explored several activities that can help students to develop algorithmic thinking in the early, middle, and senior primary school levels.

In the early years, through planning a picnic, students could develop an understanding of basic algorithms represented through drawings. In the middle years, students might generate, record, and analyze data related to playground usage. The context of Mars exploration, in the upper primary years, connects students' learning to ongoing media reports and represents an interdisciplinary and engaging approach to algorithmic thinking within STEM learning.

This entry presents algorithmic thinking as an essential and strategic focus area for primary school learning as we continue to see the demand for these technological skills increase in the workplace.

Cross-References

▶ Computational Thinking
▶ Informatics

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Anatomy Learning

▶ Indications for Kinesthetic Learning Through Haptic Devices

Android

▶ Applying Software Engineering Principles in Android Development

Android Apps-Based Learning Approach

▶ Android-Based Mobile Apps for Hands-On Education

Android-Based Mobile Apps for Hands-On Education

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Synonyms

Android apps-based learning approach; Firewall; Information security education; Security hands-on labs

Introduction

As mobile devices grow increasingly in popularity within the student community, novel educational activities and tools, as well as learning approaches, can be developed to get benefit from this prevalence of mobile devices (e.g., mobility and closeness to students' daily lives). Particularly, information security education should reflect the current trend in computing platforms away from the desktop and toward mobile devices.

Nowadays, the need to use a practice- and application-oriented approach in information security education is paramount (Chen and Lin 2007). Hands-on learning through lab exercises plays a key role in information security education. In fact, a security education curriculum that does not give the students the opportunity to experiment in practice with security techniques cannot prepare them to be able to protect efficiently the confidentiality, integrity, and availability of computer systems and assets. In addition, rather than only teaching abstract concepts and assigning abstract exercises, courses that also engage students in real-world settings will promote effective information security education (EDUCAUSE 2014; Loveland 2011).

Hands-on lab exercises on various information security topics have focus primarily on desktop environments, whether physical or virtual, and consequently can be implemented only inside isolated laboratories environments (Whitman et al. 2014; Trabelsi et al. 2013; Trabelsi and Alketbi 2013; Trabelsi 2011; Vigna 2003a, b; Yuan and Zhong 2008; Caltagirone et al. 2006; Hill et al. 2001; and Trabelsi and Mustafa 2014). Recently, the computing landscape, however, is shifting. The dominant computing platform is becoming the mobile device (Andrus and Nieh 2012). Nevertheless, the real-world constraints and operating environment of mobile devices are quite different from traditional desktop-based laboratory environment. Therefore, it is important for students to learn in this new environment whose prevalence and popularity can be used to create new hands-on lab exercises and tools for information security education (Andrus and Nieh 2012).

In fact, over the last decade, the use of mobile devices for both personal and business purposes has exploded. The arrival of smart mobile devices (Google-Android-based smartphones and tablets) and the booming of mobile applications (known as apps) in recent years have only accelerated this trend (Bhattacharya et al. 2014). Mobile devices have been consequently turned into powerful general-purpose computing platforms. More and more users and businesses use mobile devices for processing personal, financial, and commercial data or use them to organize their work and private life. Particularly, in the academia environment, more and more students are using mobile devices for both personal and academic reasons (Levine and Kossuth 2011). Hence, an enormous array of mobile devices is making its way to college campuses. As smart mobile devices grow increasingly in popularity within the student community, novel educational activities and tools, as well as learning approaches, can be developed to get benefit from this prevalence of mobile devices (e.g., mobility and closeness to students' daily lives). Hence, the teaching of information security concepts should reflect the current trend in computing platforms away from the desktop and toward mobile devices.

As the need to use a hands-on-based learning approach in information security education is paramount, and as mobile platforms grow increasingly in popularity within the students' community, learning approaches that aim at taking advantages of the benefits of mobile devices and the best practices in learning information security should be explored. The approaches should aim to promote students' interests and increase their self-efficacy. In this work, a learning approach that offers two Android apps for the students to further learn the intricacies of network traffic filtering and enhance their hands-on skills on firewall filtering rules implementation is presented. The apps allows students to further practice network traffic filtering outside the traditional isolated laboratory environment, in the real-world environment, i.e., anywhere and anytime, at the students' convenience. The two Android apps are a firewall app and a network packet generator app, called Advanced Firewall and Packet Generator, respectively. Based on statistics from Google Play Store, in September 2019, the Packet Generator app has been rated 4.0 with over 500,000 downloads worldwide. As a consequence, in addition to the traditional inside laboratory activities which are limited by the time allocated and often do not reflect the real-world settings, students will be able to continue practicing further network packet filtering using their mobile devices in the real-world environment, at their convenience. The impact of the two Android apps on the students' performance in terms of achieving the course outcomes is also discussed.

Efficient Learning Approach

The importance of hands-on learning has long been recognized in the learning theory literature (Du et al. 2010). In traditional information security programs, students are expected to be heavily involved in hands-on lab activities. Therefore, the first characteristic of an efficient learning approach is its hands-on-based learning that couples security policies analysis with protection solution practices. In practice, this consists into implementing and testing the appropriate firewall filtering rules for specific security policies, on Android mobile devices.

The second characteristic of an efficient learning approach is its real-world relevant learning. The mobile device itself is becoming more relevant than other existing learning platforms to real-world applications. As a consequence and in addition to the inside laboratory activities, students are encouraged to test and debug firewall filtering rules in the real-world environment, using mobile devices.

Thirdly, Android platform has been chosen over iOS platform to develop the proposed educational apps for several reasons. First, Android is the fastest-growing mobile platform (Andrus and Nieh 2012; Guo et al. 2013) to date, and its popularity makes it of tremendous interest to students. Second, Android platform is open-sourced, while Apple iOS platform has license restrictions. Moreover, since Android is based on the open-source Linux kernel, students can leverage a wealth of Linux tools and documentation. That is, Android allows exploration of a complete production system including the OS kernel, user space libraries, and a graphical user environment written in Java. Third, as a commercial platform, Android continues to be developed and improved which naturally evolves the platform as a pedagogical tool, enabling students to learn in a modern context.

Hands-on Learning Activities on Firewalls

A pedagogical model to teach firewalls concepts consists usually of two main phases. In the first phase, and during the hands-on lab activities, the instructor asks the students to discuss and analyze a set of security policies related to a variety of network traffic scenarios. Then, the instructor asks students to write the appropriate filtering rules for each security policy. Students are then instructed to implement and test filtering rules using classical firewall devices and wired or wireless local area networks.

In the second phase, students are then instructed on how to implement and test their firewall filtering rules on their mobile devices, using step-by-step tutorials. In fact, in addition to the inside laboratory activities, students are requested to test and debug firewall filtering rules in the real-world environment, using mobile devices. This will help students to obtain an instant gratification and confidence from the hands-on practice and encourage them to create specific filtering rules to filter real-world network traffic. This also has the additional benefits of not only facilitating students to learn network traffic filtering skills but also heightening their awareness and understanding of firewall concepts in the real-world environment.

Android-Based Mobile Apps for Hands-On Education, Fig. 1 Apps of the Android learning approach

Design Considerations

Firewalls control the access into and from networks and computers based on a set of filtering rules, which reflect and enforce the organization's security policy. It is the firewall's job to make filtering decision on every packet that crosses it: either to let it pass or to drop it.

Firewall and network packet filtering is considered an important topic for a course on network security. There are basic network packet filtering topics that should be taught when offering a security course on firewalls, namely, basic network packet filtering, common standard services filtering, and nonstandard services filtering. There are also advanced network packet filtering topics, such as stateful firewall packet filtering using TCP flags, and packet deep inspection (DPI), also known as packet content inspection, and consistency verification of the filtering rules.

Ideally, when designing and implementing an educational firewall application, the above basic and advanced topics should be taken into consideration to help students improving their hands-on security skills on firewall configuration and network packet filtering. In addition, the educational firewall application should offer a user-friendly GUI interface to allow students easily create and manipulate filtering rules, including updating the values of the filtering rule's fields and the order of the filtering rules. Students should also use means to test and debug the implemented filtering rules and should be immersed in a real-world relevant learning environment, by taking advantage of the benefits of mobile devices.

Android Apps

The discussed learning approach uses the two Android-based apps: Advanced Firewall and Packet Generator apps (Fig. 1). Advanced Firewall app allows implementing filtering rules and/or selecting rules from a set of predefined rules to filter a diversity of network traffic types and Internet services. Packet Generator app is used to generate specific network traffic to test the efficiency of the implemented filtering rules relative to the outgoing and incoming network traffic. The use of both apps allows students to practice implementation, testing, and debugging of firewall filtering rules, while they are outside the isolated laboratory environment. Hence, in addition to the inside laboratory activities, students will get further chances to improve their hands-on security skills on firewall concepts, using their Android mobile devices. The following subsections describe the two apps.

Advanced Firewall App

Advanced Firewall app offers a set of basic firewall functions that allow performing the following:

- Implement basic filtering rules to filter TCP and UDP network traffic. The filtering rules are defined by setting the values of the source/destination IP addresses and the source/destination ports.
- Implement basic filtering rules to filter ICMP network traffic. The filtering rules are defined by setting the values of the source/destination IP addresses and the ICMP Type/Code fields.

- Select rules from a list of predefined rules to filter standard Internet services, such as Web, Email (SMTP/POP3), and FTP.
- Implement filtering rules to filter nonstandard TCP and UDP services.
- View the logs data of filtered network packets.

A future version of Advanced Firewall app can be enhanced to include more educational firewall functions to cover advanced topics, such as stateful firewall packet filtering using TCP flags, application gateway firewalls (Proxy), and Virtual Private Networks (VPN). The following subsections describe in details the current main basic security functions of Advanced Firewall app.

Basic Packet Filtering

Basic firewall packet filtering is the selective passing or blocking of packets as they pass through a network interface. The most often used criteria that packet filtering use when inspecting packets are source and destination IP addresses, source and destination TCP/UDP ports, and type and code fields in an ICMP header (Northcutt et al. 2005). Firewall users need to have basic knowledge about TCP/IP protocols and Internet services in order to be able to create the appropriate rules for filtering specific network traffic.

Predefined Filtering Rules for Standard Internet Services

Standard Internet services run usually on standard ports. Standard ports range is in the interval of 1 to 1023. For example, the standard ports for Web (HTTP) and FTP services are 80 and 21, respectively. Firewalls include usually predefined rules to filter standard services. Firewall users can select rules from the list of offered predefined rules to filter network traffic relative to Internet services. However, in contrast to writing basic filtering rules, firewall users need simply to have general knowledge about Internet services, to be able to select the appropriate predefined filtering rule for each specific Internet service.

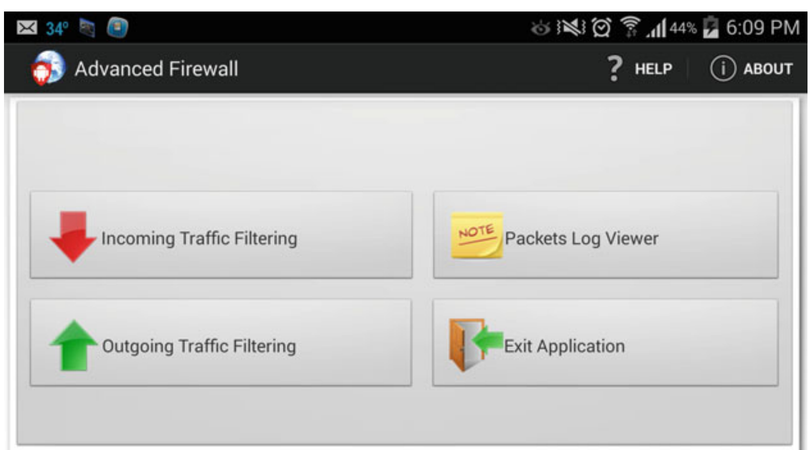
Nonstandard Services Filtering

Nonstandard services run on nonstandard ports. Nonstandard port numbers are usually larger than 1023. Firewalls are unable to filter nonstandard services unless the user provides the firewall with the TCP or UDP ports of the nonstandard services to be filtered. In practice, this is achieved by creating a new service profile for the nonstandard service, and by specifying its corresponding TCP or UDP port number.

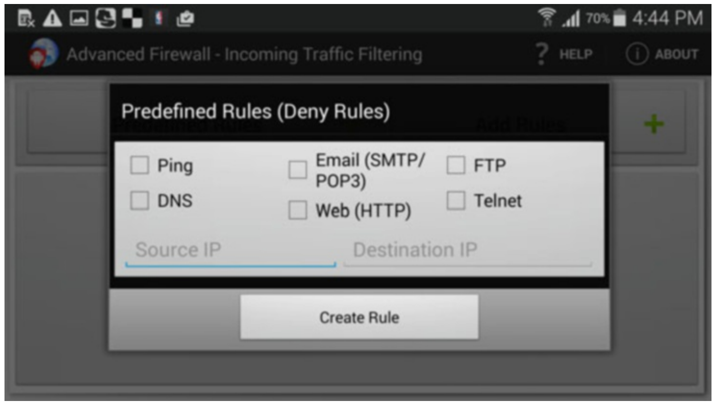
App's Implementation

Advanced Firewall app is written in Java language using Eclipse IDE. The main GUI interface of Advanced Firewall app allows the mobile device's users to select the source of the network traffic (incoming or outgoing) to be filtered or to view the log data relative to the previously filtered packets, as shown in Fig. 2.

To filter network traffic, the user can either select filtering rules, from a set of predefined



Android-Based Mobile Apps for Hands-On Education, Fig. 2 Main user interface of Advanced Firewall app



Android-Based Mobile Apps for Hands-On Education, Fig. 3 List of predefined filtering rules offered by Advanced Firewall app

Android-Based Mobile Apps for Hands-On Education, Fig. 4 List of selected and user-created filtering rules

filtering rules, or create new filtering rules. Figure 3 shows the list of predefined rules offered by Advanced Firewall app for filtering Ping traffic and Web/FTP/DNS/Email/Telnet services.

As an example, Fig. 4 shows a list of selected predefined and user-created filtering rules.

Packet Generator App

The discussed learning platform also uses a network packet generator app, named Packet Generator, for generating specific network traffic to test the efficiency and correctness of the implemented filtering rules in mobile devices. In fact, the objective behind developing this app is to allow a single student to conduct, from a mobile device, self-testing of his implemented filtering rules for the outgoing network traffic. However, to test the filtering rules for the incoming network traffic, Packet Generator app should be installed into another mobile device from which the network test traffic can be generated. Packet Generator app can be used also to test the resilience of target hosts against denial of service (DoS) attacks traffic (Trabelsi et al. 2013), by generating network flood traffic at a high rate.

Implementation of the App

Packet Generator app is written in Java language using Eclipse IDE. The application is freely downloadable from Google Play Store (https://play.google.com/). Based on statistics from the Google Play Store, and as per September 2019, Packet Generator app turned popular with over 500,000 downloads worldwide and a 4.00 users' rating.

Using a friendly GUI interface, the app allows Android mobile device's users to specify the type of the network traffic to be generated (i.e., TCP, UDP, or ICMP). Practically, for TCP and UDP network traffic, the app offers the user the options to specify the IP address of a target host and a random or specific TCP or UDP port number. For ICMP network traffic, the app offers the user the options to specify the IP address of a target host and the ICMP Type and Code field values.

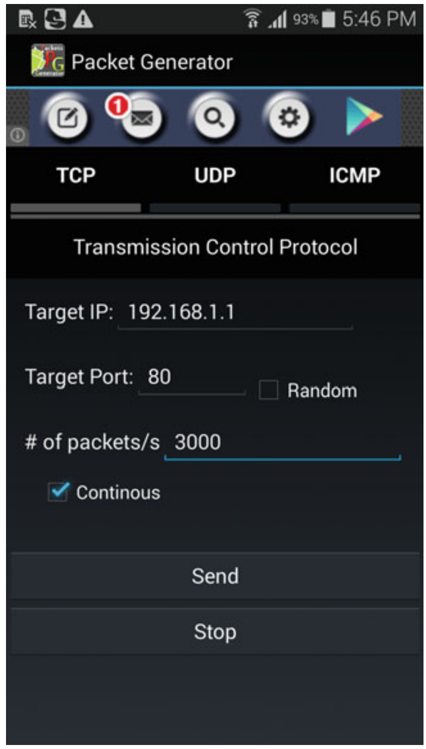
For any network traffic type, the user can choose the rate of traffic to be generated (i.e., number of packets per second) and whether or not the desired traffic will be sent continuously. In addition, for ICMP traffic, the user can select to flood the target host. In this case, the flooding traffic is sent at the highest possible rate that the mobile device can support. In general, flooding option in Packet Generator app allows testing the resilience of target hosts against DoS attack traffic.

DoS Attacks Generation Using Packet Generator App

DoS attacks topic is considered as one of the major topics for courses on network security, especially for courses that are concerned with intrusion and malicious network activities detection and prevention. Commonly, a DoS attack attempts to render a system unusable or significantly slows down the system for legitimate users by overloading the resources so no one else can access it. A DoS attack may target a user, to prevent him from making outgoing connections on the network. A DoS attack may also target an entire organization, to either prevent outgoing traffic or to prevent incoming traffic to certain network services, such as the organization web page.

DoS attacks are much easier to accomplish than remotely gaining administrative access to a target system. Because of this, DoS attacks have become very common on the Internet. Most DoS attacks rely upon weaknesses in the TCP/IP protocols. For example, a SYN flood DoS attack occurs when a host becomes so overwhelmed by SYN packets initiating incomplete connection requests that it can no longer process legitimate connection requests.

In information security education, hands-on lab exercises on DoS attacks allow usually students to learn DoS attack traffic generation and implement the corresponding defensive solutions. Practically, students can use network packet generator tools to generate DoS attack traffic. However, it is not recommended to use DoS tools developed by hackers or untrusted sources, since the tools may carry virus and malicious codes.



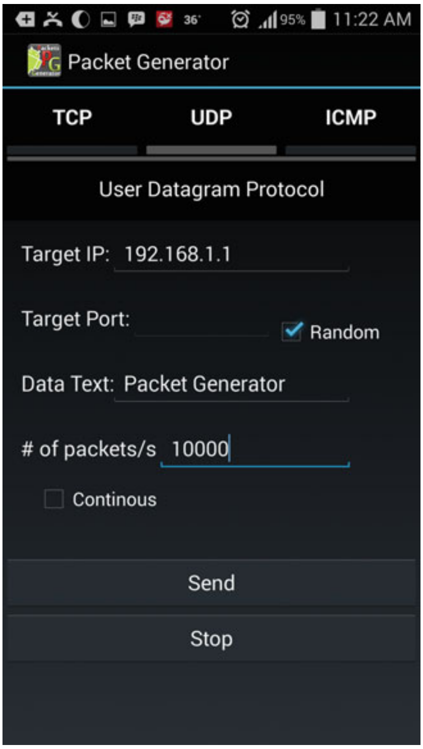
Android-Based Mobile Apps for Hands-On Education, Fig. 5 TCP packets generation example

The following screenshots are examples on how to use Packet Generator app to generate a diversity of common DoS attacks.

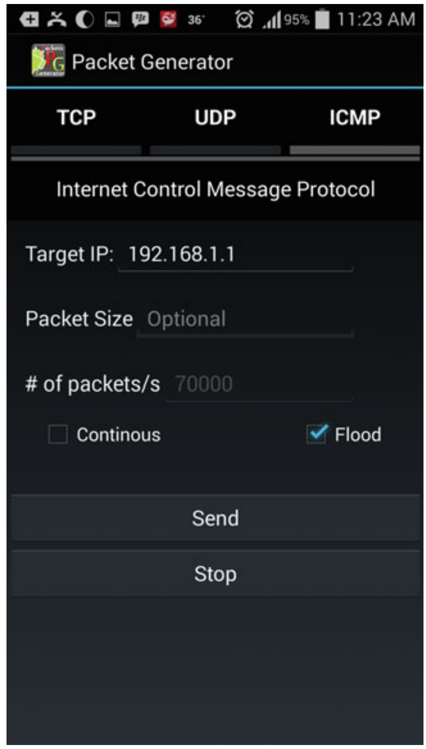
Figure 5 shows how to generate continuously TCP packets targeting port 80 in a host with IP address 192.168.1.1, at the rate of 3000 packets per second.

Figure 6 shows how to generate 1000 UDP packets in 1 s, targeting random ports in a host with IP address 192.168.1.1.

Figure 7 shows how to flood a target host with IP address 192.168.1.1 with ICMP packets, using the highest traffic rate that the mobile device can generate.



Android-Based Mobile Apps for Hands-On Education, Fig. 6 UDP packets generation example



Android-Based Mobile Apps for Hands-On Education, Fig. 7 ICMP flooding traffic generation

Related Android Firewall Apps

The development of Android firewall apps is not a new idea by itself as there are many Android apps acting as firewalls. In Google Play Store, many Android firewall apps have been identified, namely, *DroidWall*, *Android firewall*, *Root firewall*, *Mobiwol firewall*, *Firewall builder*, *Honeybadger firewall*, *Traffic firewall*, *Firewall plus*, *IP spoofing detector and firewall*, *NoRoot Firewall*, *AFWall+*, *Firewall Gold*, and *LostNet NoRoot Firewall*. Table 1 summarizes the firewall features of these Android apps, particularly their abilities to allow users to easily and freely implement and manipulate firewall filtering rules, as well as their limitations and strengths. In addition, Table 1 compares these apps with the proposed Advanced Firewall app.

The analysis results of these apps conclude that they have been designed almost without educational objectives and offer limited firewall functions to create and manipulate filtering rules. Moreover, the use of some apps is complex and often requires advanced knowledge of networking concepts and protocols. For example, *Android firewall* and *Firewall builder* allow the user to enter his/her custom filtering rules in script syntax. Also, the GUI interfaces of some apps do not allow friendly view of the implemented filtering rules. There are many apps that do not allow viewing the log data of the filtered network packets, such as *DroidWall*, *Android firewall*, *Root firewall*, *Firewall builder*, *Traffic firewall*, *Firewall plus*, *IP spoofing detector and firewall*, *Firewall Gold*, and *LostNet NoRoot Firewall*.

Other apps do not allow free manipulation of the fields of the filtering rules. For example, in the case of filtering TCP and UDP packets, many apps do not allow setting the source and destination IP addresses and/or the source and destination ports (*DroidWall*, *Android firewall*, *Root firewall*, *Mobiwol firewall*, *Traffic firewall*, *Firewall plus*, *IP spoofing detector and firewall*, *AFWall+*, *Firewall Gold*, *LostNet NoRoot Firewall*). In case of

Android-Based Mobile Apps for Hands-On Education, Table 1 Related Android firewall apps' features

Firewall features	Apps supporting this feature	Advanced Firewall (Our Firewall App)
Offer easy-to-use GUI interface	[DroidWall, Android firewall, Root firewall, Mobiwal firewall, Honeybadger firewall, Traffic firewall, Firewall plus, IP spoofing detector, NoRoot firewall, AFWall+, Firewall Gold, LostNet NoRoot firewall]	✓
Filter TCP and UDP traffic based on IP address	[Firewall builder, Honeybadger Firewall, NoRoot firewall]	✓
Filter TCP and UDP traffic based on port number	[Firewall builder, NoRoot firewall]	✓
View log data of dropped packets	[Mobiwal firewall, Honeybadger firewall, NoRoot firewall, AFWall+]	✓
Filter ICMP traffic based on the Type and Code fields' values	None	✓
Allow selecting predefined filtering rules for specific services and applications	[Firewall builder]	✓
Filter Web traffic based on URL address	[Honeybadger firewall, IP spoofing detector]	✓
Filter nonstandard services	[DroidWall, Android firewall, Root firewall, Mobiwal firewall, Honeybadger firewall, Traffic firewall, Firewall plus]	✓
Filter both incoming and outgoing traffic	[Firewall builder, Honeybadger firewall, NoRoot firewall]	✓

filtering ICMP traffic, all investigated Android firewall apps do not allow to set the ICMP Type and Code fields.

On the other hand, most investigated apps focus on controlling solely the other apps installed in the mobile device that require accessing Internet. That is, the users can solely allow or deny the installed apps to access the Internet. *DroidWall*, *Root Firewall*, and *Mobiwol* apps are examples of such apps.

In contrast, Advanced Firewall app has been designed mainly for educational purpose and offers a more user-friendly GUI interface to implement and manipulate firewall filtering rules. Furthermore, Advanced Firewall app offers a more comprehensive set of educational firewall functions that are appropriate and useful for information security education. Hence, compared to the investigated aforementioned Android firewall apps, Advanced Firewall app is more adequate for implementing educational hands-on lab exercises on firewall packet filtering, allows students to better anatomize firewall concepts in real-world environment and outside laboratory activities, and consequently enhances further student's firewall hands-on skills.

Assessment Process

Course learning outcomes achievement is assessed using a comprehensive assessment and evaluation system (Ibrahim et al. 2015). The assessment system consists of three main processes based on ABET guidelines (Sanderson 2009). At the lower level, the course assessment process is used to measure the achievement of course outcomes (COs). COs describe the knowledge, skills, and/or competencies that the students should have or be able to demonstrate upon completion of the course. COs assessment results are then combined with other program-level assessment tools (e.g., student survey, exit exams, exit interview, etc.) to measure the achievement of the student outcomes (SOs) at the next stage. SOs describe what students are expected to learn and be able to do by the time of their graduation, which include cognitive, affective, behavioral, social, and ethical performances. At the third level, the program educational objectives (PEOs) are measured and evaluated. PEOs are broad statements that describe the strategic career and long-term professional accomplishments the program is preparing its graduates to achieve 3–5 years after graduation.

During the course offering, each instructor teaching the course is responsible for collating the assessment data for the taught section(s) and preparing a simplified section assessment report. The section assessment reports are then sent to the course coordinator. To minimize the assessment effort, the section assessment report includes only the following information:

1. The number of students
2. The assessment tools used
3. The mean and standard deviation for each outcome achievement level
4. Any assessment-related remark (optional)

Although bimodal distribution could be more appropriate in some situations to model the students' performance, the tool assumed a Normal distribution for the students' performance to facilitate the aggregation of the assessment data from different sections and different assessment instruments producing the overall CO assessment results. To calculate the mean and the standard deviation for each learning outcome, the course coordinator aggregates the performance of the students in each used assessment tool. Each course c has a set of outcomes O_c, a set of assessment tools T_c, and is offered to a set of sections S_c. Therefore, the mean and standard deviation for outcome o is calculated as follows:

$$\mu_{soc} = \frac{\sum_{t \in T_c} \mu_{tsoc} \times \alpha_{to}}{\sum_{t \in T_c} \alpha_{to}} \quad (1)$$

$$\sigma_{soc} = \sqrt{\frac{\sum_{t \in T_c} \sigma^2_{tsoc} \times \alpha_{to}}{\sum_{t \in T_c} \alpha_{to}}} \quad (2)$$

where μ_{tsoc} and σ_{tsoc} are the mean and standard deviation when tool "t" is used in section "s" to assess outcome "o" of course "c," α_{to} is a mapping factor that determines the contribution of the assessment tool t to the achievement of outcome o such that $\sum_{o \in O_c} \alpha_{to} \leq 1$.

The course coordinator compiles the received section assessment reports and calculates the aggregated course-level assessment results. Using the mean and standard deviation for measuring the achievement of the outcomes at the section level facilitates the aggregation of the results from different sections to calculate the overall course assessment, regardless of the assessment tool used in each section. For each outcome o of course c, the aggregated mean and standard deviation are calculated as follows:

$$\mu_{oc} = \frac{\sum_{s \in S_c} \mu_{soc} \times n_s}{\sum_{s \in S_c} n_s}, \quad (3)$$

$$\sigma_{oc} = \sqrt{\frac{\sum_{s \in S_c} \sigma^2_{soc} \times n_s}{\sum_{s \in S_c} n_s}}, \quad (4)$$

where n_s is the number of students in section s. Assuming Normal distribution, the achievement level of outcome o of course c (noted A_{co} below) is calculated as the percentage of students who scored above a predefined cutoff threshold λ, as shown next:

$$A_{oc} = 0.5 - 0.5 \times erf\left(\frac{\lambda - \mu_{oc}}{\sigma_{oc} \times \sqrt{2}}\right). \quad (5)$$

For example, assume that $\mu_{co} = 0.74$, $\sigma_{co} = 0.093$, and $\lambda = 0.7$, the outcome achievement level in this case is the percentage of students whose score is above λ, which in this case is 66.64%.

Course Learning Outcomes Assessment

As a case study, the two discussed Android apps have been offered to students enrolled in a course called Network Border Control (SECB358)

Android-Based Mobile Apps for Hands-On Education, Table 2 Mapping the course outcomes to Bloom's taxonomy

Outcome	Level of Bloom's taxonomy
CO1: Describe TCP/IP protocols and network services	Analysis
CO2: Identify common security threats	Analysis
CO3: Configure personal firewalls, network firewalls, and VPNs	Synthesis
CO4: Implement firewall filtering rules for different network architectures and services	Synthesis
CO 5: Evaluate different types of network architectures	Evaluation

during several academic years. SECB358 is a course that is concerned mainly with network packet filtering, firewall, and VPN topics. A major topic taught in SECB358 course is firewall filtering rules implementation. The course also offers students an extensive set of hands-on lab exercises on these topics. SECB358 course has five learning outcomes, as shown in Table 2. Since SECB358 is an advanced course in information security, the outcomes have been selected carefully to reflect the top three levels in Bloom's taxonomy of cognitive domain (analysis, synthesis, and evaluation).

During the 2009/2010, 2010/2011, and 2011/2012 academic years, students enrolled in SECB358 course were not offered the two Android apps. Students had the opportunity to practice firewall packet filtering, only in the in-campus isolated labs environment. In addition, students are allowed to practice only for a limited time. However, starting from fall 2012, SECB358 course's committee decided to offer the two Android apps to allow students to further practice firewall packet filtering implementation outside the isolated lab environment.

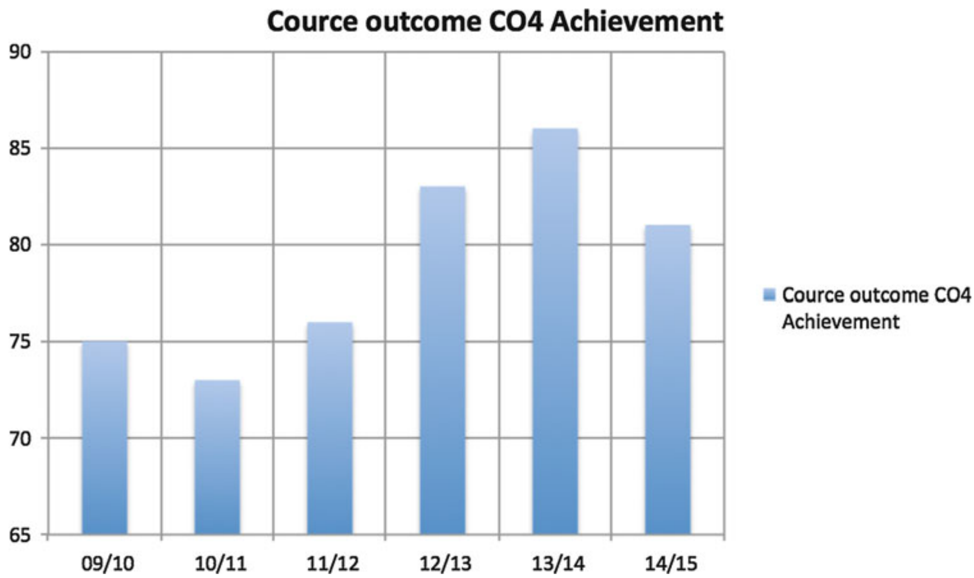
Among the five COs (Table 2), the Android apps have impact only on the course outcome CO4, since the apps are concerned with the implementation and testing of firewall filtering rules. To compare the achievement of the course outcome CO4 before and after the introduction of the Android apps, four assessment tools that are related to firewall filtering rule implementation topic have been selected, namely, two quizzes, three lab exercises, two midterm questions, and two final exam questions. The grades of the students in these quizzes, lab exercises, and questions are measured, normalized, and then aggregated using (Eqs. 1 and 2) to calculate the achievement level of the course outcome CO4.

Figure 8 illustrates the achievement of the course outcome (CO4) for six consecutive academic years, from 2009/2010 to 2014/2015. It shows an important improvement in the achievement level of the course outcome CO4 after introducing several new hands-on lab exercises on firewall filtering rules and the two discussed Android apps in fall 2012. The assessment results show that the achievement level of CO4 in fall 2012 improved by about 7%, compared to the achievement level in the previous academic year (2011–2012).

In addition, Table 3 compares the CO4 achievement level of the 2011/2012 and the 2013/2014 academic years in detail. It shows that the 9% improvement in the achievement level of CO4, from 77% to 86%, can be interpreted as 11.9% and 5.9% increase in the number of students scored above 90% and 80%, respectively, and 10.8% and 6.4% drop in the number of students scored below 60% and 70%, respectively.

The aforementioned assessment results clearly show that starting from fall 2012, the achievement level of the course outcome CO4 (which is concerned mainly with the students' hands-on skills on firewall filtering rules implementation) has improved compared to the pervious academic year. In principal, this is apparently due to the fact that the introduction of several new hands-on lab exercises on firewalls and the proposed Android apps allowed students to improve considerably their hands-on skills on firewall filtering rules implementation and better anatomized this topic. The students have learned better with the offered Android apps, which had a positive effect on their performance.

However, to show that the introduction of the apps contributed to affect those assessment results, mainly the learning outcome CO4's



Android-Based Mobile Apps for Hands-On Education, Fig. 8 Course outcome CO4 achievement

Android-Based Mobile Apps for Hands-On Education, Table 3 Detailed description of the course outcome CO4 achievement

	CO-4	
	2010/2011 (%)	2013/2014 (%)
CO $<$ 60%	20.0	9.2
60% $\leq$ CO $<$ 70%	17.8	11.4
70% $\leq$ CO $<$ 80%	21.9	21.3
80% $\leq$ CO $<$ 90%	19.6	25.5
90% $\leq$ CO	20.7	32.6

achievement level, anonymous student questionnaires were administrated to identify the level of impact of the proposed apps on the students' hands-on skills on firewalls. Overall, the questionnaire results supported the fact that the discussed learning platform had a positive impact on improving the students' hands-on security skills on firewalls and consequently contributed to enhancing the achievement of the learning outcome CO4.

Discussion

The following discussion is based on the data collected from 2 anonymous questionnaires administered to 120 students, who were enrolled in SECB358 course and who over 3 academic years (2012/2013, 2013/2014, and 2014/2015) used the 2 Android apps. The first questionnaire's objective was to measure the students' satisfaction level and collect their feedbacks. The second questionnaire's objective was to identify the locations where the apps have been used and the students' motivations behind using the apps.

In the first anonymous questionnaire, the majority of the students provided positive feedbacks and enjoyed the Android security practices. In fact, most of the students strongly agreed or agreed that Advanced Firewall app contributed significantly to the closeness of firewall technologies to their daily lives and promoted their interests on firewalls (Table 4, Q. 1 and Q. 2).

The results of the questionnaire showed that about 86% of the students who answered the questionnaire felt that Advanced Firewall app to be useful and helped them better understand the theoretical firewall concepts taught in the lecture (Table 4, Q. 3). The questionnaire also revealed that about 85% of the students strongly agreed or agreed that the proposed apps helped them to develop further their hands-on skills (Table 4, Q. 6), and about 91% of the students strongly

Android-Based Mobile Apps for Hands-On Education, Table 4 Student feedback questionnaire results

Question	Response
Q. 1. Do you think that Advanced Firewall app contributed to the closeness of firewall technologies to your daily lives?	2% Strongly disagree 1% Disagree 5% Neutral 8% Agree 85% Strongly agree
Q. 2. Do you think that Advanced Firewall app promoted your interests on firewalls?	0% Strongly disagree 1% Disagree 3% Neutral 5% Agree 91% Strongly agree
Q. 3. Do you feel that Advanced Firewall app is useful and helped you better understand the theoretical firewall concepts taught in the lecture?	4% Disagree 10% Neutral 1% Agree 85% Strongly agree
Q. 4. Do you think Advanced Firewall app offers to you the necessary basic firewall functions learned in the lecture?	3% Disagree 8% Neutral 10% Agree 77% Strongly agree
Q. 5. Do you think Advanced Firewall app offers to you the necessary advanced firewall functions learned in the lecture?	95% Disagree 3% Neutral 2% Agree 1% Strongly agree
Q. 6. Do you feel that Advanced Firewall app helped you to develop further your hands-on skills on firewall filtering rules implementation?	7% Disagree 8% Neutral 13% Agree 72% Strongly agree
Q. 7. How likely are you to recommend Advanced Firewall app to others to practice firewall filtering rules implementation outside the laboratory environment, at their convenience?	5% Disagree 6% Neutral 8% Agree 81% Strongly agree
Q. 8. Would you like to see similar Android apps offered to students for other security topics, such as intrusion detection?	5% Disagree 4% Neutral 18% Agree 73% Strongly agree
Q. 9. Do you think that Packet Generator app helped to test the correctness of your filtering rules?	5% Disagree 4% Neutral 18% Agree 73% Strongly agree

agreed or agreed to see similar Android apps offered to students for other security topics, such as intrusion detection systems (Table 4, Q. 8).

Moreover, most students recommended offering Advanced Firewall app to students to practice firewall filtering rules implementation, outside the laboratory environment, at their convenience, after practicing the traditional hands-on exercises inside the laboratory rooms (Table 4, Q. 7).

Also, the questionnaire results showed that 87% of the students strongly agreed or agreed that Advanced Firewall app offered to them all the necessary basic firewall functions learned in the lecture (Table 4, Q. 4). However, 95% of them strongly disagreed that Advanced Firewall app offered to them all the necessary advanced firewall functions, such as DPI and VPN. This is explained by the fact that the version of Advanced Firewall app offered to students lacked advanced firewall functions (Table 4, Q. 5).

Overall, the questionnaire results support the fact that the discussed Android learning platform had a positive impact on the students' hands-on security skills and consequently would contribute to enhancing the achievement of the course learning outcomes. In fact, the two Android apps allowed students to better anatomize and assimilate the firewall concepts learned from the lecture.

Regarding the second questionnaire (Table 5), the results showed that about 98% of the students used the two Android apps outside the laboratory environment at many locations, mainly at the school and homes (Table 5, Q. 1). In addition, 78% of the students used the apps to prepare for the exams and continued using the apps even after the exams to protect their mobile devices or to practice further (Table 5, Q. 2).

The results of the second questionnaire showed that the major objective of providing an Android-based learning approach to allow students to further practice firewall filtering rules implementation, outside the in-campus isolated laboratory environment, in the real-world, anywhere and anytime, and at the students' convenience, is achieved.

Conclusion

This entry discussed a learning activity that uses two Android apps to enhance students' hands-on

Android-Based Mobile Apps for Hands-On Education, Table 5 Students questionnaire results

Question	Response
Q. 1. Outside the laboratory room, where did you use *Advanced Firewall and Packet Generator* apps to implement and test firewall filtering rules?	2%: I never used them outside the laboratory room 30%: Only at the school 20%: Only at home 48%: At many locations (Schools, home, and others)
Q. 2. Outside the laboratory room, how often did you use *Advanced Firewall and Packet Generator* apps to implement and test firewall filtering rules?	2%: I never used them outside the laboratory room 20%: I used them few times to prepare for the exams 78%: I used them many times even after the exams to protect my mobile device or to practice further

skills on firewalls concepts. The main objective is to demonstrate how mobile devices can be used to develop novel educational activities and tools and learning approaches that attempt to get benefit from the prevalence of mobile devices within the student community. The data collected using assessment tools and students' feedback questionnaire demonstrates clearly that the discussed Android-based learning activity had a positive impact on the students' firewall hands-on skills and on the students' performance in terms of achieving the course learning outcomes. Moreover, a comparative analysis of various related Android apps with the discussed apps emphasizes their significance, mainly for the academic environment.

The educational case study presented in this entry demonstrates clearly that mobile technology has the potential to transform considerably the learning field by allowing to develop novel educational activities, approaches, and tools that take advantages of the benefits of this technology and its increase growth in popularity within the student community. Therefore, the existing learning approaches, pedagogical models, and educational tools should reflect the current trend in computing platforms away from the desktop and toward mobile technologies. Moreover, as institutions adopt new mobile technologies, they should look beyond using these devices for teaching and examine how mobile computing can increase engagement and cultivate strong communities of learners. In fact, mobile computing has the potential to transform learning and engages students in learning in different ways. Consequently, as mobile devices have become more common on campuses, many innovative projects have emerged that engage students and change the way faculty teach courses.

Cross-References

▶ Mobile Computing and Mobile Learning
▶ Mobile Learning and Ubiquitous Learning
▶ Mobile Learning, Challenges in
▶ WalkAbout Framework for Contextual Learning Through Mobile Serious Games

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▶ Human, Social, and Ethical Aspects of Information Technology Management Systems

Apple iPad

▶ Tablet Use in Higher Education

Applications

▶ School Management Software in a Primary School in Victoria, Use of

Applying Software Engineering Principles in Android Development

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Synonyms

Android; Java; Mobile application development; Software design; Software design principles

Introduction

The tremendous popularity of mobile computing and Android in particular has attracted millions of developers who see opportunities for building their own start-ups. As a consequence computer science students express an increasing interest into the related technology of Java development for Android applications. Android projects are complex by nature and relatively large software products, while their development calls for the application of established software engineering practices and tools.

Computer science and information technology curricula include software engineering as a key knowledge area (ACM 2013), and as a result, most computer science-related departments offer at least one "conventional" software engineering course. By conventional we mean that in most cases, the introduced concepts are exemplified on either desktop applications standing individually on a personal computer and recently on web applications employing server and/or client side development. To the best of our knowledge, there are very few courses that introduce software engineering concepts to a mobile software development course. At the same time, software development for particular platforms is often perceived and taught as a purely technological skill with no direct connections to software engineering. The consequence is that even experienced mobile application programmers do not embrace or apply software engineering practices. Moreover, the lure of Android development can serve as a vehicle for conveying software engineering concepts to computer science students in an attractive way. All these issues have resulted in interesting proposals regarding the integration of mobile devices into the computer science curriculum and relevant courses and teaching approaches.

The integration of mobile devices into the computer science curriculum has been discussed in a study by Mahmoud (2008) where the need to consider the important factor of restricted resources (small screen, limited memory, etc.) is stressed. Moreover, the author highlights the difference of compiling an application for a "normal" PC and for a mobile device. It is claimed that introducing mobile devices and the basics of mobile application development as early as possible in introductory programming courses is a necessity. In the context of the described course, the students were asked to develop two versions of a mortgage calculator application: one for a desktop and one for a mobile platform, so they could distinguish the differences (and similarities) between the two approaches.

A different approach is adopted in the work of Akopian et al. (2013) where the authors rely on already developed templates (Android programs) to teach in a short course, the basic principles of Android development. The students were asked to alter specific aspects in the program by modifying the existing code. The questions and activities have been very carefully structured and explained, in order to guide the student to the correct position of variable or code snippet that needs to be changed. Through structured colored examples, the activities for the students are slowly escalating to the most difficult ones. According to one pre-course and one post-course survey, student's satisfaction has been achieved along with a strong belief that basic skills have been obtained through the course.

Evidence from evaluations performed by Heckman et al. (2011) implies that teaching lower-level programming courses with more advanced and current technologies such as mobile devices can be beneficial. In particular, the authors taught Java and software engineering courses at the University of Virginia and North Carolina State University utilizing the Android OS platform. Although details about the course are not provided, the goals are similar to the proposed course in this paper, i.e., to teach both Java (such as abstraction) and software engineering concepts (such as design, testing, and patterns) using Android.

Petkovic et al. in 2006 (Petkovic et al. 2006) claimed that practical teaching of software engineering should also focus on teamwork, communication skills, and organizational issues to reflect the globalization and open-source aspects of real software development projects. The authors recommend that students should be divided into small groups of four to six persons in order to simulate real-life software development and undertake the task of constructing a web application through five milestones. The course also emphasizes the need of collaboration without face-to-face meetings, and to this end, the use of version control systems is essential.

The main motivator for their work was that the combination of traditional classroom teaching of processes, teamwork, and communication with a major final project, intensive instructor interaction, and realistic simulation of real software lifecycle is critical. The benefits of cooperative learning where students work together in small groups enhancing each other's learning have been recognized early in the computer science education community (Tenenberg 1995). The same belief is shared by the authors of the current work and has been taken into account during the design of the proposed course.

The challenges of designing a smartphone software development course based on Android have been discussed by Hu et al. (2010). The paper introduces a full semester course with an emphasis on the underlying platform: the first two parts of the course consist in an introduction to smartphones and their OS. The next three parts are presenting the environment for Android development, while only the seventh part is devoted to software development. The authors are acknowledging three design principles with the second stating that the teaching content should place an emphasis on practice rather than theory and the third mentioning that course contents should meet the needs of the industry.

In this entry, a short course is introduced aiming at illustrating selected software engineering principles, concepts, and techniques in the context of Android application development. The goal is to demonstrate that Java programming for Android applications – which is usually perceived as an isolated activity – can benefit largely from applying software engineering best practices. The course is structured around a base Android application that is gradually enhanced by discussing limitations or opportunities that can be addressed by appropriate techniques or guidelines such as design principles, design patterns, refactorings, software metrics, testing, version control systems, etc. The proposed course has been evaluated with positive results (Chatzigeorgiou et al. 2016), and it is in accordance with the findings of the Joint Task Force on Computing Curricula of the IEEE Computer Society and the Association for Computing Machinery (ACM) (LeBlanc and Sobel 2004), where a set of guidelines for effective education activities have been established. These guidelines emphasize the need to focus on professional issues necessary to begin practice as a software engineer and the need for students to complete tasks that involve both individual work and tasks that require collaboration among peers. Having this in mind, students were divided into small groups as described in (Petkovic et al. 2006), with the exception that they were left alone to form the groups. This approach seemed more appropriate to the Arabic or the Greek cultures, where students tend to lean toward the existing bonds among them.

The rest of the entry is outlined as follows: section "Introduction" presents an outline of the proposed course; the detailed structure along with the introduced software engineering concepts and the activities carried out at each step. Section "The Course" provides some guidelines for an effective application of the proposed course, and section "Guidelines for Delivering the Course" provides the final conclusions.

The Course

Learning Outcomes

The proposed course aims at introducing software engineering concepts and techniques in the context of Android development. The course can be delivered either in an advanced undergraduate or a postgraduate program. In case students have a background in both areas (software engineering and Java/Android development), the objective is to highlight that mobile application development can benefit from the adoption of best practices as learned in a software engineering course. In case students lack background in any of the involved areas, the course can also serve as an introductory seminar for the corresponding topic, given that it includes theoretical aspects as well as lab activities.

The short course is in agreement with the 2013 Curriculum Guidelines for undergraduate programs in computer science by ACM (2013) where Platform-Based Development (PBD) has been elevated to a Knowledge Area (KA) in the

Computer Science Body of Knowledge. The guidelines suggest that electives should be offered (in the area of programming interactive systems) covering the needs for specific programming paradigms and mobile development and these are designated as "high-demand" courses. Within the ACM report, it is noted that platform-based development as a general skill of developing with respect to an Application Programming Interface (API) or a constrained environment is directly related to other knowledge areas such as Software Development Fundamentals (SDF). As a result, the relationship between mobile development and software engineering is profound.

According to the constructive alignment approach (Biggs and Tang 2011), it is important to start reasoning about the outcomes that a planned course aims at achieving and then align the teaching and assessment strategies to those explicitly stated outcomes. Learning outcomes are statements of what a learner is expected to know, understand, and/or be able to demonstrate after completion of a lecture, course, or entire program. Compared to teaching aims or objectives, outcomes offer the advantage of being more precise, clearer, and easier to compose (Kennedy et al. 2006).

We formulate the learning outcomes of the proposed short course as follows, placing them in the appropriate knowledge and cognitive process dimension of the revised Bloom's taxonomy (Krathwohl 2002) in Table 1:

1. Explain the benefits from applying software engineering practices to Android development.
2. Apply design principles and design patterns in Android applications.
3. Identify and resolve design issues in Android applications.

Informed choices regarding the curriculum have to clearly define the desired Information and Communication Technology (ICT) skills, besides the underlying knowledge area(s) and learning outcomes. A tool that can be used for this purpose is the Skills Framework for the Information Age (SFIA), which provides 6 categories and 19 subcategories including 96 ICT-specific skills in total (SFIA Foundation 2015). These skills are defined quite generally and independently of the underlying knowledge areas, so that they are transferable to different ICT domains/disciplines. In addition to the general definition, SFIA provides a definition of each skill across the following seven levels of responsibility (that apply in each case): (1) follow; (2) assist; (3) apply; (4) enable; (5) ensure and advise; (6) initiate and influence; and (7) set strategy, inspire, and mobilize. Utilizing a tabular approach (Herbert et al. 2013), the main SFIA skills that the proposed course aims at are presented in Table 2.

The course is structured around a base Android application that is gradually enhanced over 13 consecutive steps. At each step a different software engineering concept, practice, or technique is introduced which is then exemplified through additions to the functionality of the application or restructuring of its design.

In accordance to Keller's Motivation Theory (Keller 1983), the course is designed in order to promote learning by increasing students satisfaction and attention. A feeling of satisfaction is achieved by providing students with opportunities to apply on a small, but real Android application the newly learned knowledge and the interest of the students is engaged by interleaving different software engineering practices and techniques on the same example. Since the course is structured

Applying Software Engineering Principles in Android Development, Table 1 Course learning outcomes in terms of the revised Bloom's taxonomy

Knowledge dimension	Cognitive process dimension					
	1. Remember	2. Understand	3. Apply	4. Analyze	5. Evaluate	6. Create
A. Factual knowledge		(1)				
B. Conceptual knowledge		(1)	(2)	(3)		
C. Procedural knowledge			(2)	(3)		
D. Metacognitive knowledge						

A

Applying Software Engineering Principles in Android Development, Table 2 Targeted SFIA skills of the course

Category ~ Subcategory	Skill	Level	Code*
Solution development and implementation ~ Systems development	Programming/software development (*The design, creation, testing and documenting of new and amended Android programs*)	2 – assist 3 – apply 4 – enable	PROG
Solution development and implementation ~ Systems development	Systems design (*The specification and design of information systems to meet defined business needs. The identification of concepts and their translation into implementable design*)	2 – assist 3 – apply 4 – enable	DESN
Strategy and architecture ~ Technical strategy and planning	Software development process improvement (*The provision of advice, assistance and leadership in improving the quality of software development, by focusing on measurement*)	5 – ensure, advise 6 – initiate, influence	SPIM
Strategy and architecture ~ Technical strategy and planning	Methods and tools (*Ensuring that appropriate methods and tools for the development, testing and maintenance of systems are adopted*)	4 – enable 5 – ensure, advise	METL

[a]Refers to the unique skill code in the SFIA Framework

around a central lab activity which is gradually enhanced, it adheres to the learning theory of "Learning by Doing" which is one of the most well-known theories (Dewey 1938). Instructors can decide on the importance/time that should be placed on the theoretical presentation of each software engineering concept or technique and the corresponding hands-on assignments, depending on the subjects' background. The particular contents of each step are discussed in the next section.

Course Structure and Activities

As already mentioned, the proposed course is structured as a series of incremental additions to an initial Android application with the goal of introducing a different software engineering principle, concept, or technique each time. The outline of the course is shown in Table 3, depicting the corresponding students' activity in each step, the functionality of the resulting Android Java application as well as the introduced concept. A detailed presentation of the introduced software engineering concepts, as well as the corresponding activities, is provided in the following paragraphs.

Step 1: MVC Pattern

The Model-View-Controller architecture (or pattern) is fundamental to various domain-specific architectures that entail a significant amount of interaction with the user (Ghezzi et al. 2002). The architecture suggests the use of three different components: (1) the model that manages the data of the application domain, (2) the view that takes over the graphical display of the model, and (3) the controller that interprets user actions and coordinates the view and the model. A partial illustration of the MVC pattern can be achieved with the use of `ListView` objects in Android, which show items in a vertical scrolling list. A `ListView`, as any other View in Android, is built as a separate layout XML file and plays the role of the View component in MVC. Lists are populated by retrieving data from appropriate adapters which essentially control the content displayed in the list and the way it is displayed (Controller component of the MVC). The data itself can reside in a separate object as in the proposed example and constitutes the Model component of MVC. The separation of components according to MVC is shown graphically in Fig. 1.

Step 2: Externalization of Resources

Android encourages the application of a valuable practice, namely, the externalization of non-code resources like images and string constants or even entire layouts. Keeping resources separate from source code enables easier maintenance,

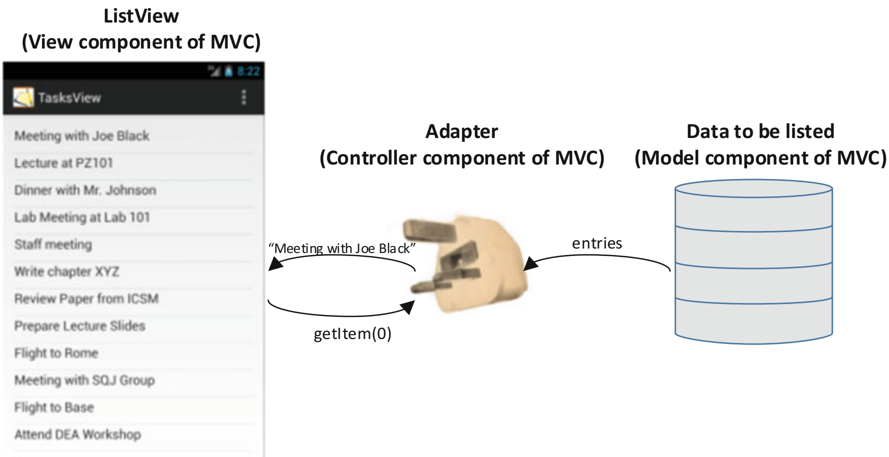
Applying Software Engineering Principles in Android Development, Table 3 Course structure

	Students' activity	Functionality of the resulting software	Introduced software engineering concept/technique
1	Downloading of initial version	Listing of future appointments in ListView	Model-View-Controller pattern Ghezzi et al. (2002)
2	Introduction of Android activity	Addition of input screen	Externalization of resources Mednieks et al. (2012)
3	Development of task hierarchy	Submission of tasks to ListView	Use of inheritance for modeling similar entities Liskov substitution principle Liskov and Wing (1994)
4	Intent handling	Display of task description and date and selection of appropriate color for each task type	Use of polymorphism. Open-Closed Principle Martin (2003)
5	Preservation of state between invocations of an activity	Display of multiple tasks in the ListView	Singleton design pattern Gamma et al. (1995)
6	Use of TreeSet structure for ordering	Ordering of tasks based on their date	Dependency inversion principle (use of TreeSet class – implementation of the Comparable interface)
7	Installation of metrics plugin. Examination of metric values	No change. Assessment of quality	Software metrics and their use for software quality evaluation. Software ageing
8	Identification of code smells	No change. Assessment of quality	Code smells (large method)
9	Unit test preparation	No change	Unit testing. Regression testing
10	Refactoring application Execution of unit tests	No change. Design improvement	Refactorings as a means to improve software. (extract method refactoring)
11	Addition of code. Identification of smell. Refactoring application	Setting task description text to title case	Smells + refactorings (extract method/move method)
12	Committing to a Git repository	No change	Distributed version control
13	Uploading to a common remote repository. Downloading by different students, edits, and merging. Viewing history	Any modification is acceptable	Collaborative software development

updating, and management. For example, internationalization can be easily supported having Android automatically select the appropriate resource values depending on the device's specific language or country, without having to modify the source code that manipulates these resources. The students' activity in this step consists in the creation of a simple Activity (by interacting with the layout) and placing emphasis on the externalization of string values that specify the text to be displayed for each graphical component. The corresponding process is depicted graphically in Fig. 2. After changing the introduced activity to a launcher activity, when the application starts, it displays the simplified input form for adding new tasks (without any functionality in the submit button so far).

Step 3: Use of Inheritance for Modeling Similar Entities

The next step in the proposed example consists in the addition of functionality to the "submit" button, so that whenever a new task is added, it will be displayed on the `TasksView` activity. The essence of this step is not the linking of a button to a class method – which is rather straightforward – but rather the need to highlight that classical object-oriented concepts, like inheritance



Applying Software Engineering Principles in Android Development, Fig. 1 Illustration of the Model-View-Controller pattern in the context of a ListView

Applying Software Engineering Principles in Android Development, Fig. 2 Introduction of Activity and externalization of strings

and abstraction, can be applied to Android applications as in any other kind of project that the students learned in the corresponding object-oriented programming courses. Once the "submit" button is pressed, the information concerning the added task (date, description, and urgency in this simplified example) should be transferred to the `ListView`, along with an intent that will cause the appearance of another activity's view (Mednieks et al. 2012). A large number of Android developers would simply transfer this information in the form of individual strings, missing the opportunity of taking advantage of an appropriate Task hierarchy. All pieces of information can be embedded into an appropriate Task object, whose class will designate the actual type of the task. Apart from the structural improvement to the source code that improves readability, the use of an inheritance relationship as shown in Fig. 3 will enable the use of polymorphism and the adherence to the "Open-Closed Principle" as it will be shown later. To make the distinction more clear, we assume that for urgent tasks the corresponding background in the `ListView` will be red (blue for NormalTasks) and that the description of each task will have as prefix the urgency of the task ("Urgent," "Normal").

In order to have task objects be conveyed by the intent that will be emitted, the corresponding Task classes should implement the `Serializable` interface. It is reminded that this is a marker interface, which means that it does not contain any methods that have to be implemented. A class implements this interface simply to indicate that its non-transient data members can be written to an output stream. The abstract superclass in Fig. 3 declares two abstract methods which are implemented in a different way in each of the subclasses. The functionality of the application after the completion of this step enables the user to add a new task and view the corresponding description in the `ListView`. Only a single task can be viewed at this point.

The class related to the input screen – whenever the submit button is pressed – reads the information in the input text fields and, depending on the selection of the radio buttons, instantiates either a `NormalTask` or an `UrgentTask` object. Then, an Intent is sent to the Android system defining explicitly the class that should be invoked `(.class)`, and the instantiated task object is passed within the intent.

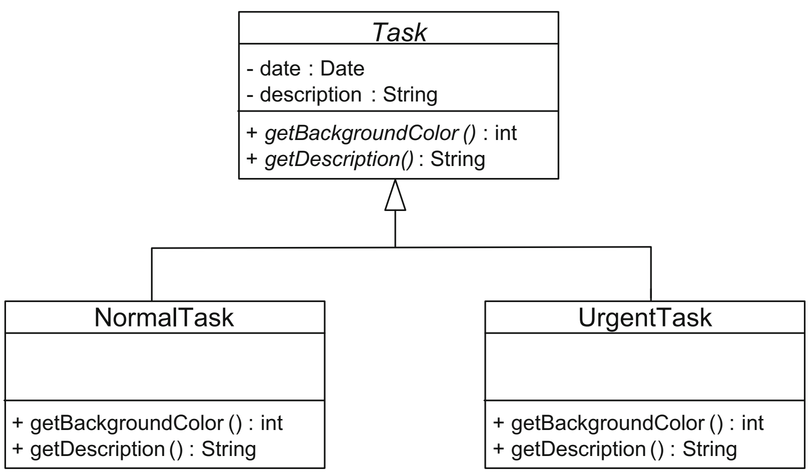
The `TasksView` class (containing the `ListView` object) receives the intent and retrieves its content without knowing which kind of task has been included. The received task object is assigned to a Task reference and transferred to the corresponding data model.

At this point, students should be reminded about the "Liskov Substitution Principle" (Liskov and Wing 1994) according to which "derived types must be completely substitutable for their base types." In other words, any method, class, or system that handles objects of a superclass should operate properly even when objects of subclasses are used. In the context of the examined application, a reference to the Task class can receive an object of any of its subclasses, namely, `NormalTask` or `UrgentTask` objects, since a generalization is an "is-a" relationship meaning that `NormalTasks` and `UrgentTasks` are also Task instances. This concept is illustrated in Fig. 4.

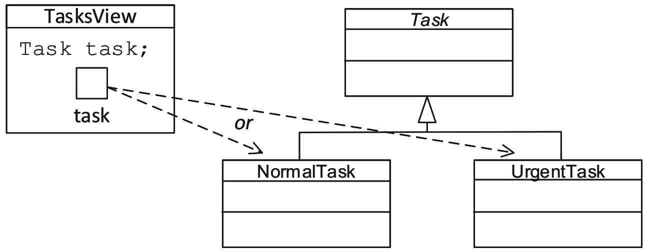
Step 4: Polymorphism and Open-Closed Principle

The real benefit from the use of polymorphism becomes evident when the handling of the received intent is performed in the `TasksView` class in order to display the newly added task. The `TasksView` retrieves the Task object from the intent and stores it in the corresponding data model. Within the adapter method which is responsible for filling in the corresponding line items of the `ListView`, the color for the background of each task is obtained by a call of the form:

```
 Task task = (retrieved from the
intent)
 . . .
 int color = task.getBackgroundColor();
```



Applying Software Engineering Principles in Android Development, Fig. 3 Task hierarchy



Applying Software Engineering Principles in Android Development, Fig. 4 Liskov Substitution Principle in the context of the examined application

Method invocation `task.getBackgroundColor()` is a polymorphic method call, since dynamic binding will be employed to invoke the appropriate method of the corresponding Task subclass, depending on the actual type of the object to which reference task will be pointing to at runtime. Students get the opportunity to understand that this essential feature of object-orientation – which is rarely employed in Android applications – can be easily integrated with the rest of an application's functionality.

At this point, the "Open-Closed Principle" of software engineering (Martin 2003) according to which "software modules should be open for extension (of functionality) but closed to modification (of existing source code)" can be reintroduced. The client of the Task hierarchy which is the Adapter/View part of the system can be extended (e.g., new kinds of Tasks can be added with different functionality in terms of background color or description formatting) without the need to modify even a single line of the code that handles the tasks. The "Open-Closed Principle" is illustrated in Fig. 5.

Step 5: Singleton Design Pattern

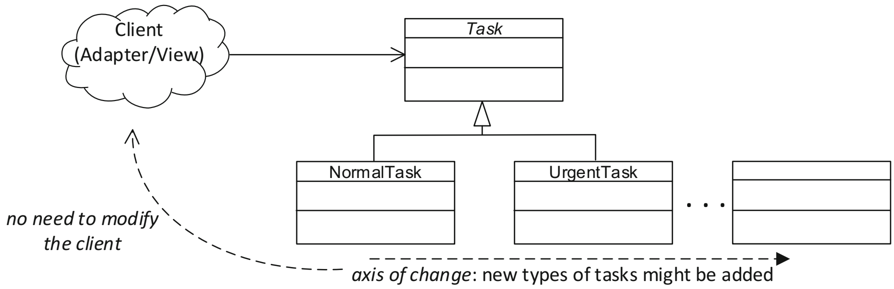
The application so far suffers from a rather serious drawback: only one task is displayed regardless of how many are introduced in the input screen. The reason is that whenever the `TasksView` activity is invoked by a new intent it leads to the construction of a new adapter associated therefore with a new data model, and previous tasks are lost. In other words there is no preservation of state between activity invocations.

Although in a real application data would be directly stored into a database to allow persistence, at this point it would be very useful to remind the notion of design patterns as a means of resolving commonly recurring problems by reusing previous experience (Gamma et al. 1995). In this particular case, the Singleton design pattern offers an elegant solution to the problem of data preservation. The goal of this pattern is to ensure that only one instance of a class is created and that a global access point is provided to that object (Gamma et al. 1995). Turning the Model class which holds the list of tasks to be displayed to a Singleton ensures that at any time the same, unique data model is used. In terms of functionality, the application allows the display of numerous tasks.

Step 6: Dependency Inversion Principle

So far, the application displays tasks in the order in which they have been added to the input screen. Obviously, there is a need for ordering tasks according to their date. This can be easily accomplished employing a data structure in which stored elements are automatically ordered. An appropriate Java data structure is the `TreeSet` where elements are retrieved based on their natural ordering. For any domain-specific class like the Task class the developer should specify the way in which tasks should be ordered by implementing the Comparable interface and overriding the `compareTo()` method (or alternatively by providing an appropriate Comparator). In this particular case, the `compareTo()` implementation can simply delegate the responsibility of comparing two tasks to their included Date objects. The resulting functionality at this point is a listing of tasks according to their date, i.e., closer tasks in time are displayed first.

While this is a rather widely known technique to Java developers, it would be important to emphasize that the designers of Java essentially adopt the "Dependency Inversion Principle"



Applying Software Engineering Principles in Android Development, Fig. 5 Open-Closed Principle in the context of the examined application

(DIP) (Martin 2003) in this context. The DIP principle states that "High-level modules should not depend on low-level modules. Both should depend on abstractions". In other words, high-level modules such as the implementation of the `TreeSet` class, which should be agnostic of the particular items that will be stored in the structure, should be decoupled from the corresponding classes, and this is achieved by declaring that `TreeSet` handles Comparable objects. Any class, whose objects should be stored in a `TreeSet` will therefore have to comply with the Comparable interface and provide an implementation to its single method taking care of the comparison between two objects. The philosophy of the DIP principle in the context of the `TreeSet` is illustrated in Fig. 6. The principle is of extreme importance for enabling the development of maintainable systems and especially APIs, and this sets an excellent opportunity for introducing the resulting benefits of DIP application to the students.

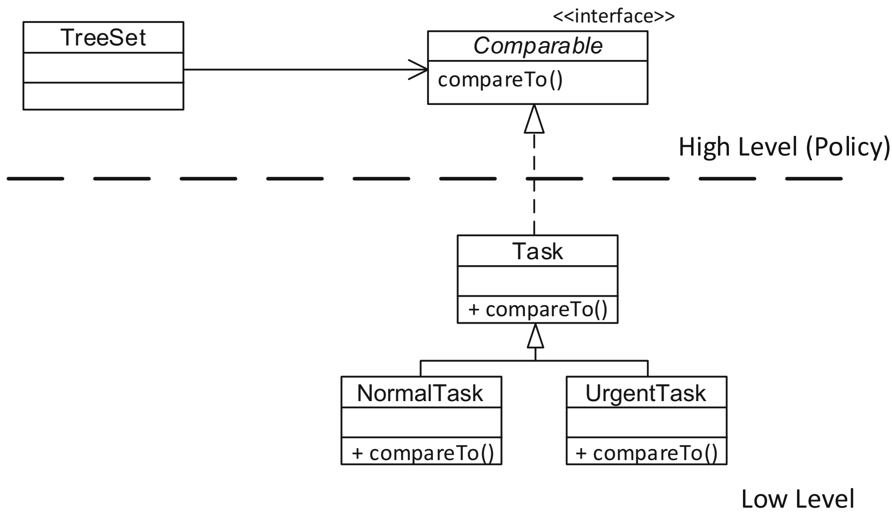
Step 7: Metrics for Software Quality Assessment

At this point the application has a reasonably large number of lines of code and methods. Moreover, the continuous evolution in terms of functionality enhancements highlights that Android applications are by nature evolving software projects. In order to assess whether the qualities of the underlying design deteriorate or not over time, software metrics can be employed as in any other type of software system. Students should be reminded about the challenges associated with software maintenance and the possibility of software ageing (Parnas 1994). From the perspective of quality assurance, monitoring software qualities by means of appropriate software metrics can offer significant help in preventing the accumulation of the so-called technical debt (Cunningham 1992).

At this step students should install a metrics collection and analysis tool, preferably one that is integrated into the employed IDE in order to assist the next steps related to preventive maintenance. Students can obtain a first impression and reason about the properties of the design by assessing metrics related to size, complexity, coupling, and cohesion. Indicative results are shown in Table 4. It is important to discuss the concept of aggregating metric values from one software level (e.g., methods) to the next (e.g., class, package, or system).

Step 8: Code Smells

According to Fowler (1999), deeper problems in the system structure often manifest themselves in the form of easily identifiable code smells, i.e., surface indications that something might be wrong at the code or design level. Hints for the presence of several smells can be provided by excessive metric values or values that deviate from the mean. As an example it can be observed that method `getView()` in the `TasksAdapter` class is much longer than the rest of the methods in that class and has a higher complexity and a larger number of parameters, a potential indication of a "long method" smell (despite the fact that in this case the smell is rather weak and presented only as an example). A long



Applying Software Engineering Principles in Android Development, Fig. 6 Dependency Inversion Principle in the context of the examined application

Applying Software Engineering Principles in Android Development, Table 4 Sample metrics related to the Android application at the method and class level

Class/method		LOC (lines of code)	Number of parameters (per method)	CC (cyclomatic complexity per method)
TasksAdapter		18	1.0	1.167
	TasksAdapter ()	1	0	1
	addTask()	1	1	1
	getCount()	1	0	1
	getItem()	1	1	1
	getItemId()	1	1	1
	getView()	13	3	2

method refers to a piece of code that is large in size, noncohesive, and relatively complex. A method with these symptoms might be difficult to comprehend, modify, test, and reuse (although for the size and complexity of the examined applications, these problems might seem too distant).

For the case of the long method, the designer should assess the intensity of the problem. This is often related to whether the method takes over more than one responsibilities. Different responsibilities might be subject to different "axes of change," implying that part of a method's body might be modified although the rest of the method's functionality should remain unchanged, often leading to the propagation of errors from one part to another. As an example, consider the method `getView()` of class `TasksAdapter` which has already been identified by the application of metrics as a larger and more complex method, in comparison to the rest of the methods in that class. Although its logic is quite simple, it contains two distinct responsibilities which are highlighted in the code fragment of Fig. 7: (a) the inflation of a new view object from the corresponding XML resource (in this case a single task list item containing the description and date of each task) and (b) the population of this view based on the information that can be retrieved from a task object. This case could be regarded as a symptom of the "long method" smell.

```
public View getView(int index, View view, ViewGroup parent) {
```

inflates view from the specified xml resource

```
    if(view == null) {
        LayoutInflater inflater = LayoutInflater.from(parent.getContext());

        view = inflater.inflate(R.layout.tasks_list_item, parent, false);

    }
```

populates the view with retrieved task data

```
    Task task = model.getItem(index);

    TextView descriptionTextView =
            (TextView)view.findViewById(R.id.description_view);

    descriptionTextView.setText(task.getDescription());

    TextView dateTextView = (TextView)view.findViewById(R.id.date_view);

    dateTextView.setText(task.getDateText());

    int color = task.getBackgroundColor();

    descriptionTextView.setBackgroundResource(color);
    dateTextView.setBackgroundResource(color);

    return view;
}
```

Applying Software Engineering Principles in Android Development, Fig. 7 Pseudocode for getView() method highlighting the different functionalities

Step 9: Unit Testing

According to the famous quote by Dijkstra, the aim of testing software systems is to reveal the presence of errors which in turn might lead to system failures (Dahl et al. 1972). One of the most effective approaches for testing large and complex systems consists in the execution of unit tests, where the goal is to compare the expected behavior of individual software modules (e.g., classes) to their actual one. The most important benefit from the construction of a set of unit tests is the ability to perform regression testing, which means that the system can be tested for possible errors after any slight modification, providing a certain degree of confidence that maintenance has not introduced additional errors.

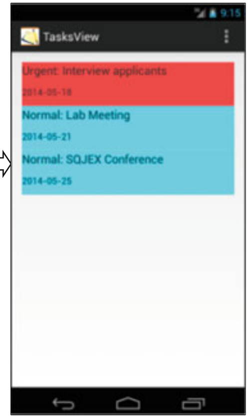
At this step of the proposed course, students are asked to generate test cases for the `TasksAdapter` class, prior to any attempt of improving the class structure, since a smell has been identified in one of its methods. The testing framework of choice to support the preparation and execution of test cases is JUnit (http://junit.org) which is an open-source, widely acknowledged and easy-to-use unit testing environment integrated into the Eclipse IDE. Test cases are written in the form of method invocations with selected parameter values and known results. A test case succeeds if the examined method fed with the selected parameters behaves as expected.

In this particular case, the goal is to test the behavior of the `getView()` method of the `TasksAdapter` class. However an adapter is always associated with the corresponding Activity containing a `ListView` object, so the goal is to add a task to the `ListView` and inspect whether the `getView()` method returns the correct task. To perform tests for activity unit testing, one should create a subclass of the `ActivityUnitTestCase` and initiate an Intent to trigger the desired activity (Android Developers 2013). The test case that contains a unit test for the `getView()` method of class `TasksAdapter` is shown in Fig. 8.

Code Under Test (Adapter)

```
public class TasksAdapter extends BaseAdapter {

  private Model model;

  . . .

  public View getView(int index, View view,
                      ViewGroup parent) {

    //constructs a view for each listview item
    //and populates it with information
    //retrieved from the corresponding Task
  }
}
```

Activity with ListView



Test Case (unit test targeting `getView()` method of the Adapter)

```
public class TasksViewTest extends ActivityUnitTestCase<TasksView> {

      private TasksView activity;
      private ListView listView;
      . . .

      protected void setUp() throws Exception {
            super.setUp();
            Date date = . . .  //create a Date object 2014/05/21
            Task newTask = new NormalTask(date, "SampleTask");

            //initiate the TasksView activity feeding it with the newTask
            Intent intent = new Intent(
                  getInstrumentation().getTargetContext(),TasksView.class);
            intent.putExtra("Task", newTask);
            startActivity(intent, null, null);

            //retrieve the activity and the enclosed listView object
            activity = getActivity();
            listView = activity.getListView();
      }

      //test whether the listView (i.e. the associated adapter)
      //retrieves the correct task
      public void testGetView() {
            Task task = (Task)listView.getItemAtPosition(0);
            assertEquals("Normal: SampleTask", task.getDescription());
            assertEquals("2014-05-21", task.getDateText());
      }
}
```

Applying Software Engineering Principles in Android Development, Fig. 8 Unit testing for Android activity/adapter

Step 10: Refactoring Application (Extract Method)

Now that the source code is equipped with test cases, developers can attempt to improve the design by applying appropriate refactorings. After any change, the test cases can serve as a checkpoint against which functionality can be verified. A refactoring is a way to improve the internal structure of software without changing its observable behavior (Fowler 1999). In most cases, refactorings are applied in order to resolve code smells that have been identified. Refactorings have been widely embraced by software developers mainly because of the simplicity in applying them. Currently, numerous IDEs provide support for the automatic application of refactorings relieving the designers from the burden of their mechanics (Murphy-Hill et al. 2009). Although the impact of a single refactoring might seem limited, the cumulative effect of successive refactorings on design quality can be significant.

Test cases can guarantee (with a certain degree of confidence) that any modification to the design has not altered the functionality of the methods. Returning to the "long method" smell observed for the `getView()` method of the `TasksAdapter` class, the appropriate refactoring would be to split the existing method in two more cohesive methods. According to Fowler's catalog (Fowler 1999), this corresponds to the "Extract Method" refactoring, whose goal is to "turn a fragment of code into a method whose name explains the purpose of the method." For the `getView()` method, the functionality related to the retrieval of information from the Task object in order to populate the view's contents can be extracted as a separate populateView() method, which will be invoked by the original method as shown in Fig. 9. The Eclipse IDE can automatically apply the Extract Method refactoring by simply designating the fragment of code that needs to be extracted and automatically identifies the parameters that have to be passed from the original to the extracted method. The application of the JUnit tests validates that the application of the refactoring did not break the existing functionality. As it can be deduced, the resulting methods are smaller, less complex, and more cohesive than the original one.

Step 11: Refactoring Application (Extract Method + Move Method)

As software evolves, additional functionality is gradually added to address the needs of clients. Let us assume that the `populateView()` method of the `TasksAdapter` has been enhanced in order to display the description of the forthcoming tasks in title case (Fig. 10). The method's code has once again become large and relatively complex, and since the conversion of a string to title case is a rather distinct responsibility, it should be extracted as a separate method by applying the Extract Method refactoring as previously (Fig. 10).

However, in this case the extracted method `convertToTitleCase(Task task)` has nothing to do with the `TasksAdapter` class in which it resides. The method accesses only methods from another class, and this is a clear symptom of the "Feature Envy" smell, which according to Fowler (1999) exists when "a method seems more interested in a class other than the one it is in." The appropriate refactoring to address this design problem is the "Move Method" which consists in moving the method to the target class. In this case the `convertToTitleCase()` method should be moved to the Task class, where it also belongs conceptually, since the ability to format the description of a task is related to the task itself, rather than any other class. Eclipse IDE provides support for this refactoring and automatically identifies the Task class as the target for moving the method. The existence of the unit tests enables the validation that the application of the refactoring keeps the functionality intact. The series of two refactorings is graphically illustrated in Fig. 10.

Step 12: Distributed Version Control Systems

Software systems are multi-version projects that continuously undergo adaptive, corrective, and perfective maintenance. Even the simplified example outlined in this entry has evolved over a number of versions. An essential part of each software project is its configuration management which deals with tracking and controlling changes in software artifacts, including revision control.

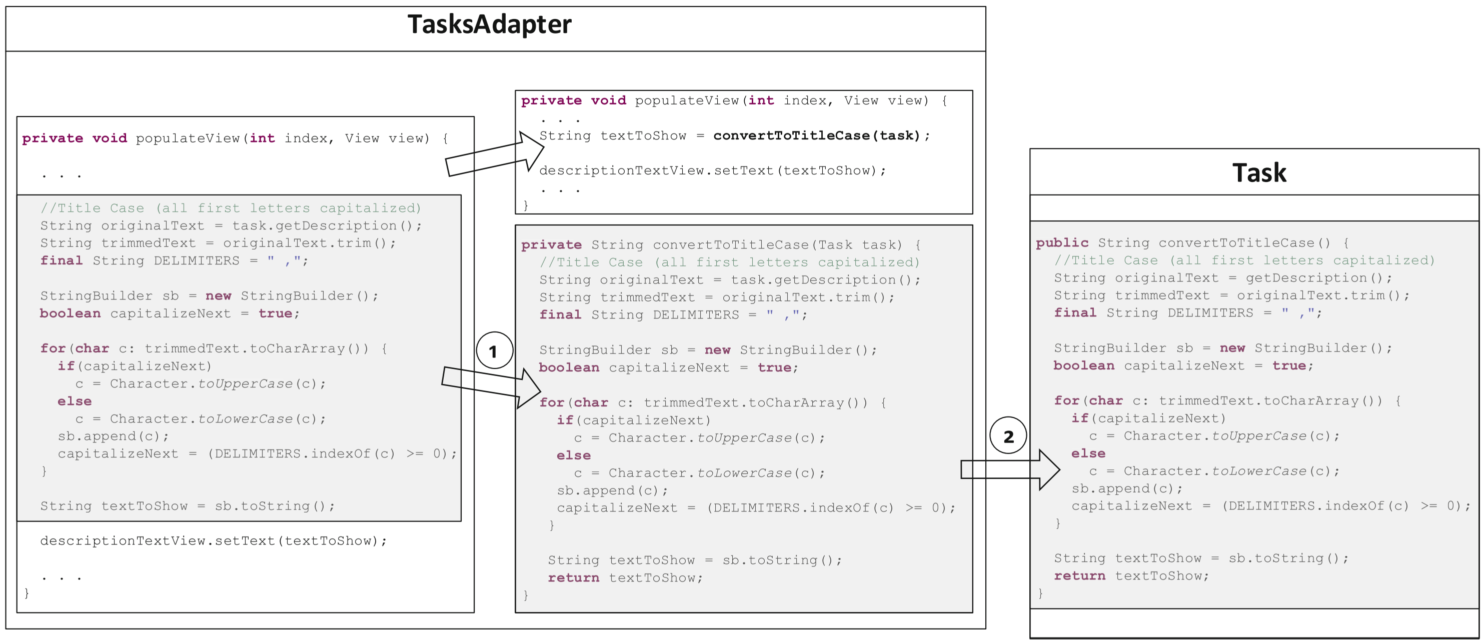
```java
public View getView(int index, View view, ViewGroup parent) {

  if(view == null) {
    LayoutInflater inflater = LayoutInflater.from(parent.getContext());

    view = inflater.inflate(R.layout.tasks_list_item, parent, false);
  }

  Task task = model.getItem(index);

  TextView descriptionTextView =
     (TextView)view.findViewById(R.id.description_view);

  descriptionTextView.setText(task.getDescription());

  TextView dateTextView = (TextView)view.findViewById(R.id.date_view);

  dateTextView.setText(task.getDateText());

  int color = task.getBackgroundColor();

  descriptionTextView.setBackgroundResource(color);
  dateTextView.setBackgroundResource(color);

  return view;
}
```

```java
public View getView(int index, View view, ViewGroup parent) {

  if(view == null) {
    LayoutInflater inflater = LayoutInflater.from(parent.getContext());

    view = inflater.inflate(R.layout.tasks_list_item, parent, false);

  }

  populateView(index, view);

  return view;
}
```

```java
private void populateView(int index, View view) {
  Task task = model.getItem(index);

  TextView descriptionTextView =
     (TextView)view.findViewById(R.id.description_view);

  descriptionTextView.setText(task.getDescription());

  TextView dateTextView = (TextView)view.findViewById(R.id.date_view);

  dateTextView.setText(task.getDateText());

  int color = task.getBackgroundColor();

  descriptionTextView.setBackgroundResource(color);
  dateTextView.setBackgroundResource(color);
}
```

Applying Software Engineering Principles in Android Development, Fig. 9 Extract Method refactoring

A



Applying Software Engineering Principles in Android Development, Fig. 10 Extract (1) and Move (2) Method refactorings

Version Control Systems (VCS) refer to software that allows the management and monitoring of changes that occur in any artifact of a project during its initial development or maintenance (Spinellis 2003). Version control offers significant benefits to the development team, including the ability to retrieve and compare either the entire project or individual files created at any time point, access to a log of all past changes, and under certain conditions support for collaborative software development.

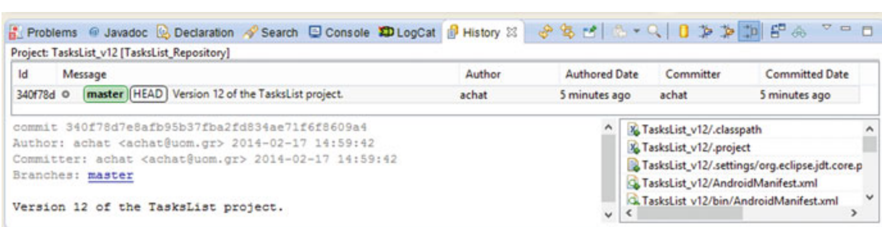
Nowadays, it is hard to find an industrial project that is not backed up by a VCS, and thus it would be extremely beneficial to introduce students to the corresponding practices. It should be mentioned that the use of a VCS exhibits several challenges which cannot be covered by a short course. In the proposed example, the goal is to highlight the key benefits from using a VCS. Due to its widespread adoption, emphasis is placed on distributed VCS such as Git (https://git-scm.com/). Although distributed VCSs can also share a common remote repository, they adopt a peer-to-peer approach where each peer has his own full-fledged repository with complete history and the use of version tracking does not depend on access to a central server. The Git functionality can be accessed through the EGit Eclipse plug-in and thus be integrated in the IDE used for development.

At this step of the course, students are asked to install EGit, create a Git repository, and commit the project to the repository. Details about EGit usage can be found at the corresponding EGit documentation (http://www.eclipse.org/egit/documentation). Students are asked to enter a log message that will be attached to each individual commit. Once the commit is performed, students will be able to track the history of the project as shown in Fig. 11. Students can be introduced to the concept of the main development branch (master), the HEAD pointer referencing the branch that the user is currently on, the importance of good commit messages, and the unique identifier assigned to each Git commit object in the form of a SHA-1 hash value.

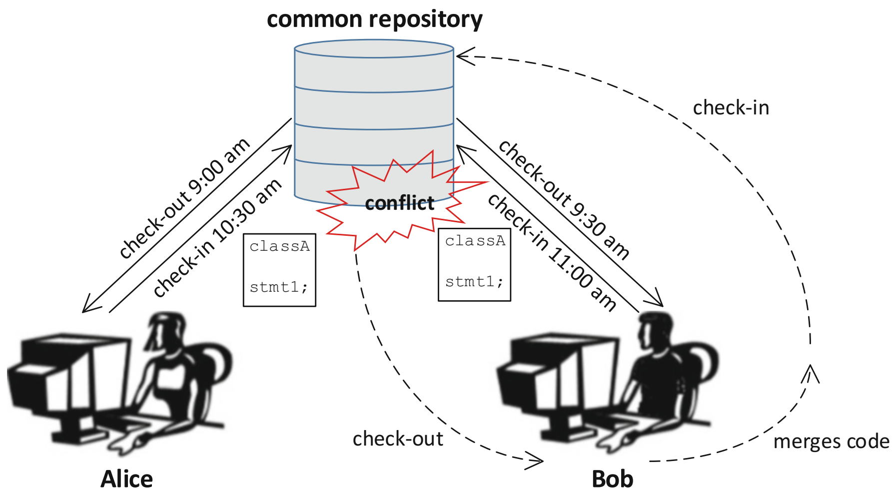
Step 13: Collaborative Software Development

Contemporary software development teams consist of members which often are not located in the same geographical area and might even be working at different time zones. To enable the collaboration between multiple developers, VCSs require the use of a common, remote repository that can be used for sharing software artifacts to the rest of the team. A popular hosting provider for Git projects is GitHub (https://github.com/) and can be used for the proposed course since public repositories are hosted for free. The instructor (or any student) can create a repository and add fellow students as collaborators to the project (such a project has been created for this course at GitHub).

Students can now start experimenting with collaborative software development based on the Android project that has been developed so far. For example, the instructor can push his own Android project to GitHub and allow students to clone the existing version. Students can simulate the automatic resolution of conflicts when two developers modify at different times two different files and commit and push them to the remote repository. The system will automatically deduce the reasonable course of action which is to accept



Applying Software Engineering Principles in Android Development, Fig. 11 Use of the local repository in EGit



Applying Software Engineering Principles in Android Development, Fig. 12 Handling of conflicts during collaborative software development

and merge the changes. However, in the case when two students make edits to the same file, a conflict will be raised when the second student attempts to commit and push his work. The second student will be informed about the conflict and be prompted to choose one edit over the other or revise the affected lines entirely (such a case is illustrated in Fig. 12). The fact that a VCS can handle similar situations can be an extremely valuable asset in mobile software development.

Guidelines for Delivering the Course

The proposed short course has been delivered to three groups of undergraduate and postgraduate students at two different institutes (Table 5). The course has been evaluated: (a) by performing a student satisfaction survey, (b) by summatively assessing students' performance, (c) by investigating whether the proposed course modified the students' career interests, and (d) by employing assessment by peers based on rubrics. The results are presented in detail in a previous paper (Chatzigeorgiou et al. 2016) and indicate that such a short course is capable of increasing student's interest on Android development as well as their awareness of the importance of software engineering concepts on mobile application software development. Based on the accumulated experience and the results of the course's evaluation, some guidelines are provided for a more successful teaching.

Utilize a Wiki Page for Supporting the Teaching Process and Communication

A wiki is a web application that gives the chance to collaborate online (Parker and Chao 2007), while it supports online classroom management and offers peer and self-assessment features (Schwartz et al. 2004).

In order to support the teaching process and the communication among students and instructor, a wiki page was developed when delivering the proposed course using as a development environment "Wikispaces" (www.wikispaces.com). Moreover, in order to develop and conduct the online assessment (multiple choice questions) in this course, the "ThatQuiz" online examination system was used (available through http://www.thatquiz.org).

The wiki page that was developed for the proposed course can be viewed from the following perspectives:

Applying Software Engineering Principles in Android Development, Table 5 Details of groups to which the course has been delivered

Group ID	Degree	Department	University/ college	Enrollment	Prior Java course	Prior Android course	Prior SE course
1	Undergraduate	Information Technology	Institute 1	16	Yes	No	No
2	Undergraduate	Computer Science	Institute 2	30	Yes	No	No
3	Postgraduate	Computer Science	Institute 2	12	Yes	No	Yes

- *A content delivery system*: providing course objectives, guidelines for the required software infrastructure, and a course outline. The course outline consists of hyperlinks to webpages that provide an overview of the objectives for each step, an explanation on how these objectives can be achieved, additional educational material such as PowerPoint presentations, as well as a link to download the appropriate source code example that is needed for the corresponding step.
- An *online examination platform* that gives students the chance to download the exam as a document file that can be printed and answered offline or connect to the online examination system and get immediate feedback for their answers.
- A *forum* allowing online discussion where participants can hold conversations, post messages, and questions regarding the course.

Take into Account Students' Prior Knowledge
To ensure a smooth progression of the course, the instructor should be aware in advance of the students' level of knowledge and skills in both software engineering and Java development. Ideally, the proposed course should be delivered right after a software engineering course, or at least a course related to Object-Oriented Software Development.

Provide the Appropriate Time for Students to Assimilate the Content
Covering all of the introduced concepts and techniques and carrying out the related activities require no less than 12–16 teaching hours, depending on the students' background.

Provide the Necessary Software Infrastructure
The course relies on a multitude of tools such as the Eclipse IDE for programming, Android SDT, tools for unit testing, metrics calculation, refactoring application, version control, and possibly computer-aided software engineering (CASE) tools. Using a lab where the workstations are ready to use can help students focus on the learning goals. Also, running the course in a lab where all workstations can be accessed from each other or from a central server is important, since it might be often required to deliver one working version of the project to all students.

Try to Keep Students Synchronized
The course is structured as a series of small incremental steps, exactly as it would occur during the actual development of a software project in a small team. Given that the students have often a completely different working pace from each other, it is really challenging to keep them synchronized, but at the same time, it is important in order for them to remain focused.

Try to Monitor Students' Participation
As in any other programming course, student participation should be a key objective of the course. Students can actively participate by asking questions, providing feedback on encountered problems, suggesting alternative implementations and even developing a solution, and implementing and sharing it with the rest of the students' groups. However, the multitude of introduced concepts, tools, libraries along with the compile, runtime, or emulator errors that can arise in Android hinders student's participation

who find themselves in the process of "making their own project work." The instructor should be aware of this issue and resolve persistent problems so that students can take on the essence of the delivered material.

Conclusions

The popularity of mobile devices running the Android OS and the bright prospects for mobile application developers in the IT market has raised students' interest in Android development courses in higher education institutes around the world. However, Android software systems are becoming increasingly complex, and designing relevant courses is not an easy task. In order for an Android development course to be successful, it must combine Android programming with state-of-the-art software engineering content.

In this entry, a short course is introduced aiming at illustrating selected software engineering principles, concepts, and techniques in the context of Android application development. It must be noted that there is no need for an instructor to strictly follow the order, number, and content of the steps analyzed. Based on the students' prior knowledge and the particular goals of each curriculum, the short course can be modified accordingly. As an example, the course could be extended to a full semester course by adding an introduction to the basics of Android development (e.g., Android components and life cycles, building of views, etc.) as well as additional steps illustrating the use of additional software engineering concepts or more cases of the already examined ones (i.e., more design patterns, metrics, and refactoring types). Another axis along which the course can be extended concerns the functionality of the application itself, which can be turned into a much more complicated one, involving 2D graphics, storage in a database, and communication with a server. However, it should be borne in mind that the essential goal of such a course is not an introduction to Android programming per se, but rather the leveraging of well-established software engineering practices to the benefit of mobile application development.

Cross-References

▶ Teaching Software Design Techniques in University Courses

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Architectural Pattern

► Teaching Software Design Techniques in University Courses

Art Component of Remote Training

► Art Component of Remote Training in Russian Universities

Art Component of Remote Training in Russian Universities

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Synonyms

Art component of remote training; e-learning; Remote training

The e-learning has started to develop in Russia since the beginning of the 2000s. The e-learning service consumers are as follows:

- Companies that need to systematically provide a large number of seminars devoted to their products and services to a large number of employees. Banks, financial corporations and insurance companies may be referred to as such types of companies, where all of them have rather large and simultaneously constantly changing product lines. In this regard, it is rather impossible to constantly develop and conduct in-person product trainings since it is too expensive and slow.
- Companies with standardized technologies and procedures. They have a library of standard courses, for instance, fire safety courses, or

courses on how to process some documents. These courses usually require minimal changes over a long period of time. Indeed, this approach saves the company's money and staff's time significantly.

- Companies with high turnover of employees, for example, tellers or sellers.
- Companies (including secondary and higher educational institutions) with geographically distributed branch networks. On one hand, the use of remote training products allows for providing the same training regardless of the branch location, and, on the other hand, it allows for saving a large amount of the company's money at the expense of travel costs for teachers and/or employees.

The analysis of the remote training organization experience at the Russian universities has shown that managements of many universities have developed and approved the models and road maps to introduce e-learning into the educational process, and allocated funds for material incentives for teachers. There has been developed and implemented a provision on implementation of e-learning. An additional monthly fee calculation method for teachers working with students through e-courses has been introduced. Parameters like technological course card formation, student e-course access, student e-course enrollment percentage, course grade book completeness, and percentage of students who took part in the education quality questionnaire served as additional monthly fees criteria.

The main difficulties in the e-learning introduction process are as follows:

- Solid belief among the education quality experts that the training efficacy depends solely on introduction of new electronic tools into the learning process.
- Lack of understanding among experienced teachers of what e-learning means. Many of them see e-learning as a dangerous competitor to the traditional learning model. Note that their worries are rather well founded in some cases (depending on the subject features).
- There are some teachers who clearly understand that, with the introduction of new technologies, they will have to change their formal approach to teaching and authoritarian teacher–student communication style formed during the recent years and therefore resist the student feedback.
- A fairly large group of proactive and, as a rule, younger teachers has emerged who arrange their work with students by means of electronic courses which, however, cannot be considered satisfactory in many cases due to professional insufficiency.
- Low information culture level among employees.
- Poor knowledge of advanced methods and practices.
- Outdated employee motivation system.

For the purposes of legal registration and development impulse, the Russian Law "On Education" has been developed stating that e-learning should be considered an auxiliary tool for the traditional learning process.

Depending on the level of enhancing the learning process with the online content delivery technologies, the nature of interaction among participants and peculiarities of some subjects, the experts distinguish:

- Conventional training (without electronic technologies)
- Conventional web-supported training

The blended training system, which has been considered the highest quality and most promising learning process model worldwide (MIT Open Courseware 2014; Stanford Online 2014; Söderström et al. 2012), still constitutes a terra incognita for the Russian educational system. Russian experts believe that the blended training aimed at reduction of the number of classrooms due to transfer of a part of classes to the electronic environment will extremely impact the quality of professional training. In this sense, the flipped classroom technology is considered unacceptable since its essence is in the rearrangement of the key components of the educational process based on the active use of the electronic learning environment.

The traditional Russian web-based training system requires a teacher who will develop distance learning courses, electronic textbooks, training aids and assessment tools.

In this sense, a great role is played by the creative method of teaching, which, to a large extent, can influence the formation of students' attitudes toward science. Every teacher knows that the student's attitude to the subject, and, hence, to science, may be different. It may cause hate or disgust in some, dislike or indifference in others, or interest, love, and, finally, passion which may then develop into an obsession. In this case, the entire responsibility lies on a teacher almost exclusively, since, beyond any doubt, every subject studied by the listener is forever associated in his/her mind with a person who taught the subject.

However, a teacher, a lecturer, or an artist who is able to captivate listeners and evoke their interest with his/her topic from the other side of a screen is a rarity. We must admit that not many people are endowed with this gift.

There are many teachers who are fluent in the subject matter; they are wonderful researchers, but they absolutely lack any artistic ability. Many lecturers are too static and tense in front of a camera. They lack the freedom of communication that is usually there between the lecturer and the students in the classroom. A teacher who lectures from a monitor screen may be called a speaker in most cases.

Therefore, great attention is given to the quality of the basic element of distance learning – video lectures (Ardowsky 2006; Komarova 2006). The degree of professional preparation will determine the training success. Below are the recommendations for creating a high-quality video product.

Each lecture should be performed enthusiastically. If a teacher finds the lecture boring, then it is ten times more boring to the audience.

The lecture must be created like artwork. It must have a plot, plot development, and denouement despite the fact that the lecture cannot be considered a genuine artwork since it is only a part of the course, its piece. Nevertheless, the lecture must be created based on a certain emotional curve. Emotion is understandable: it is the mood, which marks the whole lecture. To be more understandable during a lecture, as well as, for example, in a dramatic performance, a certain curve must always be present (e.g., Schiller's dramas are structured in a way that the central action, the maximum emotion is always present in the third act).

Since a lecturer enters the audience knowing his/her first word, he/she should know the last word before leaving the room. The end of the lecture should be thought over carefully just like the beginning.

Great attention should be paid to the direction of the lecture and its rehearsal. The direction of the form begins only after the thought-out content of the lecture, drawn-up emotions, developed drawings, selected examples. The first thing to do is find out what classroom and what blackboard you will use for your lecture. The direction of the text on the board is of great importance: you should know the board size to write the first line, if the board space is enough to provide some drawings, and so on.

A very important thing is the audience entrance plan: how would you enter it, if it is very large, for example?

It is necessary to think in advance about your posture and the words you will say. You should also know how to enter a specific lecture. This will largely determine its color, its tonality. The audience is a very accurate instrument that may reflect the lecturer's mood.

An important point is the direction of your gestures. It is necessary to think in advance whether you could help the audience understand your words using your gestures.

After the plan of directing all your gestures has been thoroughly thought out, it is necessary to think about your voice intonation, which is inextricably linked with the presentation. You should decide which intonation should be in which place of the lecture, where and how you could emphasize it. Intonation is very important since it can even give the audience some rest during the lecture.

Then a lecture rehearsal goes. First of all, a purely formal rehearsal is needed: it is necessary to check if everything you say can be quickly recalled.

After the rehearsal of the lecture contents, a rehearsal of all that has been intended should begin: your intonation, gestures, and so on. Then you need to put your watch on the table and repeat everything over again. This is especially important for the young teachers since they usually do not have a sense of time. The sense of time is one of the qualities that a lecturer needs.

A lecturer should give time to himself/herself and the audience to concentrate and create the necessary mood.

It is necessary to introduce elements of philosophy of a subject into the subject course, as well as historical, biographical information on the major persons into the presentation. Introduction of the elements of history into the training course should be performed in three directions:

- Paul Painlevé wrote, “It is necessary to give students an opportunity of touching the very roots of experimental methods and learn the most skillful techniques created by great researchers—skills and methods that are extremely subject-specific and much more convincing and fruitful than any theorem or rule” (Painlevé 1922).
- Extensive use of the richest historical material during the lectures. For example, the history of every general engineering science is very rich in examples emphasizing its importance to develop the military power of the countries and their equipment in general. Certainly, such examples can significantly increase the interest of students in the subject they study.
- Inclusion of biographies of the creators of certain sciences into the lecture. The pedagogical experience shows that a lively, vivid display of the leading figures in the world science like Galileo, Kepler, Lagrange, Coriolis, Bernoulli, and others helps not only reveal the methods and techniques of the scientific research to the students but also “breathe” that very scientific pathos into the audience, that very passionate attitude toward science which these great scientists were living with.

Summarizing the above, we can draw the following conclusions:

1. It is necessary to create high-quality multimedia applications for distant teachers so that these multimedia applications can be compiled taking into account the teacher’s rich past training experience.
2. A distant lecturer should undergo special artistic training whether it is an advanced training course or some acting technique classes.
3. An alliance between two professionals is also possible where one is a teacher and researcher and the other is a professional artist: the first one develops the course content and the second embodies the idea in front of the camera while both of them do one common thing.

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Artificial Intelligence in Education

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Synonyms

Adaptive learning; Augmented intelligence in education; Dialogue-based Tutoring systems; Intelligent tutoring systems; Personalised learning

Introduction

Artificial Intelligence (AI) technologies have been researched in educational contexts for more than 30 years (Woolf 1988; Cumming and McDougall 2000; du Boulay 2016). More recently, commercial AI products have also entered the classroom. However, while many assume that Artificial Intelligence in Education (AIED) means students taught by robot teachers, the reality is more prosaic yet still has the potential to be transformative (Holmes et al. 2019). This chapter introduces AIED, an approach that has so far received little mainstream attention, both as a set of technologies and as a field of inquiry. It discusses AIED's AI foundations, its use of models, its possible future, and the human context. It begins with some brief examples of AIED technologies.

The first example, *Cognitive Tutor*, is a type of AIED known as an *intelligent tutoring system* (ITS, which currently are the most common of AIED technologies). It addresses the domain of mathematics for students of primary or secondary school age, and aims to mirror a human tutor by delivering instruction personalized to each individual. *Cognitive Tutor* is also a rare case of an AIED technology that has bridged the gap from university research (at Carnegie Mellon University) to a successful commercial operation (Carnegie Learning (http://www.carnegielearning.com) and is also unusual in having robust independent evidence of its effectiveness (Pane et al. 2014). As individual students work through carefully structured mathematics tasks, the system monitors the student's progress (successes and misconceptions), re-phrases questions, and re-directs the student along more suitable learning pathways and provides individualized feedback (explaining not just why the student got something wrong but also how they can get it right). It achieves all this by combining individual student interaction data with the interaction data of the many thousands of students who have already experienced the system, using that data to learn, adapt, and improve its models of mathematical skills and student learning.

A second quite different AIED example is *MASELTOV* (http://www.open.ac.uk/iet/main/research-innovation/research-projects/maseltov), a research project in which AI was used to support language learning by recent migrants to the UK, using devices that many people carry with them all the time – smartphones (Gaved et al. 2014). The *MASELTOV* smartphone app used GPS data and AI techniques to provide context-sensitive and personalized language-learning support. For example, the app was able to detect when a user entered a doctor's surgery or a supermarket, each of which would trigger it to recommend appropriate English resources personalized to the individual's language skills. In the supermarket, the app would provide vocabulary and phrases to help the user find the items that they wanted to buy; in the doctor's surgery, it would provide appropriate words (such as symptoms, parts of the body and diagnoses) together with information about the available health services.

A final brief example comes from China. *Smart Learning Partner*, from Beijing Normal University's Advanced Innovation Center for Future Education, is a mobile app that enables students to connect with tutors using their smartphones. Students can use the app at any time of the day or night to search for a tutor, in order to ask them specific questions about any school topic for which they want some additional support. There are several thousands of tutors available on the app, thanks to local government funding, all of whom have been rated (much like a shopping app or a dating app) by users (in this case, the users are other students). The student chooses their tutor (based on the school topic and the tutor ratings), connects and is given 30 min of free one-to-one online tuition (sharing voice and screens but not video). Although the AI is relatively simple, *Smart Learning Partner* uses it to provide a unique student-centered system that enables students to get exactly the support that they want (rather than the instruction that a system such as an ITS might prescribe). Data from all the interactions are then aggregated and made available to the schools, so that trends in student questions can in a virtuous circle be identified and given more attention in the classroom.

The AI Foundations of AIED

A full understanding of AIED depends on understanding something about AI more generally. The field of AI first emerged from a seminal workshop held at Dartmouth College in the USA as long ago as 1956. Over the following decades, AI developed in fits and starts with periods of rapid progress interspaced with periods, known as *AI winters*, where confidence and funding all but evaporated. Most recently, over the past decade, with the advent of faster computer processors, the availability of large amounts of big data, and the development of new computational approaches, AI has entered a period of renaissance.

Nonetheless, what actually constitutes AI still is often disputed (as is the name itself, with some researchers preferring *augmented* rather than *artificial* intelligence). In fact, for many, as has been suggested earlier, AI is synonymous with humanoid robots, which might be because AI and robots seem to feature together in the news and on television almost every day. In fact, while robotics is a core area of AI research, AI is being used in many different ways and is growing exponentially (while the dystopian images of futuristic robots remain firmly in the realm of science fiction). Paradoxically, though, the more that AI is integrated into our daily lives, the less we think of it as AI:

> A lot of cutting edge AI has filtered into general applications, often without being called AI because once something becomes useful enough and common enough, it is not labeled AI anymore (Nick Bostrom, Director of the Future of Humanity Institute, University of Oxford) (http://edition.cnn.com/2006/TECH/science/07/24/ai.bostrom/index.html)

Instead, AI is often labeled as a computer program (such as email spam filtering), a mobile phone assistant (such as *Siri*), or perhaps an app (such as *Duolingo*). Nonetheless, many recent developments in AI have been both ground-breaking and transformative. AI techniques such as machine learning, neural networks, evolutionary computation, and supervised, unsupervised, and reinforcement learning have been used in applications as diverse as autonomous vehicles, online shopping, auto-journalism, online dating, stocks and shares dealing, and legal and financial services.

Automatic face recognition, for example, is one area that has fairly recently made a dramatic leap forward while simultaneously becoming almost invisible in daily life (it is the technology used in smartphone cameras to ensure that faces are always in sharp focus and at e-passport gates to identify travelers before allowing them to enter a country). Face recognition was noticeably improved when, in 2012, Google presented a brain-inspired AI *neural network* comprising 16,000 computer processors with 10 million randomly selected YouTube video thumbnails. By using *deep-learning* techniques, and despite not being told how to recognize anything in particular, this *machine learning* system soon *learned* how to detect human faces in photographs. Two years later, Facebook introduced a nine-layer deep AI *neural network*, involving more than 120 million parameters, to identify (not just detect) faces in timeline photographs. It was trained on a dataset of four million images of faces that had previously been labeled by humans (Facebook users), and achieved an accuracy in excess of 97%, which almost matches human-level performance. However, although impressive, these examples also highlight a key difference between AI and human intelligence: a human does not need to see ten, or even four, million faces before it can recognize a family member, a friend, or a celebrity.

Another area that has seen much AI development is meteorological forecasting, with machine learning being shown to be more accurate at predicting weather than traditional simulation-based forecasting. Meteorologists have long tracked weather data which they enter into complex knowledge-based simulations to make forecasts. However, AI forecasting mines vast amounts of historical weather data, and uses *neural networks* and *deep learning* to identify data patterns (rather than to feed into simulations) in order to make data-based predictions about future weather conditions.

A final brief example is the use of AI in medical diagnosis, with AI techniques being used by radiologists to help them identify anomalies in medical images more quickly and while making fewer mistakes. For example, one system looks for irregularities in X-ray images and, depending on what it finds, assigns it a priority. If it finds nodules on an image of a pair of lungs, it assigns a high-priority status and sends it to a pulmonary radiologist for further checks.

One thing that all these examples demonstrate is that AI is a highly technical area, which is too complex to explore in depth here (two seminal books that do cover much of AI's complexity are Russell and Norvig 2016; Domingos 2017). In fact, many people involved have advanced degrees in mathematics or physics, although AI is increasingly being offered as a "service" (for example, Google's TensorFlow, IBM's Watson and Microsoft's Azure). Nonetheless, because some have already been mentioned repeatedly and because they play an important role in AIED, some closely interlinked AI topics will be briefly introduced: algorithms, machine learning, deep learning, neural networks, and Bayesian networks. The section then concludes with a brief mention of so-called *General Artificial Intelligence*.

Algorithms

AI often involves talk of *algorithms*, which are simply descriptions of the steps needed to solve problems (ordinary computer programs are really nothing more than lengthy algorithms). It is probably fair to say that Google owes its existence to a single algorithm, PageRank (Fig. 1), which was developed in 1996 by the Google founders at Stanford University. PageRank (apparently named after the Google founder Larry Page rather than web pages) is an algorithm that ranked the relative importance of a website by counting the number and quality of external links to the website's pages, to determine where the website appeared in a Google search.

In fact, the history of AI might be thought of as the history of the development of increasingly sophisticated and increasingly efficient (or elegant) algorithms; while what makes AI algorithms distinct from other software is simply that they are applied to areas we might think of as essentially human (such as visual perception, speech recognition, decision-making, and learning).

Machine Learning

While most computer software (including much early AI) involves writing in advance the exact steps that the software will take, or specifying rules that will be followed exactly, machine learning is about getting computers to act without being given explicit steps or rules. Instead of the algorithms being *programmed* what to do, they have the ability to *learn* what to do. Image and speech recognition, self-driving cars, computational biology (for example, using computers to identify tumors), and digital companions (such as Amazon's Alexa), as well as the Google DeepMind AlphaGo program that beat the world's number one player of Go, have all been made possible thanks to machine learning. In fact, machine learning is so widespread today (almost everyone has experienced some form of machine learning usually without being aware of it) that for some researchers and developers it has become synonymous with AI.

There are three headline approaches to machine learning: supervised, unsupervised, and reinforcement. In **supervised learning**, the AI is first trained with data for which the output is already known. For example, the AI might be trained with many thousands of photographs of people that have already been labeled by humans (this is broadly speaking the approach, mentioned earlier, used by Facebook to *identify* people in photographs). The AI can then be used to label automatically new data (in this example, to

$$PageRank\ of\ site = \sum \frac{PageRank\ of\ inbound\ link}{Number\ of\ links\ on\ that\ page}$$

Artificial Intelligence in Education, Fig. 1 The PageRank algorithm that played a major role in the early years of Google identify and label automatically the same Facebook users in new photographs). In **unsupervised learning**, on the other hand, the program is provided with even larger amounts of unlabeled data, which it uses to find patterns that enable it to classify new data (this is broadly the approach, mentioned earlier, used by Google to detect faces in photographs). Finally, in **reinforcement learning** the program is provided with some initial data from which it derives an outcome that is assessed as correct or incorrect, and rewarded accordingly (for example in an AI-driven computer game, the score is increased) or punished (the score is reduced). The program uses this to update itself and then it tries again, thus developing iteratively (evolving) over time.

Neural Networks

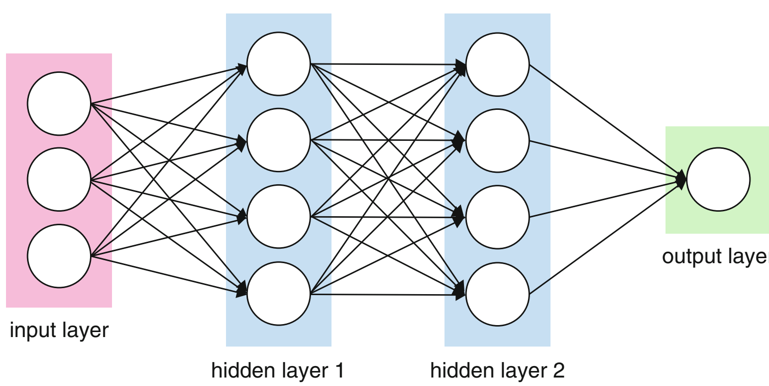
Machine learning often uses *neural networks*, so named because they are inspired by how neurons work and are connected in animal brains. However, although AI neural networks have been trained to do some incredible things, they are primitive in comparison to most higher-order animal brains. They usually involve only a few thousand *neurons* (in some exceptional cases, a few million) compared to the human brain, which has around 100 billion neurons and trillions of connections. In any case, AI neural networks comprise several layers of neurons (Fig. 2): typically an input layer (that takes stimuli from the environment), one or more hidden computational layers, and an output layer (that delivers the result of the computation). All the neurons are interconnected, with each connection having a weighting to determine whether one neuron excites or inhibits the next neuron (again in a process inspired by synapses in animal brains). During the machine learning process, it is these weightings that are adjusted, usually by reinforcement learning, and that allow the AI subsequently to compute outputs for new stimuli. Neural networks have been shown to be particularly effective in many different AI systems, for example, for image recognition (identifying people) and natural language processing.

The hidden layers are key to the power of neural networks but they also bring an important problem. It is not possible (or at the very least it is not easy) to interrogate a neural network to find out how it came up with its solution (for example, how did it identify a particular person or a particular need?). In other words, neural networks can lead to decision-making for which the rationalization is hidden and unknowable, and possibly unjust (O'Neil 2017), a critical issue that is the subject of much research (e.g., Morcos et al. 2018).

Deep Learning

Neural networks comprising multiple hidden layers are known as *deep learning*. This involves automatic iterative analysis that clusters and classifies data and makes predictions. For example, once a deep learning algorithm determines that a picture contains a particular shape, it cycles again to find other shapes, and then cycles again to identify the connections between those shapes, iterating repeatedly until it has recognized what it is looking at (for example, a face). Deep

Artificial Intelligence in Education, Fig. 2 A representation of a typical simple neural network



learning is the headline approach used by *AlphaGo*, to learn how to win at the game of *Go*.

Bayesian Networks

Bayesian networks are a type of statistical model employed by some AI algorithms that enable, in uncertain domains, computational tasks such as prediction, anomaly detection and diagnostics. They combine principles from graph theory, probability theory, and statistics. Drawn graphically, a Bayes net comprises various lines (also known as edges) which intersect at nodes, with the nodes representing variables and the lines representing interdependencies between those variables.

To give a simple example, using a Bayes net approach, an AI system might be designed to predict (calculate the probability of) the flavor of ice-cream that a customer might buy depending on the weather and temperature of the day. Here, the nodes represent the known data (whether it is sunny, whether it is hot, and choices of ice cream flavor made by previous customers) and an uncertain outcome (what ice cream flavor will be chosen today). The Bayes net computation begins with probabilities given in each node that have been derived from training data (comprising records of weather, temperature and customers' choice of ice-cream flavors) to derive the probabilities of various outcomes (the ice-cream flavors that will be chosen by customers in a combination of weather and temperature circumstances). In fact, a typical AI Bayesian network might comprise tens (or hundreds) of variables (nodes) with intricate interdependencies (edges). However, the Bayesian computational approach makes it possible to infer precise probabilities in such complex environments in order to inform usable predictions (to continue with the example, to help the ice-cream seller decide how much of each ice-cream flavor to make).

General Artificial Intelligence

All the examples of AI mentioned so far are domain-specific, which means that they are tightly constrained and very limited. For example, the AI used to win at Go cannot play a game of chess, the AI used to predict the weather cannot predict movements in the stock market, and the AI used to drive a car cannot be used to fly an aeroplane. So-called General Artificial Intelligence, AI that like human intelligence can be used in any circumstances, does not yet exist. And, despite the rapid developments in AI and the concerns expressed by many leading scientists (e.g., Hawkin et al. 2014), it is unlikely to exist for decades (even for leading AI advocates, General AI appears to be due to arrive at some ever-receding future date, usually around 30 years from the time of writing, Müller and Bostrom 2016). In fact, currently, rather than general applications (AI that can be used in any context, Domingos 2017), the focus for most AI research continues to be on domain-specific areas – such as autonomous vehicles, health, weather forecasting and stocks trading, and education.

Introducing AI in Education

AI in education research (AIED) has considered a variety of ways in which AI systems might be used to support both formal and informal learning. It has involved the development of many online tools that aim to support learning while being flexible, inclusive, personalized, engaging, and effective (Holmes et al. 2018). AIED brings together AI and the learning sciences, and thus involves two main complementary strands: developing AI-based tools to support learning and using these tools to help understand learning (how learning happens).

> In addition to being the engine behind much "smart" ed tech, AIED is also a powerful tool to open up what is sometimes called the "black box of learning", giving us deeper, and more fine-grained understandings of how learning actually happens. (Luckin et al. 2016, p. 18)

In other words, AIED research can have an important impact both on classroom tools (such as Cognitive Tutor) and on learning theories applicable in classrooms where there is no AI. For example, by modeling how students go about solving an arithmetic problem and, for example, identifying misconceptions that might have been previously unknown to educators, researchers and teachers can begin to understand much more about the process of learning itself which can then be applied to classroom practices.

AIED Models

AIED often involves computational *models* (in AI, a model is a highly simplified computational representation of something in the real world, just like a model car is a simplified representation of a real car). In particular, *intelligent tutoring systems* (ITS such as Cognitive Tutor) are often built around three core models: *pedagogy*, *domain*, and *learner*, all of which interact in complex ways and are combined to adapt a sequence of learning activities for each individual student (Fig. 3). A fourth AIED model is the *open learner* model.

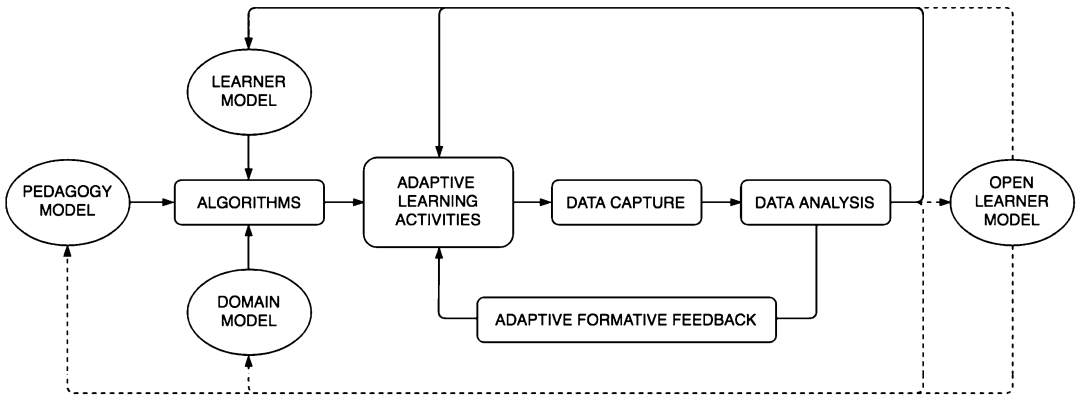
The AIED **pedagogy model** represents knowledge about effective teaching and learning approaches that have been elicited from teaching experts (and that constitute the learning sciences). This includes, for example, knowledge of instructional approaches (Bereiter and Scardamalia 1989), productive failure (Kapur 2008), guided discovery learning (Bruner 1961), collaborative learning (Dillenbourg 1999), the zone of proximal development (Vygotsky 1978), deliberate practice (Ericsson et al. 1993), interleaved practice (Rohrer and Taylor 2007), cognitive overload (Mayer and Moreno 2003), formative feedback (Shute 2008), uncertain rewards (Fiorillo 2003), and assessment for learning (Black et al. 2003).

The AIED **domain model**, on the other hand, represents knowledge about the subject that the system aims to help the students learn. This might, for example, be knowledge about mathematical procedures, genetic inheritance, or the causes of World War I. In fact, over the years, mathematics for primary and secondary school students has dominated AIED (mathematics, along with physics and computer science, are AIED's low-hanging fruits because they are, at least at school and undergraduate level, well-structured and clearly delineated), although recent AIED research has investigated AI to support learning in less well-defined areas (such as essay writing across the humanities, Landauer et al. 2009; Whitelock et al. 2015). Finally, the AIED **learner model** represents knowledge about the students (for example, about student interactions, achievements, challenges, misconceptions, responses, and emotional states while using the system), both for all the students who have used the system so far and for the individual student using the system right now. Figure 3 shows how these three models might be connected in a typical AIED intelligent tutoring system.

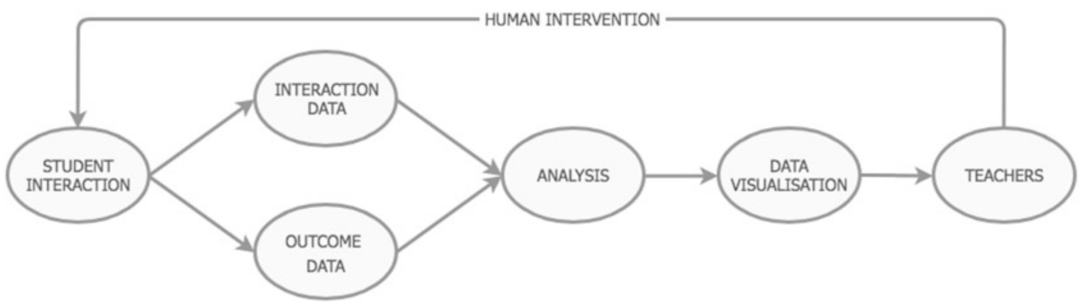
In this exemplar architecture, algorithms draw on the pedagogy, domain, and learner models to determine what specific learning activity (for example, some textual content or a collaborative learning activity) should be presented to the individual student and how it should be adapted to that student's needs and capabilities (over time, this means that individual students experience their own unique personalized learning pathways). Then, while the student engages with this adaptive learning activity, the system automatically captures thousands of data points representing each individual interaction, the student's achievements, and any misconceptions that they have demonstrated. Some systems also capture other data such as the student's speech and an indication of their affective (emotional) state.

All of this data is then analyzed (possibly using machine learning or Bayesian network techniques), both to provide the student with individualized formative feedback (to support their learning according to their individual needs) and to update the learner model (to inform the system's next adaptive learning experience). The analysis might also, in some circumstances, update the pedagogy model (with those approaches to pedagogy used by the system that have been shown to support student learning most effectively) and domain models (perhaps with previously unknown but apparently not uncommon misconceptions).

Some AIED ITS also feature a fourth model, the open learner model shown in Fig. 3 (Dimitrova et al. 2007). Open learner models aim to make visible (explicit), for the learners and teachers to inspect, both the teaching and learning that has taken place and the decisions that have been taken by the system (which is especially important if the system uses a neural network approach where, as noted earlier, it can be otherwise difficult to decipher how a decision has been made). This enables learners to monitor their achievements and



Artificial Intelligence in Education, Fig. 3 Flowchart representing a typical AIED intelligent tutoring system architecture, including the pedagogy, domain, learner and open learner models



Artificial Intelligence in Education, Fig. 4 A simplified overview of learning analytics

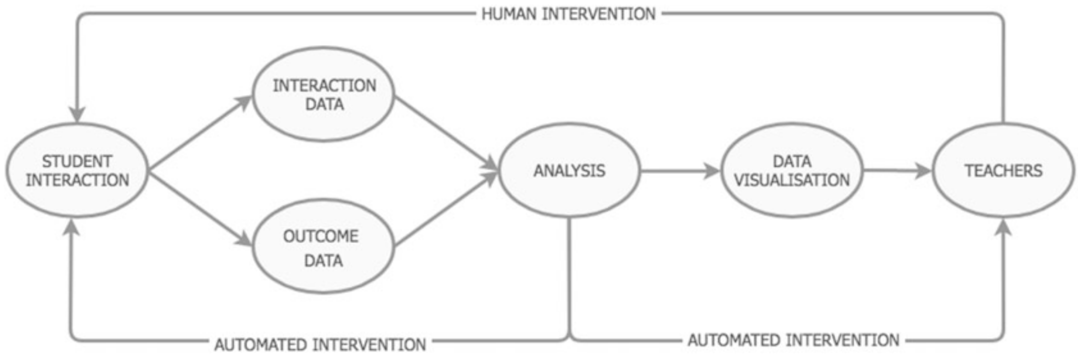
personal challenges, supporting their metacognition, and enables teachers to better understand each individual learner's learning (their approach, any misconceptions, and their learning trajectories) in the context of the whole class.

AIED and Learning Analytics

AIED is sometimes linked to another developing field of research in education known as Learning Analytics (LA) or Educational Data Mining (EDM). LA, to focus on just one, involves *"the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs"* (Siemens 2011). It applies statistical techniques from *big data* research (Mayer-Schonberger and Cukier 2013) to digital traces in educational contexts. In many ways, there are clear overlaps between LA and AIED (Figs. 4 and 5). In both LA and AIED, student interaction and outcomes data are analyzed, and the results may be shown in visualizations (for example, in student dashboards). However, although the distinction is becoming increasingly blurred, while LA typically uses the data and analysis to provide insights to inform *human intervention* (by, for example, teachers), AIED uses the data and analysis to initiate some kind of *automatic intervention* (such as personalized feedback or learning pathways for students, or automatic student forum post aggregation for teachers).

AIED Applications

There are many AIED-driven applications being used in schools and universities. Here, building on



Artificial Intelligence in Education, Fig. 5 A simplified overview of AIED

the examples mentioned earlier, an illustrative sample is surveyed. As mentioned earlier, the most common types of AIED are so-called *intelligent tutoring systems* (ITS), with Cognitive Tutor being a leading example (for a comprehensive history and discussion of ITS see Woolf 2008). ITS aim to simulate one-to-one (personal) human tutoring, which has long been thought to be the optimum condition for learning, although it is typically costly (at least in terms of teacher time) and so beyond the reach of most students. Famously, Benjamin Bloom (1984) calculated that students receiving personal tuition could achieve outcomes that were two standard deviations (2-sigma) above students taught in conventional classrooms. Although the accuracy of this has recently been challenged (VanLehn 2011), the aim of many ITS researchers has been to devise systems that answer the "*'2-sigma problem'. Can researchers and teachers devise teaching-learning conditions that will enable the majority of students . . . to attain levels of achievement that can at present be reached only under good tutoring conditions?*" (Bloom 1984). In fact, VanLehn calculates that the correct figure for human tutoring is closer to 0.8 sigma and that many ITS are already almost as effective (VanLehn 2011).

Three influential examples of personal tutors are *AutoTutor, Andes*, and *CIRCSIM*, each of which has been shown to achieve at least 1.0 sigma improvement over conventional classroom teaching. ***AutoTutor*** was an online system that aimed to *"simulate the dialogue patterns of typical human tutors"* in the domain of computing (Graesser et al. 2001). The system's pedagogy model adopted the principle that it is important *"to encourage students to articulate lengthier answers that exhibit deep reasoning rather than deliver short snippets of shallow knowledge"* (ibid.), which it addressed by engaging students in a series of written exchanges and by prompting them to elaborate. Meanwhile, feedback mechanisms included providing hints, extending student responses, and correcting misunderstandings. ***Andes***, on the other hand, was an ITS focusing on the domain of physics that aimed to replace students' pencil and paper homework with an interactive and intelligent interface. The system presented students with physics problems for them to solve, each of which usually consisted of many steps (such as drawing vectors, drawing coordinate systems, defining variables and writing equations). After the student completed each step, the system gave feedback, such as hints on what was wrong with an incorrect step or what kind of step to try next. Finally, ***CIRCSIM*** was a language-based ITS for 1st-year medical students, which was designed to help them learn about the reflex control of blood pressure. It involved one-to-one interactions between the student and the computer, using natural language processing and generation, adopting a pedagogy model that assumes *"real understanding of something involves, at least in part, an ability to describe the basic concepts in appropriate language"* (Evens and Michael 2006). Accordingly, students were asked to solve small problems while engaging (similarly to *AutoTutor*) in a Socratic dialog (an iterative conversation of questions and responses) with the computer.

An example alternative to ITS is *iTalk2Learn*, an AIED system for children aged 8–12 years old who are learning fractions, which was designed to detect, analyze and respond to speech in real time in order to improve learning (Rummel et al. 2016). Specifically, the platform supported the robust learning of fractions by providing activities to help develop both *conceptual* and *procedural* knowledge of fractions. Conceptual knowledge is fostered in an exploratory learning environment called *Fractions Lab*, which facilitates students to answer given fractions tasks using virtual manipulatives (graphical representations of fractions) in any way that they choose. Procedural knowledge, on the other hand, is fostered by structured practice activities, in a commercial ITS called *Maths Whizz*. A student's unique sequence of interleaved exploratory and structured practice activities is determined by an overarching intervention model (Mazziotti et al. 2015), the aim being to achieve optimum conditions for learning (avoiding students being under- or over-challenged, which may trigger either boredom or anxiety). Sequencing decisions are made according to the student's level of *challenge* and their *affective state*, both of which are inferred from the student's interaction (what they click and the actions they take on the screen) and their speech (including key words and prosodic features such as "um's" and pauses) and all of which are recorded in the student model. Throughout, the system uses a Bayesian network approach to deliver targeted formative feedback at three levels: *Socratic*, *guidance*, and *didactic* (Holmes et al. 2015). *Socratic* feedback draws on the dialogic approach to teaching (Alexander 2010), which emphasizes the benefits of open questioning to encourage students to consider and verbalize possible solutions. The second level, *guidance*, reminds students of key domain-specific rules and the system's affordances. The third level, *didactic* specifies the next step that needs to be undertaken in order to move forward (this rarely-delivered final feedback also operates as a backstop, ensuring that the student is not left floundering).

Another example AIED is *OpenEssayist* (Whitelock et al. 2013), which uses Natural Language Processing to provide automated meaningful feedback on draft essays. Unlike earlier AIED systems that were developed to *grade* essays and to *instruct* students how to fix problems (such as Criterion, Burstein and Marcu 2003; Summary Street, Franzke and Streeter 2006; and IntelliMetric, Rudner et al. 2006), *OpenEssayist* encourages the user to reflect on the content of their essay in order to promote self-regulated learning, self-knowledge, and metacognition. It uses linguistic technologies, graphics, animations, and interactive exercises to enable users to reflect on whether the essay adequately conveys the intended meaning and to self-correct before submitting their essay for summative assessment. The system was based on the assumption that the quality and position of key phrases in an essay illustrate how complete and well-structured the essay is, which it determined by means of key phrase extraction, identifying which short phrases are the most suggestive of an essay's content, and extract summarization.

Another use of AI in education is to focus on supporting teachers to support students, rather than on supporting the students directly. One example of this is the *Virtual Teaching Assistant* known as *Jill Watson* (JW), developed at Georgia Tech to address difficulties in providing automatic online assistance for large cohorts of students, particularly in online courses (Goel and Polepeddi 2017). JW was designed to monitor the online forum of a computer science course, to recognize common questions raised by the students, and to provide answers both accurately and quickly. Rather than replacing the human teaching assistants, JW aimed to relieve them of having to respond to low-level questions (such as enquiries about length of assignments, dates for submission, and required readings), which can be both time-consuming and tedious, to allow them to focus on higher-level and thus typically more interesting questions and other teaching activities. JW was originally developed using the IBM Watson AI as a service platform and broadly adopted a supervised learning approach. It was trained with two connected datasets developed over three semesters: the questions that students had asked, mapped to (labeled with) the answers that the human teaching assistants had provided. Thus trained, the system evaluates new student questions to determine if they can be mapped to question/answer dyads for which the system has confidence (because similar questions have been posed and answered many times). The appropriate answer is then selected and immediately returned to the student. On the other hand, if an appropriate answer cannot be identified with confidence, the question is referred up to a human teaching assistant without introducing any noticeable delay.

Finally, some brief examples involving AIED and two quite different learning approaches: collaborative learning and virtual reality. Research (e.g., Dillenbourg 1999) has shown that collaborative learning, which might involve two or more students undertaking a project together, can be more effective than learning alone. Collaborative learning can, for example, encourage students to articulate their thinking, to resolve differences through constructive dialogue, and to build shared knowledge. However, other research (e.g., Slavin 2010) suggests that collaboration between learners rarely happens without appropriate support. For this reason, various approaches using AI to support collaborative learning have been researched.

AI-driven adaptive group formation, for example, uses knowledge about the participants, most often in learner models, and self-learning algorithms to form a group best suited to a particular collaborative task (perhaps students are all at a similar cognitive level and have similar interests, or they bring different but complementary knowledge and skills) (Mujkanovic et al. 2012). Meanwhile, expert facilitation can involve training systems to support students collaboratively sharing knowledge. For example, Soller et al. (2002) developed a system using Hidden Markov Modeling (another probabilistic technique used in AI) to identify effective and ineffective knowledge sharing between students, so that intelligent guidance might be provided to foster more productive knowledge exchange (while blockchain technologies might enable the fair attribution of credit for individual contributions, Mathews et al. 2017). Finally, intelligent virtual agents might mediate online student interaction, or simply contribute to the dialogues by acting as a coach, a virtual peer, or a teachable agent (i.e., a virtual peer that the participants might themselves teach). For example, Goodman et al. (2005) developed an agent that interacted with the participants when it detected something happening that was interfering with the learning (such as a student's confusion about a problem or a participant who is dominating the discussion or not interacting productively with other participants).

Virtual reality (VR) and augmented reality (AR) enhanced with AI are both being promoted as having potential for learning. VR can provide authentic experiences that, using VR headsets, headphones, and controllers, simulate in immersive 4D (the three dimensions of space plus sound or haptics) a small part of the real world to which the user would not otherwise have access. These include places such as dangerous environments (like the interior of a volcano) or somewhere geographically or historically inaccessible (such as a black hole or the Cretaceous Period). However, while some (e.g., Hassani et al. 2013) have suggested that learning in virtual realities can enable the student to better transfer that learning to the real world (transfer of learning has long been known to be a problem), and there are examples of VR being used to support medical training (e.g., Ruthenbeck and Reynolds 2015), in a review of VR in K-12 education, Freina and Ott (2015) were unable to find any robust learning outcomes.

Augmented Reality adopts a different approach. Instead of providing an alternative reality, AR overlays rich media (virtual objects such as text, still images, video clips, 3D models, and animations) onto live video images of the existing reality, by means of the cameras and screens on smartphones and tablet devices, in such a way that users perceive the virtual objects as if they are coexisting with the real-world environment. There are many examples. AR techniques can be used to show textual information about a specific mountain (such as its name and maximum elevation) when a smartphone's camera is pointed at it (https://www.peakfinder.org/mobile); while another AR app has been developed, for use in a university science course, that allows the user to view and interact with an anatomically correct 3D model of a human heart. (https://appstore.open.ac.uk/humanheart) Nevertheless, despite the promise, again there is currently little evidence that AR leads to any notable learning gains (Bower et al. 2014; Radu 2014).

The Future of AIED

As is clear from both media and this brief review, AI and AIED are rapidly developing areas of research and development. In particular, AIED applications that yesterday seemed fanciful, today are being widely used by students, independently or in schools and universities. Future possibilities are limited only by the imagination and are thus difficult to predict. Here, therefore, briefly surveying four areas in which AIED has substantial potential (building on Luckin et al. 2016) will have to suffice.

Twenty-First-Century Skills

What have been called *twenty-first-century skills* have repeatedly been identified as essential for future students, future work, and future economies (e.g., World Economic Forum and The Boston Consulting Group 2016). These skills include competencies such as critical thinking, problem-solving, creativity, communication, and collaboration, together with character qualities such as curiosity, persistence, adaptability, leadership, social and cultural awareness, and initiative. However, although these essential skills and character qualities may be important, it is unclear how they might best be developed or supported.

AIED might help enhance students' twenty-first-century skills by providing dynamic tools that iteratively improve. For example, while students engage in collaborative problem solving activities in a particular context, the tools might monitor student actions (Who is interacting with the available learning resources and how?), eye contact (What are learners focusing on at any particular time?) and dialogue between groups of students (Who is saying what and to whom?). Over time, it will be possible to identify indicators of the most effective collaborative problem solving strategies, so that students might be guided (perhaps through automated feedback) in those directions. Monitoring and analyzing dialogue might also be used to connect students engaged in similar conversations, either on opposite sides of the room or in different countries, helping to build AIED-supported communities of practice. Meanwhile, the impact of the context may be further accommodated by means of an additional model built into the AIED system, which might help identify how the combinations of technology, teachers, and environment might be adjusted to improve teaching (Luckin 2010).

Twenty-First-Century Assessment

AIED technologies also have the potential to replace the *stop and test* approach to assessment, as exemplified in examinations. It is well-known that teaching-to-the-test, an inevitable consequence of examinations, impoverishes learning. In any case, exams (for which there is little evidence of efficacy or validity) can only assess a fraction of what has been learned and so provide only a partial picture of a student's capabilities. Exams can also be the cause of serious anxiety for many students.

AIED techniques could, on the other hand, provide continuous formative assessment and just-in-time feedback about learner successes, challenges, and needs that can then be used to shape the learning experience itself (c.f., Foltz 2014). For example, AIED could monitor changes in learner confidence and motivation as they achieve competencies in a new language or in a new topic in geography or history. Alternatively, AIED-driven *stealth* assessments (Shute 2011) could be built into meaningful learning activities, for example, in digital games-based learning or collaborative projects. This might involve continuously monitoring the various indicators of learning, accrediting, and recording the learning as it happens (perhaps in blockchain-secured robust e-portfolios, Sharples and Domingue 2016), and automatically providing guidance on appropriate next learning steps.

Twenty-First-Century Learning Partners

Finally, AIED also has the potential to build artificial *learning companions* that might accompany and support individual learners throughout their lives. These lifelong learning companions could be accessible via speech on smartphones (and on other smart devices such as Alexa, Siri, or Google Home), and could provide an easy-to-access record of a student's individual learning experiences, successes, and challenges, together with suggestions and ongoing guidance for future study. They might also connect just-in-time with other specialist AIED systems, or with humans who have expertise in particular subject areas (building on the approach used by the *Smart Learning Partner* from Beijing mentioned earlier). Inevitably, at first there will be objections, that learning companions discourage the students from learning the classroom knowledge that has traditionally been deemed to be important. However, in time, as the learning companions enable and support students to make novel connections between learning objects and learning domains that otherwise would have been difficult if not impossible, helping them to build upon and enhance their learning wherever it happens, and as the learning companions become commonplace, perhaps their value will eventually be accepted (in much the same way that calculators are finally becoming accepted in classrooms, Hodgen et al. 2018). Similar AIED could also be used to develop AI teaching assistants, designed to support teachers in their day-to-day work, removing some of the drudgery of teaching and allowing them to focus on the more human aspects of learning.

The Ethics of AIED

No discussion of AI in education can be complete without some consideration of the ethical implications. Yet, while the range of AI technologies being introduced in schools and universities around the world are extensive and growing, the ethics are rarely investigated. There has been work around the ethics of AI in general (e.g., Bostrom and Yudkowsky 2014) and around the ethics of Learning Analytics (e.g., Slade and Prinsloo 2013). However, at the time of writing, around the world, virtually no research has been undertaken, no guidelines have been provided, no policies have been developed, and no regulations have been enacted to address the specific ethical issues raised by AIED. In short, researchers and developers in AIED are proceeding without any fully worked out ethical groundings, such that it might be argued that all AIED technologies, including those that have been introduced in this chapter, exist in a moral vacuum.

In fact, although perhaps not as newsworthy as robots or self-driving cars, the use of artificial intelligence techniques (such as neural networks, machine learning and Bayes nets) in education has profound implications for students (their skills, knowledge and developing minds) and thus for wider society. In parallel, this also raises an indeterminate number of as yet unanswered ethical questions. To begin with, concerns exist about the large volumes of data collected to support AIED (such as the recording of student competencies, emotions, strategies, and misconceptions). Who owns and who is able to access this data; what are the privacy concerns; how should the data be analyzed, interpreted, and shared; and who should be considered responsible if something goes wrong? For these questions, AIED might usefully draw on the work that investigates the ethics of Learning Analytics (e.g., Slade and Prinsloo 2013). However, while data raises major ethical concerns for the field of AIED, AIED ethics cannot be reduced to questions about data. Other major ethical concerns include the potential for bias (conscious or unconscious) incorporated into AIED algorithms and impacting negatively on the civil rights of individual students (in terms of gender, age, race, social status, income inequality. . .). For these questions, AIED might usefully draw on the work that investigates the ethics of AI in general (e.g., Caliskan et al. 2017). But the AIED ethical concerns centered on data and bias are the "known unknowns." What about the "unknown unknowns," the ethical issues raised by and specific to the field of AIED that have yet to be even identified?

One approach is to consider ethical issues in terms of the three main AIED models introduced earlier. At the pedagogical level, the impact of

AIED on pedagogical relationships and how best they can be supported first needs to be addressed. For example, what kinds of AIED interventions are ethically warranted, what kinds of information should be used to justify an AIED intervention, and what kinds of behavioral changes is AIED intended to bring about? At the domain level, it is important to consider how the adaptation of particular subject content amenable to AIED influences the learner experience and their understanding of that content. Finally, at the level of individual learners, issues center on the use of personal information. In addition to the use of learning analytics to profile learners, these include issues around surveillance and covert data collection (involving cutting edge technologies that are poised to collect ever more personal information), and the tension between paternalistic systems and the autonomy of the learner.

Specific AIED ethical questions include: What are the criteria for ethically acceptable AIED? How does the transient nature of student goals, interests, and emotions impact on the ethics of AIED? What are the AIED ethical obligations of private organizations (developers of AIED products) and public authorities (schools and universities involved in AIED research)? How might schools, students, and teachers opt out from, or challenge, how they are represented in large datasets? And, what are the ethical implications of not being able to easily interrogate how AIED deep decisions (using multi-level neural networks) are made?

Strategies are also needed for risk amelioration, since AI algorithms are vulnerable to hacking and manipulation. Where AIED interventions target behavioral change (such as by "nudging" individuals towards a particular course of action), the entire sequence of AIED enhanced pedagogical activity also needs to be ethically warranted. And finally, it is important to recognize another perspective on AIED ethical questions: in each instance, the ethical cost of *inaction* and *failure to innovate* must be balanced against the potential for AIED innovation to result in real benefits for learners, educators, and educational institutions.

Cross-References

▶ Augmented Reality in Education, Scope of Use and Potential
▶ Computer-Assisted Instruction, Changes in Educational Practice as a Result of Adoption of ICT
▶ Computer-Assisted Learning
▶ Computer-Based Training and School ICT Adoption, A Sociocultural Perspective
▶ Educational Assessment, Educational Data Mining, and Learning Analytics
▶ Robotics in Education
▶ Technology Enhanced Learning

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A

Assessment

► Competency Models in Computing Education

Assisting Elderly Non-computer-Literate People with Computer-Based Communications

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Synonyms

Access; Active aging; Computer-based communications; Health information; Internet

Introduction

Aging is emerging as an issue since both the proportion and absolute number of older people in populations around the world are dramatically increasing (WHO 2015). With advances in medicine helping more people to live longer lives, the number of people over the age of 60 years is expected to double by 2050; global life expectancy has increased by 5 years since 2000 (Gulland 2016) and is expected to increase in industrialized countries. With societies aiming to provide an active aging context for the elderly, a fourth age challenge is emerging. In this context, in addition to the importance of considering the views and needs of the eldest, it is also pertinent that their continuous participation in social, economic, cultural, and spiritual dimension opportunities, together with the promotion of healthy physical development, is ensured.

Assisting elderly non-computer-literate people with, and in the familiar/friendly use of, computer-based communications and Internet access answers a challenge of today's society. Through collaboration between aging and active people and bearing in mind the potential of information and communication technology, it is possible to ensure basic rights to well-being, thus contributing to a better culture of old age (Baltes and Smith 2003). This acknowledges older people's continuing aspirations to well-being and respect (WHO 2015). In a context of progressive Internet societal omnipresence, many believe that if offline older citizens remain offline, they will become increasingly disadvantaged from a socio-ecological point of view. Encouraging older adults' use of information and communication technologies (ICTs) is essential for the creation of bona fide information societies (Selwyn et al. 2003).

Computer-Mediated Communication and Digital Technology Development

With the digital revolution, in the digital era, all entities, collectively or individually considered, are connected to each other, anytime and anywhere, through ubiquitous and pervasive computing. Wireless and mobile technologies, sensing devices, and virtual and augmented reality applications are examples of available technology that has an impact in societies and in the lives of everyone. The complementarity of the Internet of Things, consisting of intelligent and self-configuring nodes interconnected in a dynamic and global network infrastructure, and of cloud computing, which makes real virtually limitless storage and on-demand processing power (Botta et al. 2016), enables a varied and large number of application scenarios.

Nowadays, computer-mediated communication and digital technologies are increasingly ubiquitous, easily available, and, most of them, user-friendly. Being able to use a digital tool or an application is being facilitated by a number of institutions and structures in societies, via international, regional, and national programs, sometimes through social and educational activities where, despite any initial negative attitudes, success in training is more a function of a proper training program than participants' attitudes (Mitzner et al. 2016).

Adoption and Use of Computer-Mediated Communication by the Elderly

Elderly people are users of computer-mediated communication for a variety of purposes, such as seeking general information, accessing health documentation, and managing health issues, shopping, banking, or online learning. Further to these kinds of pragmatic uses, computer-mediated communication and the Internet may have a role in reducing social isolation and in promoting interconnectedness and social stimulation; information and communication technology, in general, may offer intelligent and supportive living environments that support older people's cognitive and physical problems (Nugent 2007). Despite concerns that some of these technologies also have the potential to restrict freedom of movement and intrude into privacy (Bennett et al. 2017), research also shows that Internet usage by healthy older adults is a safe activity (Karin and Martin 2013). Published research clearly shows evidence that technology, in general, and more specifically computer-mediated communication, can play a relevant role in assisting the elderly: (i) if introduced with foresight and careful guidelines, robots and robotic technology can improve the lives of the elderly, reducing their dependence and creating more opportunities for social interaction (Sharkey and Sharkey 2012); (ii) information and communications technologies may, to some extent, play an instrumental role in interconnectedness and social stimulation, between the elderly and their families (Bobillier Chaumon et al. 2014); and (iii) in long-term care institutions, the Internet may become an important window to the community (Seifert et al. 2017).

Research and Policy

Research through a systematic review by Peek et al. (2014) shows that technology that enhances safety or provides social interaction is influenced by multiple factors; its authors called for further research to determine if and how the factors are interrelated and how they relate to existing models of technology acceptance. Knowing and understanding how to assist non-computer-literate elderly with computer-based communications is an established field of research, where it has been noted that higher levels of Internet use may be significant predictors of higher levels of social support, reduced loneliness, and better life satisfaction and psychological well-being among older adults (Heo et al. 2015). However, the impact of the Internet on the well-being of the elderly may well be complex (Mellor et al. 2008) and requires continuous research. As stated by Wagner et al. (2010), computer use by older adults is a multidisciplinary topic by nature, requiring research through different methodologies, operationalizations, constructs, or relationships from different disciplines.

In addition to research, the wider community should ensure adequate policy that provides the non-computer-literate elderly with proper state-of-the-art assistive technology and personalized and knowledgeable assistance. Programs and initiatives that may take place can be illustrated by case studies already conducted and published: (i) Patrício and Osório (2016) showed that intergenerational learning with information and communication technology (ICT) contributes to the digital literacy of adults and seniors and fosters lifelong learning, active aging, and understanding and solidarity among generations; (ii) Horwitz and Huss (2016) studied online cultural products as a mediating element for communication between youth and elders; (iii) Brites-Pereira et al. (2017) are studying how the elderly learn to use digital technologies of movement detection, in a context of developing active aging.

In addition to challenging strategies, such as intergenerational learning, and rich cultural content stimuli, programs and policies need to comply with a multitude of conditions (Larsson et al. 2013), and providers may ponder the enjoyment benefit of the Internet (Lee et al. 2014). Furthermore, for digital seniors, ICT use is not a binary choice because they want to have the flexibility to select for themselves under what circumstances and for what purposes the use of ICTs is appropriate (Quan-Haase et al. 2016).

Listening to the voices of people who have learnt through a whole life will certainly be helpful to assist the elderly not only in computer-mediated communication literacy but also in the adoption of a lifelong learning paradigm.

In summary, a fourth age is emerging, in which assisting the elderly in the use of computer-based communications answers a challenge of today's society. Nowadays, computer-mediated communication and digital technologies are increasingly ubiquitous, easily available, and (for the most of them) user-friendly; in addition, research shows that technology can play a relevant role in assisting the elderly. Therefore, assisting the elderly in using computer-mediated communications not only provides the discovery of new knowledge but also contributes to an active meaningful and dignified aging.

Cross-References

▶ Assistive Technology and Inclusion, Philosophical Foundation
▶ Lifelong Learning for Working People
▶ Literacy and technology
▶ Policy Rationales and Integration Rationales, Implications for Subject Area Teaching

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Assisting People Who Are Deaf or Hard of Hearing Through Technology

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Synonyms

Alerting devices; Assistive listening devices; Captions; Deaf; Hard of hearing; Text messaging; Video streaming

Introduction

Technologies assist individuals who are deaf or hard of hearing (DHH) with access to spoken information in classrooms, at work, and in primarily social situations; technologies also help individuals who are DHH share information with hearing individuals. These technologies make it possible for individuals who are DHH to participate effectively in activities, when it would not otherwise be possible, such as by providing captions so that individuals who are DHH can follow television programs. Some of these technologies provide information visually, and others enhance auditory information (Gallaudet 2014). Technologies that assist individuals who are DHH may have a feature, such as captions, which is specially designed for them, or may be intended for a wide range of individuals and also meet the needs of individuals who are DHH in certain situations such as the use of networked messaging to facilitate communication between individuals who are DHH and individuals who are hearing (Gray 2008; Gray et al. 2011).

This entry will consider the following five types of technologies that facilitate communication, learning, and participation of DHH individuals:

1. Assistive listening devices (ALDs) that facilitate the access of individuals who are DHH to auditory signals by improving the loudness or clarity of the signal.
2. Captioning technologies that provide individuals who are DHH access to spoken information in classrooms, to television programs and web material, and to phone conversations.
3. Text messaging technologies that enable synchronous (simultaneous) and asynchronous (nonsimultaneous) text communication between individuals who are DHH and individuals who are hearing, often in situations where an interpreter is not available to facilitate communication.
4. Video streaming technologies that make possible remote conversations between individuals who use a sign language.
5. Alarm and alerting devices that help individuals who are DHH with numerous functions in everyday life, such as answering the doorbell; these technologies also operate as signal alerts, such as for catastrophic weather.

Factors that Affect Use of Technology

Before considering these five sets of technologies, the following discussion briefly summarizes three issues that have implications for the nature and effectiveness of technology used with individuals who are DHH: (a) education and work settings, (b) language and academic skills of DHH individuals, and (c) trends in technology.

Educational and Work Settings

With respect to education, virtually all students who are DHH are educated in two types of classrooms, special and general education (mainstream). Special classes typically have a teacher of the deaf, and communication tends to be in a sign language. Communication is more accessible to students who are DHH because if they are in that setting, the teacher regulates the flow of communication and adjusts to the children's communication needs so that the students can understand (Stinson and Kluwin 2011). General education classes are those with primarily hearing students and a regular teacher. Typically, only one student who is DHH (or only a few) is placed into any particular general education class. In these classes, the teacher and students almost always use a spoken language (e.g., English, Greek), and the students who are DHH in these classes usually have difficulty understanding at least some of this communication, unless they receive special services to support communication access and learning. A somewhat similar type of distinction occurs when individuals who are DHH enter the work world. These individuals may work in positions with primarily hearing co-employees, and thus there is often a need for technology that can help individuals who are DHH have access to the spoken communication of hearing employees. A good, but relatively small, number of employees who are DHH work in settings where most employees know a sign language (such as in a school for the deaf), and for them much communication with fellow employees is through a sign language (Kelly et al. 2016).

Communication Characteristics

Two characteristics of individuals who are DHH that affect learning and employment are limited proficiency in reading and writing (Qi and Mitchell 2012; Nikolaraizi et al. 2013) and considerable diversity in communication characteristics (Knoors and Hermans 2010). Students who are DHH vary in the knowledge, understanding and use of a sign or a spoken language, and proficiency in reading and writing. These variations relate to the extent that students are placed in general education or special education classes, as well as the nature of accommodations that a student may request, including provision of a sign language interpreter or real-time captioning (Knoors and Hermans 2010; Stinson and Kluwin 2011).

Five Assistive Technologies

Assistive Listening Devices

Language development in a spoken language among individuals who are DHH is associated with the use of the proper listening devices and the benefit that this device provides (Ambrose et al. 2014). In addition to the personal listening device, either hearing aids or cochlear implant, assistive listening devices can improve the quality, audibility, and clarity of the speech signal. In many listening environments, the signal-to-noise ratio (SNR) is very low, that is, that the level of signal (i.e., teacher) is lower than the level of the background noise. This prevents speech perception for an individual, particularly a child, with functional hearing, who needs the signal to be louder than the background noise. The use of assistive listening devices (ALDs) can facilitate the detection of the sound and improve SNR by minimizing background noise, the distance between the sound source and listener, and reverberation (Hinman et al. 2003; Kim and Kim 2014; Dillon 2012; Zanin and Rance 2016).

The most common assistive listening devices include the soundfield amplification systems, the frequency modulated (FM) radio systems, the infrared (IR) transmission, and the magnetic induction loop. The soundfield systems include a wireless microphone and wireless receiver/amplifier that powers loudspeakers that are placed around the classroom, often on the walls. These speakers are linked to a control center, which can transmit sound from various devices – for example, a microphone worn by a person speaking, a music system, or a whiteboard. The portable systems can be moved around to wherever they are most needed. In rooms with poor acoustics, soundfield systems might be of less benefit because they increase the loudness of the speech signal as well as reverberation. Therefore, the ideal is to use a soundfield system in a classroom with good acoustics. Also, a pass-around microphone is often important because it can amplify the voice of other speakers (i.e., classmates) who might make comments and ask questions (Aussie Deaf Kids 2015; Dillon 2012; Hinman et al. 2003; Inglehart 2002; NDCS 2017; Zanin and Rance 2016).

Additional ALDs include the FM and the IR systems which are both wireless systems that consist of two units, a portable receiver for the listener and a microphone transmitter for the speaker. FM systems use radio waves, while IR systems use light waves. Radio waves travel through the walls, and therefore FM systems in nearby rooms must use different channels. In the case of IR, there are no such issues because walls are opaque to light. Another ALD is the induction loop system which uses an electromagnetic field to carry the sound to the user's ears with or without a personal listening assistive device. In this system, a loop of insulated wire, which might be worn around the neck or might encircle an entire room, is connected to a power source, an amplifier, and a microphone. An amplifier transmits the electrical signal from the microphone to the wire, and this electrical current creates an electromagentic field that is picked up by the hearing aids or the cochlear implants with a telecoil feature. The users sitting within the loop system can pick up the speaker's voice or TV without distortion and no background noise. The loop is fully adaptable to television, radio, stereo, and tape recorder (Aussie Deaf

Kids 2015; Dillon 2012; Hinman et al. 2003; Inglehart 2002; NDCS 2017a, b; Zanin and Rance 2016).

Further, ALDs are digital transmission technologies that use increased audio bandwidth (up to 7300 Hz) and frequency-hopping to prevent electromagnetic interference and therefore improve the SNR for the listener (Wolfe et al. 2013). Finally, Bluetooth technology allows two electronic devices such as a cell phone, a computer, the TV on one hand, and a hearing aid or a cochlear implant on the other to connect to each other (Hinman et al. 2003; De Raeve 2015).

Captioning

Three types of captioning that individuals who are DHH use are real-time captioning in classrooms, television captioning, and captioned telephones.

Real-time captioning in the classroom. Real-time captioning meets the communication access needs of some DHH students in classes with primarily hearing students. The provider of the service, who is often in the classroom next to the student(s) who are DHH, produces text as it is being spoken by the teacher or other students and displays it on a portable device so that the student can access instruction and, more generally, understand what is taking place in the classroom. In the two common real-time captioning options, the provider uses either a standard typing (QWERTY) keyboard with computerized word abbreviation expansion or a stenographic (stenotype) machine. A little used option, with greater promise for the future, is automatic speech recognition (Ruan et al. 2016; Stinson et al. 2008). The typing-based services often include a messaging feature so that student users, who are unable or uncomfortable using their voice, can ask questions or make comments by typing a message that the service provider can view and read aloud to the class.

Real-time captioning services may be provided in the classroom or remotely. If remotely, the speaker, such as a teacher, typically wears a Bluetooth microphone, and the spoken message is delivered using either a cellular phone or Voice over Internet Protocol (VoIP) via a cellular or broadband Internet connection (i.e., Skype, Google Hangout). These services also support display of text on diverse devices (standard laptops, smartphones, etc.). Display of the text may be based on an easily downloadable app that runs on iOS and Android devices. To use the service, the user simply connects and then begins to use the service. Some services use a web browser for display of captions. Real-time captioning services usually distribute notes, or saved text, to students after classes (Cawthon et al. 2013; Stinson et al. 2014a). Notes produced by real-time captioning service and a note taker are different from each other. Notes produced with captioning are the saved transcript of the lecture, which may or may not be modified by condensing, bulleting, etc. Compared to this text, handwritten notes involve more rephrasing of concepts and greater condensing.

Real-time captioning is frequently a desirable option for students who are DHH because it helps them understand and learn classroom material by providing information that is permanent and distributing notes (saved text) that contain the actual vocabulary used by a teacher. Also, it helps them deal with the multiple visual demands of the classroom. Based on studies that compared real-time captioning with other services, the students learn the same amount or more with real-time captioning as with interpreting (Marschark et al. 2006; Stinson et al. 2009). Also, sometimes, students rate their understanding of the instructor higher when they receive this service than when they receive interpreting (Stinson et al. 2017a).

Television captioning. Television exerts a substantial influence upon children's learning and socialization. 85% of more than 50 million children in the United States watch television everyday (National Captioning Institute 1983). Children who are DHH watch television as often as children who are hearing do (Lewis and Jackson 2001; Liss and Price 1981). Today, television programs may be viewed with captions. These captions are a text display of the audio component of the television program, which is generally displayed at the bottom of the television screen (Lewis and Jackson 2001). In order to see these captions, which are generally transmitted in closed format, the viewer must set the caption decoder, which is contained in virtually all television sets, so that it displays captions. A major reason for production of captions is to provide individuals who are DHH access to the audio component of the program. Open captions can be distinguished from closed captions. Open captions are displayed to all individuals who view the video. Closed captions are only viewed when the caption decoder is set to display captions on the screen.

Despite the barriers that individuals who are DHH face in becoming a proficient reader, research has indicated that captions are beneficial to them (Qi and Mitchell 2012). This is consistent with the regular use of various forms of printed information by individuals who are DHH (Stinson 2010).

Researchers have attempted to identify ways of increasing the comprehension of captions by individuals who are DHH, but research to date does not clearly indicate that factors that might be expected to facilitate comprehension, such as caption rate and linguistic complexity, consistently increase comprehension. Reading proficiency has been found to affect comprehension of captions (Braverman and Hertzog 1980; Burnham et al. 2008).

Captioned telephone. Telecommunications relay services allow persons who are deaf, hard of hearing, and deaf-blind or who have speech disabilities to place and receive telephone calls. A communication assistant relays the call back and forth between the person with a disability and the other party to the call. There are different variations in how the service may work. In one option, Internet Protocol-Captioned Telephone Service (IP-CTS), persons with hearing loss are able to almost simultaneously hear and read the communication from the person with whom they are having a telephone conversation. The communication assistant listens to what the party being called says and produces text, such as with a stenotype machine or through re-speaking with automatic speech recognition that automatically transcribes these words, with the words reappearing nearly simultaneously after they are being spoken by the other party.

Through text-to-voice telecommunications relay services, an individual who is DHH communicates in text what she/he wishes to communicate to the other party, and the assistant repeats in voice what the user has typed and types for the user who is DHH the hearing telephone user's response. Users who are DHH may view telephone captions through a special phone that displays captions, through a downloadable application on a mobile device or a website. These services are often delivered via the Internet. Some countries that provide this service also tend to support it with a small surcharge on users of telephone services (FCC 2017; Power et al. 2007).

This service can enable individuals who are DHH to more effectively use a telephone at their home or jobs. Individuals who use a form of captioned telephone, as opposed to video relay service with a signing interpreter, tend to be individuals who are DHH with relatively good proficiency in their native spoken language (e.g., English), such as those with an acquired hearing loss. When these individuals prefer to communicate by speaking and have enough residual hearing to at least partly be able to follow the conversation of the other party on the phone, they are likely to value using the IP-CTS service (MITRE 2016).

Currently, just more than half of the users of telephones who are DHH are satisfied with use of the phone with the assistance of their hearing aids (MITRE 2016; Payton et al. 2017). In addition, these users report that hearing aids provide on average only 55% benefit during phone conversation (Kochkin 2013).

Text Messaging to Facilitate Communication in Small Groups

A new area of work is an accommodation to facilitate communication between individuals who are DHH and individuals who are hearing in small groups who work together on a task.

These small group situations are quite common. At school, cooperative learning and collaboration learning promote deep, meaningful learning (Cohen 2002; Esmonde 2009; Lunetta et al. 2007; Pintrich et al. 1993; Schuell 1996). However, the benefits of collaboration in school are only possible when students successfully exchange ideas, comments, and insights. Students who are DHH often face communication challenges because the provided services are not adequate for the situation. Furthermore, even in classes where there is a range of services such as professional sign language interpreters, real-time captioning, and note takers, if more than one individual who is DHH attends this class and they participate in more than one group, there may not be enough interpreters to support each of these students. Often mobile devices can help communication in small groups with students who are DHH and students who are hearing. A technology that produces typing or drawing for all group members to see can help level the playing field when DHH students participate. Because typing and drawing are visual and remain visible longer than speech or sign, these are reliable forms of communication.

This text-based communication may be face-to-face or online. The use of messaging and shared documents, such as in Google Docs, has emerged with the growth of wireless Internet services and widespread use of mobile devices. Messaging applications, such as iMessage, may enable participants to more easily communicate with each other longer, relatively complex statements compared to using paper and pencil, gesture, pointing, etc. This form of communication is more likely to occur when a sign language interpreter is not available, when hearing participants do not know sign language, when the DHH participants cannot readily understand spoken communication of the hearing participants through speech-reading and residual hearing, and/or when the DHH individual's speech is unintelligible. A new way for hearing participants in groups to produce messages is through automatic speech recognition. Hearing users voice into a Smartphone, a tablet computer, etc., and the automatic speech recognition engine converts their spoken messages into print for viewing by all participants with devices networked to share the conversation (Stinson et al. 2017b).

An experimental study of the effect of an iMessage intervention in a situation where two of the participants were DHH and two were hearing provided evidence of the effectiveness of technology in facilitating communication between DHH and hearing individuals in small groups. Results indicated that when iMessage was available, the two students who were DHH stopped signing, the two students who were hearing stopped talking to each other, and everyone, instead, communicated primarily with the whole group through the technology (Stinson et al. 2014b). In addition, research has found that students who are DHH are now increasingly using technology, such as cell phones and laptops, to communicate with students who are hearing in small groups (Stinson et al. 2014b, 2017b).

Video Streaming Communication Technologies

Video streaming technologies allow individuals who are DHH who use a sign language to communicate with other individuals who are DHH and with individuals who are hearing and use sign language over the Internet through video chat and through video relay services.

Online video communication technologies. Video chat, where the participants simultaneously communicate via sign and/or voice over the Internet is a technology that individuals who are DHH often use with each other or with a hearing individual. Examples of video chat include Google Hangout, Skype, and FaceTime. Some educational programs use this technology for an individual with expertise in a field to provide tutoring to a student who is DHH (Elliot et al. 2013). Video chat may be supplemented with simultaneous sharing of photos and documents. When video chat is used for tutoring, it may use virtual whiteboards such as Conceptboard to share this information. For example, in tutoring in mathematics, tutor and tutee may exchange written board work related to solving the problem by using Conceptboard, or alternatively they may focus their web camera on the mathematical notation that they handwrote on their own whiteboards or paper. Individuals that are using video chat may sometimes switch to using text messaging, such as when there are technical issues with the video (CAT 2015; Elliot et al. 2013). An advantage of the Google Hangouts software application relative to other video chat programs is that it allows multi-platform communication (e.g., video feed, document sharing). Individuals who wish to communicate by sign with each other use video chat to communicate with each other for a variety of purposes, such as for social communication, in addition to using this technology for education.

The idea of using video chat for education of students who are DHH is quite new. The limited evidence to date indicates that this approach is usable and effective and that online tutoring with signing may work as effectively as face-to-face tutoring with signing in assisting students who are DHH (Elliot et al. 2013; Lissaman et al. 2009; Richardson 2009).

Video relay services. Video relay services (VRS) are implemented with the goal to ensure effective phone communication between signing deaf persons and hearing persons. Furthermore, video relay services are provided to enable individuals who are DHH and individuals who are deaf-blind make telephone calls with hearing individuals that function as well as the phone calls between individuals who are hearing and communicate though speech.While captioned phone services are used by individuals who are DHH and who want to use captions to help access the spoken communication over a phone, video relay services are used by individuals who are DHH and who communicate via a sign language. Video relay services use video streaming technology so that the individual who is DHH is able to view a communication assistant who signs the spoken message produced by the hearing individual that the DHH person has called; in addition, the video technology enables the communication assistant to view the signing of the DHH individual so that the assistant can relay the DHH person's signed message to the hearing party on the phone. The typical VRS communication sequence consists of (a) the user who is DHH signing a message to the VRS communication assistant, (b) the communication assistant relaying this message to the hearing user participating in the phone conversation by converting it into a spoken message, (c) the hearing user replying to the message produced by the user who is DHH with speech, and (d) the communication assistant relaying this message to the user who is DHH by converting it into a signed message. Both the individual who is DHH and the communication assistant use specific software on a computer and a computer web cam to enable this communication (FCC 2017; MITRE 2016; Power et al. 2007). Some countries offer these services through a small charge that is included in the telephone service charge of all of the users of phones in a country. These services are important for enabling persons who are DHH to make all the kinds of phone calls that hearing individuals make: e.g., for work, medical services (appointments), shopping, communication with friends and family, etc.

The limited research and experience in provision of services indicates that while individuals who are DHH, who are primarily users of a sign language, benefit from video relay services and that these individuals prefer video relay to a text-based telecommunication service, video relay lags behind technological advances, and it is not at a level that satisfactorily meets the needs of users who are DHH (MITRE 2016; Steinberg et al. 2006).

Alarm and Alerting Devices

A wide range of alerting or alarm devices are available with a number of features that may help individuals who are DHH to wake up, keep track of time, and be notified of various happenings. Sometimes these devices can inform or alert individuals who are DHH of quite risky happenings, such as incoming weather that is potentially dangerous. An alarm device might have various features such as adjustable volume, vibrating pads, display screen size, flashing lights, or a combination of these features. Also, the alarm device might sit on a table or be portable. Furthermore, alarm systems may be connected to various household devices such as doorbells, smoke alarm, kitchen timers, and telephone alerts. In addition, instead of using separate notification devices, such as an alarm clock, personal alert systems can inform individuals who are DHH about various sounds around the home such as those created by a telephone, doorbell, smoke alarm, or an alarm clock by being wirelessly connected to each item. When one of these devices is activated, it sends a signal to the personal alert system, which may provide a visible or vibrating warning, such as on a wristwatch, or phone (Kim and Kim 2014; NDCS 2017).

In addition, current mobile devices may capture vibration signals nearby or a spoken public announcement that are poorly accessible to people who are DHH. Vibratory signals through mobile devices have proved to be effective when their duration is long, around 13–14 s (Harkins and Bakke 2011). Of course, it is important to stress that current streaming technology is able to link several devices, including mobile or non-mobile ones, to the user's personal hearing devices (hearing aids and cochlear implants) (NDCS 2017). That is, the alert signals, which are usually auditory ones, cannot only be sent to the mobile device as vibrating signals, but they also can be directly streamed to the hearing aids or cochlear implants and be perceived as auditory signals by users with functional hearing.

Conclusion

Assistive technology can play a major role in the access and participation of individuals who are DHH in daily life, in a variety of environments, such as home, work, school, playgrounds, sport activities, social events, and cultural centers. There is a wide range of assistive technologies that can benefit different users depending on their functional hearing, the way that they communicate, and the environment where they are. Nevertheless, despite the positive role of assistive technology, many individuals who are DHH do not use them.

The use of assistive technology has been limited due to psychosocial factors such as social stigma, low self-esteem, and cosmetic appearance associated with the use of these technologies, as well as to difficulty in adjusting to using a new technology (Cienkowski and Pimentel 2001; Rekkedal 2011). Such concerns seem to have been addressed lately by the mobile phone technology, which allow users to control their hearing aid or the cochlear implant through their mobile phone. In this way, users do not need to carry extra devices, and they also avoid the social stigma that concerns some of them because the use of a mobile phone is common (Compton-Conley n.d.). Another reason for the low use of assistive technogies is that in many countries these devices are not available or are costly. Also, the regulations regarding accessibility and the implementation of these regulations vary from country to country. Although personal amplification systems, such as hearing aids or cochlear implants, seem to be widely used, assistive technologies are not always so widely known or provided.

Therefore, in order for these technologies to become more widely used, they need to be broadly available, and additionally there is a need for the mandatory application of Universal Design principles that would address the needs of clients with different characteristics and skills including individuals who are DHH (Office of Educational Technology 2010; Varzhel et al. 2017). Under Universal Design, assistive technologies will be included in the planning of buildings, events, learning programs, and all products ensuring or facilitating the access of individuals who are DHH.

Cross-References

- ▶ Assisting Students with Learning Disabilities Through Technology
- ▶ Assistive Technology and Inclusion, Philosophical Foundation
- ▶ Distance Learning
- ▶ Online Teaching, Emotions, and Emoticons in Computer-Mediated Communication

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Assisting People with Autism Spectrum Disorder Through Technology

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Introduction

This entry seeks to provide a review and overview of technology that has been used to support autistic people. The aim of this entry is to provide an overview of technology used by autistic groups contextually and historically. Materials covered will include virtual reality technologies, touch screens, and more traditional media types (i.e., multimedia). The entry will include a historical overview of the field and provide some detailed explanations of technologies that have been used, mainly in scientific literature. In addition to this, the entry will explore autism and paradigms of exploring the field of technology used by autistic people. Finally, the entry concludes with some views, perspectives, and the potential for future work in this area, coupled with messages for practitioners and ways that technology can be most fruitfully used with, by, and for autistic groups.

Autism and Autism-Based Paradigms

Autism spectrum conditions (ASCs) are pervasive and enduring conditions, characterized by a qualitative impairment in social functioning and communication and restricted or stereotyped behaviors. Autism is also described as a neurodevelopmental condition characterized by core differences in social communication, interaction, and repetitive behaviors across a variety of contexts. In terms of autism being described as a "spectrum," there are ways that this has been contextualized in recent years. Most recently, a "spectrum" is referred to as people who meet the main criteria (outlined above) in addition to having associated learning difficulties – or not. So terms such as "high functioning" and "low functioning" are used and associated with autistic people without or with learning difficulties (respectively). This entry takes the position that using terms such as "autistic people" is preferred by the autistic community and as such will use this language.

In terms of its impact, the National Autistic Society predict that "Around 700,000 people in the UK are on the autism spectrum [. . .] together with their families, this means autism is a part of daily life for 2.8 million people" (National Autistic Society 2018). This number of autistic people reflects about 1:68 within the UK and, in studies undertaken in parts of the USA, can rise to 1:56. In addition, the condition is reported more in males than females with about four in every five autistic people being male. Recent evidence tends to suggest that one reason for this male/female ratio could be due to females being better able to shield their condition. Notwithstanding various limitations, discussions, perspectives, and reasons related to the data above (and either way), there is a growing population of autistic children and adults. As diagnosis, support, and educational provision are improving, there is an increasing need to identify ways to support key areas related to education, support, and transition from adolescence to adulthood.

Despite increasing diagnoses and better recognition and support for autistic communities there are still limited positive outcomes for autistic youths and adults. There remains a significant gap, for example, in employment prospects for autistic adults. With data from the UK, for example, reporting about 32% of autistic people in paid employment (this falls to 16% for data related to full-time employment), there is a specific and urgent need to consider ways to help improve this. A number of approaches that have been identified in recent years include (1) identifying and positively utilizing the strengths of autistic groups, (2) educating employers and others as to how autistic individuals can successfully be integrated into workplace settings, and (3) employing a range of technology tools to help assist successful transition routes into employment. These factors can also be said to apply to a range of other contexts including education, socializing, learning, and training, to name a few. The specific focus of this entry is to present ways in which autistic people are engaging with and using a range of technology tools to help assist in a variety of ways. The following sections will outline:

1. Paradigms and perspectives of evaluating and using technology for autistic groups
2. Why technology has been seen to be a good fit for autistic users
3. Types of technology use for autistic users
4. Conclusions and future directions

Paradigms and Perspectives

It is important to understand that technology applied to autistic contexts has been situated in a range of perspectives or for the purposes of research: paradigms. This is useful to briefly mention as it *can* cause tensions between not only the types of data that are used to report studies across paradigms but as it can also raise concerns for terminologies and the applied use of technology. In medical-based perspectives, autism has been seen as a disorder and in many cases reported as requiring "interventions" to help improve the skills and therefore outcomes of autistic people. Technology-based research within this paradigm has sought to develop interventions with a view that autistic individuals can have gaps/problems in their condition managed. These examples have highlighted a deficit-based model of autism.

However, and in recent years, there are other paradigms and perspectives that have sought to develop the use of technology as a way to support, develop, and enable autistic people. These types of studies and projects are situated more closely, in many cases, toward a socially integrated, progressive, and accepting views of autistic people. This is not to suggest that medical-based ideals have not been accepting or socially progressive, but rather that they tend to focus on fixing deficits in individuals. Constructivist and interpretivist models accept differences and try to situate their work within understanding how autistic people view the world and how others view them. In fact, most recently (2018) there have been initiatives toward recognizing autistic individuals' strengths and how these can be harnessed and utilized within a range of opportunities. The role of technology in constructivist domains tends to seek ways of augmenting and adapting the lives of autistic people. For more on this perspective and overview, please refer to the work of Milton (2014).

Next, various types of technology used with/by/for autistic groups will be introduced, outlined, and discussed.

Why Technology and Autism?

Before discussing types of technology used by, with, and for autistic groups, the following table provides an overview of the technology discussed in this entry along with definitions related to these technologies (Table 1).

Key features of virtual environments have been cited as having potential benefits for autistic individuals as they can be individualized, controllable and predictable and offer "safe spaces" for users to learn new skills (Parsons and Mitchell 2002; Kandalaft et al. 2013). This means that autistic individuals can practice interactions within a realistic environment that can be programmed to reduce sensory and social inputs to a manageable level.

The publication of several conceptual and state-of-the-art reviews in recent years has focused the debate more widely on issues relating to the use of VR by, and with, autistic individuals (see Bellani et al. 2011; Parsons and Cobb 2011; Parsons 2016; Bradley and Newbutt 2018). In addition, the immersive nature of virtual environments (VEs) has been shown to enable a sense of presence for autistic adolescents (Wallace et al. 2010) as well as providing a motivating tool for learning (Parsons and Mitchell 2002). There is evidence that the ability to individualize, rehearse, and repeat social scenarios across different contexts has afforded opportunities for the generalization of social skills learned in VE to everyday life interactions (Didehbani et al. 2016; Parsons and Cobb 2011; Tzanavari et al. 2015).

Assisting People with Autism Spectrum Disorder Through Technology, Table 1 Key terms, abbreviations, and definitions used in this entry

Term in full	Abbreviation (if applicable)	Definition with reference point
Virtual reality technology	VRT	This is used as an umbrella term to describe the technologies below and in general, encompassing all virtual reality-type experiences
Virtual reality	VR	Virtual reality specifically refers to the computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors (ref: Google.com)
Virtual environment	VE	A computer-generated, three-dimensional representation of a setting in which the user of the technology perceives themselves to be and within which interaction takes place (ref: Dictionary.com)
Collaborative virtual environment	CVE	The same as a VE, plus the ability to collaborate with others within a 3D simulated space
Single virtual environment	SVE	The same as a VE without the ability to interact with others
Virtual world	VW	A virtual world is a computer-based online community environment that is designed and shared by individuals so that they can interact in a custom-built, simulated world. Users interact with each other in this simulated world using text-based, two-dimensional, or three-dimensional graphical models called avatars (ref: Techopedia.com)
Head-mounted display	HMD	A type of computer display device or monitor that is worn on the head or is built in as part of a helmet. This type of display is meant for a total immersion of the user in whatever experience the display is meant for, as it ensures that no matter where the user's head may turn, the display is positioned right in front of the user's eyes (ref: Techopedia.com)

Note: Link to full-res images that are included, is below. https://www.dropbox.com/sh/20252dtc1a14kmp/AAA0D80gWafQmkYdwsf2Ooy0a?dl=0

The recreation of realistic settings and contexts by researchers and developers has enabled skills to be learned and reinforced in VE in ways which were not always possible or, more problematic, in real life. A range of different scenarios have been designed to enable autistic individuals to learn skills that may be supportive of independent living, positive social interactions, or maintaining their personal safety. For example, researchers have developed VE that recreate celebrating with a friend and meeting strangers (Kandalaft et al. 2013) or crossing a road safely (Strickland et al. 1996) and learning social conventions (Parsons et al. 2006).

This research indicates that VRTs have valuable potential for both support and the education of children, young people, and adults who are autistic. Many studies show promising results regarding users learning and generalizing new skills and knowledge and showing changes or developments in their responses over time (Parsons 2016). However, there remain significant challenges for testing the relevance and applicability of VR for autistic children in educational contexts.

Within the field of assistive technology (AT), various virtual technologies have been used with the aim to help and assist autistic people in a variety of ways. They have been used in ways to help enable spatial awareness (Strickland et al. 1996), to help understand facial expressions (Fabri and Moore 2005), to understand social skills and social awareness (Parsons et al. 2005; Parsons 2007), and as a tool to help support social cognition training (Kandalaft et al. 2013). Additionally, Alcorn et al. (2011) have undertaken work in virtual environments to help facilitate joint attention cues. Studies within the area of virtual reality technology (VRT) have mostly reported positive outcomes and highlighted how, in many cases, people with autism have adapted to VE interfaces (Parsons 2007; Guldberg et al. 2010), used VR with comfort and enjoyment (Strickland et al. 1996), developed social skills (Parsons et al. 2005), and found comfort in the communication afforded by VE interfaces (Fabri et al. 2004). In addition to this developing evidence-based, screen-based media is also something that research has concluded autistic people can be attracted to, in some cases more so than their typically developing peers (Mazurek and Wenstrup 2013). This highlights perhaps a preference for the use of material presented through screen-based media formats. For example, and as Mazurek and Wenstrup (2013, p. 1265) report: "Children with ASD spend approximately 62% more time watching television and playing video games than engaged in non-screen activities (including reading, studying, spending time with friends, and engaging in physical activities)." This is also a view previously reported by Mineo et al. (2009).

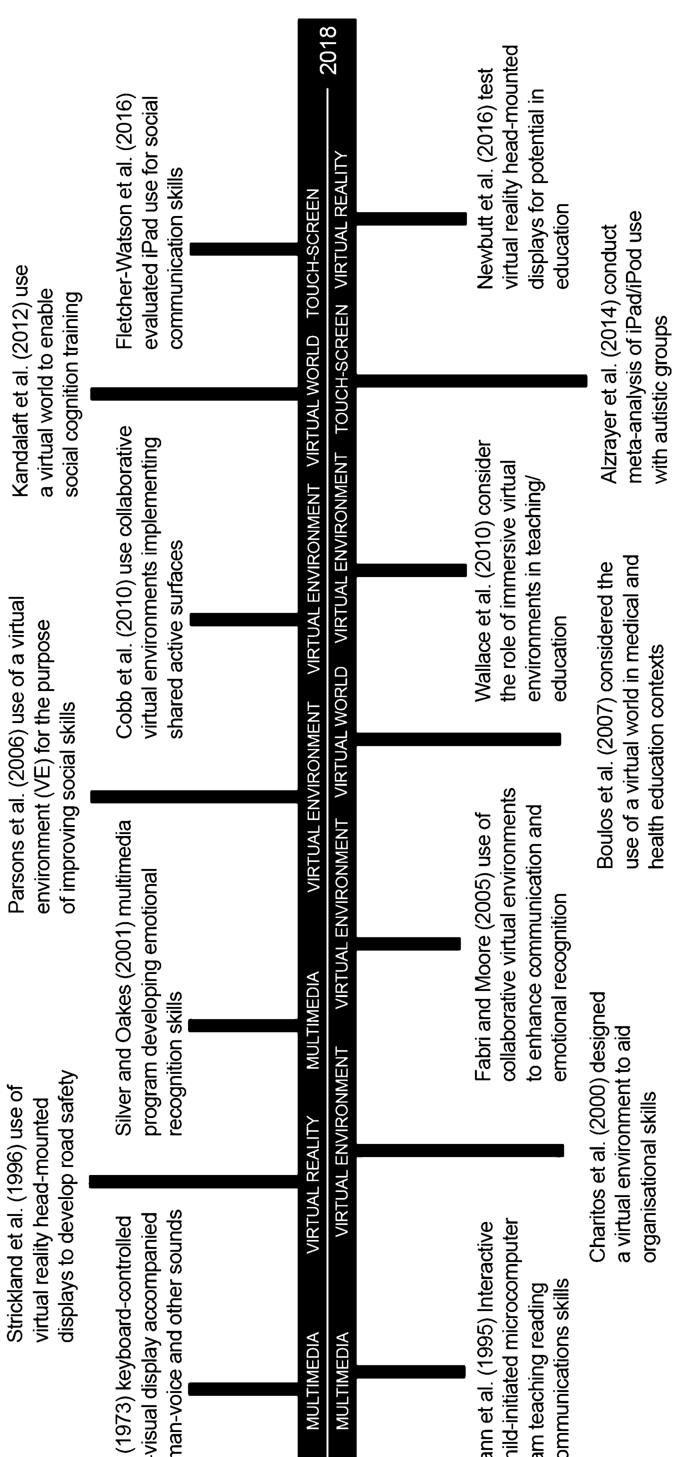
Examples of Technologies Used to Support Autistic Groups

This section seeks to identify and outline a range of technology tools that have been used by, with, and for autistic groups. Before moving onto this, the following figure (Fig. 1) provides an overview of the timeline for technology used with autistic groups. This is situated within the evidence-based research conducted over a period of time (1970s–2018). This is not meant to represent a detailed overview, but rather some key points when specific technologies have been used, applied, and evaluated with autistic individuals and groups.

While Fig. 1 provides a visual representation of key technologies across the last 40 or so years, the following sections aim to provide a more detailed overview and review of these technologies and where/how they have been applied for autistic users.

Virtual Environments and Collaborative Virtual Environments

Initially within the area of virtual reality technologies (VRTs), Strickland et al. (1996) presented an early study that assessed the effectiveness of virtual reality (VR) as a learning tool to engage autistic children; their study was primarily designed to determine if autistic children would tolerate VR equipment and respond to a computer-generated world. They considered the differences between VR and computer programs, the level of interaction with computer-generated images, and independence in determining motion and objects in a VR world as a way to present real-life experiences. The use of VR for autistic children was considered, based on sensory problems, lack of generalization, visual thought patterns, individualized treatment, and responsiveness to computer technology. The aim of the study was to help children with autism learn how to cross a road safely. They used VR helmets to immerse the users in a 3D environment, so that users could identify cars, the colors of objects, and how they were moving. The children were presented with various scenarios to determine generalization and were asked to "walk" into the scene and interact with signs. Conclusions gained from the study suggested that the two participants were able to interact with the environments successfully (accepted the virtual helmet, tracked in-world objects, moved their bodies and heads, located in-world objects, and moved toward them). In addition the study suggested that the participants appeared to become immersed (labeling in-world objects and moving their bodies interactively). These aspects tended to suggest that VR afforded far-reaching advantages to autistic children, including encouraging interaction, exploring, and learning. A limitation of the study was the small number of participants included; while two children accepted the use of VR devices (helmet, joystick, gloves, etc.), it does not follow that others would. Newbutt et al. (2016) readdressed these points later (in 2016). This will be discussed in later sections of this entry.



Assisting People with Autism Spectrum Disorder Through Technology, Fig. 1 Overview aligning key technologies used with autistic groups since the 1970s to 2018

Building on the work of Strickland et al. (1996), Charitos et al. (2000) designed a virtual environment that was controlled by virtual reality input devices, to aid the organizational skills of people with autism. The study aimed to teach social skills through providing a virtual interface for people with autism to navigate through. Charitos et al. provided a series of reasons why computer-based systems are well suited for autistic people, based on the work of Murray (1997). Examples cited by Murray included being able to set clear boundaries and controlling the stimuli (through a step-by-step process). These both allowed for greater control and focus of material in the presentation and learning. Another advantage cited by Murray links to joint attention and restrictive context. These both, in some ways, play to the strengths of autistic people in that focus of interest can be taken into account in addition to restricting other sources of information. Overarching these aspects, Murray suggests that safety, flexibility, and adaptability can all be instilled along with a sense of prediction.

On this basis, Charitos et al. (2000) proposed designing a virtual environment to aid children with autism in undertaking everyday tasks. This, more specifically, pertained to "returning home" and builds on a traditional teaching practice used within the school. It was an aim of the project reported in this paper to "improve the potential for effective teaching" (Charitos et al. 2000, p. 150).

Interestingly, although not surprisingly, Charitos et al. arrived at similar conclusions to those of Strickland et al., including the notion that structured environments go some way to help users feel confident and that a range of input devices could be used. The work presented by Charitos et al., while including more participants than that of Strickland et al., still has limited participant detail which would help provide useful contextual data, helping us to better understand the study in the exploratory manner it is intended.

Elsewhere, Fabri and Moore (2004) developed a simple platform that integrates the use of images (avatar representations) and animated facial expression sequences, to help in the understanding of facial emotion and communication for users with autism. They present three stages to their product: (1) avatar representations in isolation, to help initial emotional understanding; (2) prediction of emotions in contextual situations – own feelings and feelings of others; and (3) avatar emotional representation, paired with a selection of events. The tasks involved recognition of an emotion from a facial expression, selection of an expression to represent an emotion, and prediction of an expression. The user at stage 3 is required to select an event that may have caused an emotional response and is asked to infer their own emotion to that of another (cause and effect). In order to identify whether participants were successful in selecting appropriate emotional avatars for each section of their program, Moore et al. compared the observed responses of the participants to the questions against chance responding. The results showed that over 88% of participants performed above the level of chance. Moore et al. conclude that the study offers evidence that the majority of participants involved were able to interpret and understand the emotions of the avatars appropriately. This study demonstrates that people with autism have both the ability and predisposition to use CVEs and that they can, via this medium, identify emotion, apply emotion, and predict emotion from facial expressions (Moore et al. 2005).

This study does, however, offer clear evidence that using virtual animated facial expression can help autistic users to understand and decipher emotion. The study recognizes that a small minority of participants found it difficult to understand the emotions represented by the avatars, and for this reason, more details on the individual participants would have been useful, allowing greater insight into who CVEs could be most beneficial for.

Cheng and Fan (2008) also used a CVE to experiment with the representation of emotions for autistic children. This study included 2D image representations of 3D avatars, rather than 3D avatars as used in Parsons et al. (2005). In Cheng and Fan's study, ten participants ranging from 5 to 17 years old were selected; they all had a local (school) diagnosis of autism. The study was focused on considering the role of expressive avatars used in conjunction with text chat communication or computer-medicated communication (CMC). To investigate this aspect of CMC, the authors conducted an interview with the ten participants via the CMC program created for the purpose of the study. One of the primary aims was to judge how the participants with autism responded with text and expressive avatars throughout the communication process. In other words, they provided an interface that allowed users to talk one-to-one, through the medium of text and visual representations of faces. Each of these faces displayed a different emotion. They were modeled in 3D, then rendered and exported as 2D images. Cheng and Fan concluded that eight of the ten of participants were able to successfully use the system to identify emotion as represented by a graphic. Moreover, the participants were able to interpret the emotions of others through the system.

Another study that builds on the work carried out by Strickland et al. (1996) and Cromby et al. (1996), and adds to limited knowledge in the field, is that of Parsons et al. (2006), where newer and different technology is applied. The study of Parsons et al. (2006) involved the creation of a virtual environment (VE) for the purpose of improving social skills in two autistic children. This study included two children within the high-functioning range (i.e., without ID). However, Parsons et al. introduce a VE that involves navigating through simple scenes (a café and a bus stop), rather than presenting a one-to-one communication tool (building on the findings of Cobb et al. 2002). In other words, the users were able to navigate through an environment or space as part of the simulation. The scene includes other characters, who are passive, but are pre-programmed to respond to user input. In their analysis, Parsons et al. consider five areas for review and discussion: (1) repetition of response, (2) physical and literal interpretations, (3) treating the VE like a game, (4) putting learning into practice, and (5) recognizing changes and usefulness. Repetition of response was an area of the research that provided mixed results. Both users would navigate through the café scene in exactly the same way, individually, each time they approached the tasks, although one of the participants would maintain their route through the scene despite encounters with chairs, tables, and other objects.

Parsons et al. (2006) also report some repetitive statements/verbal responses, although the participants did change some responses in the VE, in particular choices of food ordered and when asking if they could sit down to eat their food. Furthermore, the participants sat in different places each time they used the environment, suggesting that they were "responding differently to the changing demands of the VE" (Parsons et al. 2006, p. 13). Literal interpretations were an issue for the participants: one of them could not understand why, for example, they could not sit in an empty chair when the person sitting at the table said, "Excuse me, that seat is taken." The participant thus highlighted a problem with accepting that a seat can belong to a person socially. However, after repeating this several times, and with some help from the facilitators, the participant was able to understand the need to ask if a seat is taken, out of courtesy.

One of the main difficulties in using VEs, and in particular for autistic users, is in creating the perception of reality, so that the user can identify and provide natural responses. It was noted by Parsons et al. that the participants viewed the VE as a game and would not therefore interact as they might in real life. However, it was observed that there were occasions when the participants would apply real-world and appropriate actions to the VE. A specific example relates to the choice of seats on a bus – the participant chose a seat that had enough legroom and one that was facing in the preferred direction. This perhaps shows how immersed the participant had become and that they did view the VE as a "real world." A similar finding, but with more participants, was reported in an earlier study by Parsons et al. (2005).

In sum and taken as a whole, the role and potential of VRTs and specifically VEs, for autistic users, has been shown to have some benefits and possible useful application for skills development, specifically testing social situations and visiting places. Both of these contexts can be designed in ways to reduce cognitive pressures and real-life consequences or indeed any other types of interactions. This, along with the predictable nature of using a computer simulation, can provide a suitable or preferred space for autistic groups. The next section will briefly discuss virtual worlds and how these have been used by and for autistic users.

Virtual Worlds

Boulos et al. (2007) considered the use of Second Life (a type of virtual world) in medical and health education. Their article helps to provide a clear indication of the potential of VWs in health-related conditions – in an educational context. The authors discuss and present two case studies of recent and successful VW endeavors, in Second Life (Healthinfo Island and VNEC – Virtual Neurological Education Centre), and are able to present a detailed insight into the advantages afforded by the platform. These include the use across a distance-learning education model and for older people and people with physical disabilities; real-time social networking and state-of-the-art graphical representations are also highlighted. Boulos et al., in addition, identify several challenges pertaining to the use of VWs. These include Internet addiction, gambling, violence, trust, identity, copyright, and vandalism. These all relate to ethical concerns and are something all VW studies need to address and consider for their user groups, more broadly.

Recently, Stendal and Balandin (2015) report on the use of Second Life and therefore VWs. Here they suggest that "people with ASD enjoy using a virtual world and may feel more comfortable communicating in the virtual world context than the physical world" (p. 1591). They also highlight several self-reported affordances of VWs including:

- Autistic people enjoy using a virtual world and can feel more comfortable communicating in the virtual world context than the physical world.
- Virtual worlds offer a venue for autistic people to be a part of a virtual society.
- Virtual worlds offer an arena for autistic people to meet their peers on equal terms, not being dependent on social cues, which in the physical world can be a barrier for this group (Stendal and Balandin 2015).

These are similar to findings reported by Newbutt (2013) who also found that autistic children reported preferences for using text chat to communicate with others (their peers and teachers), in a virtual world. The fact that text chat can be undertaken at the pace of the individual, and that extra thought can go into what they would like to say, helps, especially autistic individuals, in communicating with more confidence.

Virtual worlds (VWs) also offer potential for autistic users, and in fact one of the largest, Second Life, has many registered users who have such conditions (Salman 2006). However, to date few, if any, formal studies have been carried out to assess the impact such environments are having on users with autism, even though virtual worlds have contributed to this field of study and could provide a form of assistive technology.

In a brief correspondence, Fusar-Poli et al. (2008, p. 980) hypothesize that Second Life could be used to "develop social and communicative skills of autistic people." They go on to outline the same affordances as Cobb, Parsons, Moore, and Fabri, stating that ". . . it allows anonymous social interactions, and provides high levels of social interactivity but without complex linguistic and social-behavioral processing necessary for face-to-face conversations" (Fusar-Poli et al. 2008, p. 980). Further, Fusar-Poli et al. suggest that it "levels the playing field for autistic people," in that it offers a new space to rehearse social skills. This last statement, although a value statement, does suggest that people with autism and related conditions can enter VWs without any preconceptions or assumptions placed upon them. Fusar-Poli et al. also say that a secure and safe space is needed in which social mistakes can be made so that a sense of collaboration and community can be established. The authors propose Second Life as an ideal tool for allowing participants with autism to benefit from the affordances mentioned.

In a specific example of the use, potential, and application of VWs, a charity (Autus; https://www.autus.org.uk) has implemented the use of a VW to help connect and open employment opportunities for autistic groups in the UK. Here they have designed virtual job centers (in a virtual world) to help provide access for autistic groups who might find it difficult to access resources in real-world job centers. There are other such initiatives designed and implemented by the group, all building on the affordances of VWs for autistic groups. Figure 2 provides an example of how this looked, visually.

It is through the affordance of VWs that can provide a fruitful space for autistic users to develop confidence and test situations out. The use of text chat and body movements (and facial expressions) can all be used as/when to help open modes of communication in VWs. This has been seen to be a positive effect in the work of Autus (above) and the work of Newbutt (2013).

More recent developments have provided newer lines of inquiry (i.e., touch screen devices) and renewed lines of inquiry (i.e., VR and HMDs). The next two sections review work in the area of both touch screen devices and HMDs.

Touch Screen Devices

The arena of touch screen devices applied to autistic groups is something first investigated since the introduction of affordable and freely available touch screen technologies, namely, the iPad. Since then many studies have sought to investigate the possibility of how iPads (and other touch screen devices) can be used to develop communication, social, and initiation skills. For example, and recently, Xin and Leonard (2015) investigated the role of an iPad in developing communication skills in "three 10 years old learners diagnosed with autism who present little or no functional speech" (p. 4154). As a result of using an iPad, the authors concluded that all students increased initiating requests, responding to questions and making social comments in both class and recess settings. This provides some positive and helpful insights to the way that iPads and touch screen technology can be used to help aid communication endeavors of autistic users.

Assisting People with Autism Spectrum Disorder Through Technology, Fig. 2 Example of interface developed by Autus for an employment project. Using a VW to help provide access to employment services, removing the need to visit a real-world job center (in the UK)

However, and as with many of the studies already reviewed, the sample was very small and so generalizing across populations is impossible; therefore, the study is mainly contextualized within the details of the specific project.

In earlier work, Alzrayer et al. (2014) surveyed all previous (previous to 2014) studies conducted with autistic users related to touch screen devices. They found that "tablet-based devices, especially iOS devices (i.e., iPad and iPod Touch) were highly effective in increasing the communication skills of individuals with autism" (p. 179). In addition to positive reported outcomes for communication, the authors found that touch screen devices "also have positive effects on decreasing challenging behaviors" (p. 189). This started to provide some insights that suggest touch screen devices not only have educational outcomes for autistic users but that they could also be used and implemented as a way to help calm users. However much more work is needed to validate both these suggestions.

In more recent work, Fletcher-Watson et al. (2016) undertook a randomized control trial of an iPad App to "evaluated a technology-based early intervention for social communication skills in pre-schoolers" (p. 771). The authors developed an app with the aim to develop specific outcomes for communication domains (reciprocation, social, words, etc.). Most interestingly, this study found that the "intervention did not have an observable impact on real-world social communication skills" and they suggested that "caution is recommended about the potential usefulness of iPad™ apps for amelioration of difficulties in interaction" (p. 781).

Therefore, it is evident that the possible potential of touch screen devices is mixed and evidence is contradictory. The work of Fletch-Watson and colleagues included a large sample, larger than work carried out previously. However, it should be underlined that this was only the case for the app that the authors used in their study – it does not mean all apps would yield the same results.

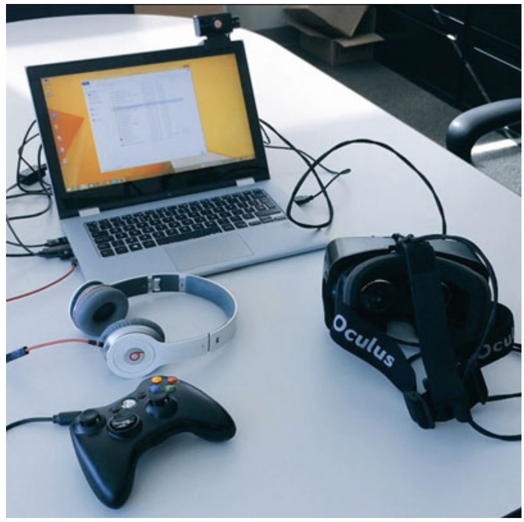
Despite the range of evidence associated with touch screen devices, there should remain positive attitudes toward their use for autistic groups. At a very fundamental level, touch screen devices provide ways for nonverbal users to effectively communicate with caregivers and other people they need to communicate with.

Virtual Reality Head-Mounted Displays (VR-HMDs)

This technology has recently (2016–2018) become relevant and of interest – again – as it was first used in 1996 by Strickland and colleagues. They used the technology as a tool for teaching road safety and also to assess whether autistic children would be willing to wear a large HMD. However, the work of Strickland et al. (1996) was based in a lab and involved only two children, who were both encouraged to use the technology. As there have been a range of HMDs since the introduction of the Oculus Rift™ and increase in content (i.e., software) via the Steam network (https://store.steampowered.com/), there was a sudden and interesting need to investigate the potential of this technology for autistic groups. This was especially timely as there were many reports (without evidence or data) suggesting that VR and HMDs were a good fit for autistic users. However, with so few studies, it was difficult to assess the potential of HMDs without first asking autistic users about their willingness to wear and experience VR, especially based on concerns around sensitivity concerns (i.e., wearing a headset) and possible side/negative effects of HMDs (e.g., sickness, eyestrain).

As previously mentioned, the acceptance of VR technology among users with ASD has been studied over the last decade. Although some studies have established a safe way/process for the use of VR technology among autism populations, the technology itself has evolved and advanced in many ways since earlier work of Strickland and colleagues. For instance, VR technology and the head-mounted display used to be only an extension of the traditional monitors, which merely increase the viewing size and the viewable angle. The users of these VR devices acted as a passive role and did not have control over what was presented to them. Much has changed in the VR arena. The interaction components have since been introduced and integrated in the VR applications. For example, users can now use a joystick to browse and maneuver in the virtual space. In addition, more current head-mounted display can also capture and respond to users' head movement to simulate a real-world 3D experience.

In addressing the need for a timely examination of HMDs (the newer generation), Newbutt et al. (2016) asked questions in a study related to acceptance of HMDs for autistic groups (a range in terms of age and the spectrum; remembering this relates to associated learning difficulties – or not). The findings from this work provided insights of how an autistic group felt about wearing a HMD and experience a range of VR experiences and how they reported sense of presence, immersion, and negative effects. Results, using an Oculus Rift HMD, highlighted a general level of acceptance (100% willing to try the HMD on and experience two VR scenarios) and high levels of self-reported presence and immersion. Most vitally, negative effects (i.e., feeling sick, eye-strain, etc.) were reported as being very low. These results were reported across an age range of 17–53. The equipment used was portable and taken into a workplace setting. The equipment used can be seen in Fig. 3, while Fig. 4 shows more recent technology (HTC Vive) being used in a school (in 2018).



Assisting People with Autism Spectrum Disorder Through Technology, Fig. 3 Example of VR-HMD kit used in Newbutt et al. (2016) study, highlighting the size, portability, and unobstructive nature of HMDs in 2016. This equipment was tested in a center for autistic groups in the USA

Assisting People with Autism Spectrum Disorder Through Technology, Fig. 4 Example of an HTC Vive kit being used with an autistic individual in school, again highlighting the possible inclusion in school-based settings. This was trialed in UK schools

Currently (as of 2018), there is a plethora of head-mounted displays available for the general public to purchase and use in their daily life. Depending on the purpose and the affordable budget, one can select inexpensive VR goggle such as the Google Cardboard, which costs approximately 20 dollars a pair. The design of Google Cardboard is to insert a smartphone into a pair of goggles made of cardboard with two lenses to simulate the 3D immersive effect. Because of its low-cost design, there is no audio or interactive component built in for the device. Users merely use it to simulate a visual 3D effect. The more sophisticated options are also available such as Samsung Gear VR, HTC Vive, and Oculus Rift (ranging from $400 to $800 without associated gaming computer, currently about $1300). These VR devices capture the user's head movement and can be used to play video games.

Despite the potential of VR and HMDs, there are only six studies that comprehensively report of the use and/or potential of HMDs for autistic groups. These are reviewed by Bradley and Newbutt (2018) and cover work reported in the following studies:

1. Adjorlu et al. (2017)
2. Bozgeyikli et al. (2017)
3. Cheng et al. (2015)
4. Mundy et al. (2016)
5. Newbutt et al. (2016)
6. Strickland et al. (1996)

The work covered in these studies includes acceptance, willingness to wear HMDs, and the potential for learning and transferring learning using HMDs, mostly reporting positive findings in this area. However, there are several gaps and opportunities that arise from reviewing this work.

Though several studies had an element of participatory research methodologies, only two explicitly sought feedback from practitioners about the intervention (see Adjorlu et al. 2017; Bozgeyikli et al. 2017). This type of information is valuable and would enable more robust recommendations to be made on the sustainability of educational interventions and approaches using - VR-HMD technologies within educational, health, or community settings. Furthermore, the inclusion of autistic individuals in the research was predominantly in the role of passive participants whose experiences of the interventions were primarily gained through quantitative data. It can be argued that the lack of qualitative data, i.e., interviews with participants, limits our understanding of how they perceive VR technology and the use of HMD. It is therefore important to evaluate both outcomes and the process of implementation of VR technology through the involvement and experience of autistic individuals and the practitioners who work with them.

The variance in both technologies used (including how realistic the VEs are, type of HMD, and how tasks were carried out) and the diagnostic features of the autistic participants supported the finding that “the state-of-the-art in the literature is that there is no single study, or series of studies, that has systematically unpicked and interrogated the ways in which these features may combine to influence responding and understanding” (Parsons 2016, p. 153). As with other research in this field, there has been a focus on autistic children, young people, and adults who have average or above average IQs and at therefore autistic without intellectual difficulties, which means the findings of these studies may not be applicable to a wider range of autistic individuals. The heterogeneity of response to VR-HMD applications and experiences indicates a need for further research that should take account of both the characteristics of this population and the specific features, characteristics, and affordances of this technology, to consider how these features might best support and motivate them. The issue of veridicality is of importance in this context, and the results from the six studies were mixed. Promising results were reported by Newbutt et al. (2016), with participants showing high levels of engagement, spatial presence, and ecological validity within VEs. In contrast, participants gave a more nuanced response in the study by Bozgeyikli et al. (2017) and indicated that while they were immersed in the VR activity, they were aware it was not real. As such, more work is needed on how VR-HMD technologies can be designed and developed to act as an authentic real-world experience for this population.

Conclusion

The increase of multimedia computing within the area of educational support for children with autism has been the focus of much research, from the early works of Colby (1973) and Heimann et al. (1995) to the work of Silver and Oakes (2001). These published works examined specific skills that multimedia could address in the educational development of children with autism. Through such studies, an argument has been constructed, for the use of virtual environments in providing a unique affordance for users with ASCs. Scholars such as Strickland et al. (1996), Parsons et al. (2005, 2006), Wallace et al. (2010), and Cheng et al. (2010) have each explored the role of immersion, realism, engagement, and learning within virtual environments. Building on this, Kandalaft et al. (2013) have provided a specific example of the role virtual worlds can play in social cognition training. Yet, there remains a limited understanding in the literature of users' perspectives with a range of technologies.

Overall, the area of technology used by autistic people, and the potential benefits they hold, is still at an early stage in terms of research. While this field was developed and initiated in the 1970s, there has been slow progress with limited evidence related to:

- What types of technology are most suitable for autistic people?
- How and when should technology be used?
- For what age groups and levels of associated learning difficulties should specific and particular technology be used?
- Where is technology best deployed and utilized for autistic groups?

So far these questions remain underexplored in research studies, and so evidence supporting these is difficult to locate. Moreover, if technology is to have real potential for autistic groups, there is an urgent need to address the what, why, where, and how questions if there is to be more upscaling and utilization of technology for autistic people. Addressing these questions will also help to enable key stakeholders to place technology in the hand of the people it can most benefit. At the moment this is not happening.

In addition, and as highlighted above, no studies have applied a longitudinal or mixed-methods approach to this area, something that would yield a far better picture in terms of the longer-term outcomes, frameworks for continued application of technology (updates, development, versions), and refined software/hardware that might be most suitable and applicable in a variety of contexts (school, home, centers, etc.).

The future for technology used by, with, and for autistic people remains positive, especially based on nearly 40 years of evidence using a range of technologies. By working more closely with autistic advocates, groups, and individuals, the field will be better placed to design, develop, and deploy technology that is suitable, usable, and effective in the future.

Cross-References

- ▶ Assistive Technology and Inclusion, Philosophical Foundation
- ▶ Game-based Learning

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Assisting People with Physical Disabilities Through Technology

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Synonyms

Accessibility; Assistive technology; Augmentative and alternative communication; Physical access

Introduction

The term physical disabilities often refers to a broad range of disabilities of people facing difficulties in limitation on physical functioning, mobility, dexterity, or stamina. These may include orthopedic and neuromuscular disabilities (such as cerebral palsy, spina bifida, muscular dystrophy, rheumatoid arthritis, spinal cord injuries, traumatic brain injury, multiple sclerosis, ALS, and other orthopedic difficulties inherent or acquired), as well as sensory disabilities (e.g., visual or hearing impairment), and chronic health issues, cardiovascular or respiratory difficulties. Furthermore, the complexity of a number of diagnoses of physical disabilities often involve identification of difficulties in various aspects and interrelated sectors of the human activity and quality of life. Hence, as Heward (2011) identifies, people with physical disabilities compose an extremely complex and heterogeneous population which is impossible to describe in a single set of characteristics and terms. Similarly the use of technology for addressing the needs of people with physical disabilities lies in a huge spectrum covering all aspects of everyday life such as sitting and positioning, mobility, transportation, physical accessibility, access to digital technology, communication, and learning and cognition, as well as medical devices for care and health conditions (e.g., assistive products for respiration, for dialysis therapies, etc.). For example, the ISO 2016 assistive technology classification holds an enormous list of assistive technology items that can be used for the needs of people with physical disabilities in all areas of life, including health, care and well-being, workplace, education, everyday life activities, and more (ISO 9999:2016 Assistive products for persons with disability – Classification and terminology, available at https://www.iso.org/standard/60547.html (accessed 20 February 2018)).

In order to maintain focus, as well as coherence with the structure and content of this volume, this present entry will mostly concentrate on particular aspects of the use of technology for people with physical disabilities (not including sensory disabilities as these are covered elsewhere in the volume), involving physical access to digital technology and connections to communication and learning. Specifically, the aim of this entry is to present examples of assistive technology products for the various needs of people with physical disabilities but also to identify and discuss methodologies and models of assistive technology assessment, issues of implementation, and barriers and opportunities. Previous research studies through the years (e.g., Judge 2000; Copley and Ziviani 2004; Mavrou 2011a; Layton 2012; Mavrou et al. 2017) suggest that as the number of people using assistive technology increases, the following areas are highlighted as particularly significant: accessing assistive technology, matching needs of person to technology, funding for assistive devices and service provision, and training of professionals and family members. In the present entry, this discussion is further supported by an example of a research case study.

Technologies for Physical Disabilities: Examples for Access, Communication, and Learning

Historically the various definitions of assistive technology placed assistive devices in the framework of functionality and accessibility often leading to connections with physical disabilities and mostly physical access and mobility. Gradually these definitions developed through the social and human rights approaches to disability, indicating the role of assistive technology in reducing environmental barriers (Scherer 2005) and in promoting equality, quality of life, and participation (see definitions of the WHO 2017 and ISO 2016). Nevertheless, as mentioned earlier, assistive technology for physical disabilities is primarily connected to physical access and includes a range of low-tech or simple devices (e.g., walkers or pencil grips) to high-tech ones (e.g., power wheelchairs or digital communication systems) (Huang et al. 2009). In 2014 the World Health Organization launched the Global Cooperation on Assistive Technology (GATE) initiative which aims to actions that will promote access to “high-quality, affordable assistive products to lead a healthy, productive, and dignified life” for every person in need of assistive technology, targeting especially the low-resourced areas of the world (Global Cooperation on Assistive Technology (GATE) of the WHO, available at http://www.who.int/phi/implementation/assistive_technology/phi_gate/en/ (accessed 20 February 2018)). Among other activities in the framework of this initiative, a Priority Assistive Products List (APL) was developed (WHO 2016), after a scoping review and a high range Delphi exercise. The list, which of course is not restricted, includes 50 priority assistive products and aims to provide the UN member states with a model from which to develop a national priority assistive products list according to national need and available resources. The majority of the products included in the list concern physical access and are very relevant to the needs of people with physical disabilities but at the same time beneficial for other groups of people facing different challenges. Nevertheless, the composition of the list indicates the significance of low- and high-tech assistive products for physical access and their relevance to the range of people that these are essential for.

Hence, in this section of the entry, an overview of the main assistive technology products is presented, identified as essential for physical disabilities (and not only) in the digital era. This overview includes discussion of digital technology access devices and augmentative and alternative communication for physical disabilities.

Access to Digital Technology

The growth of computer and digital technology led to the emergence of the field of human-computer interaction (HCI) and the researchers’ and developers’ considerations on the communication and interaction between humans (people as users) and the artifact (computers and technology). Researchers in the field of HCI study the ways in which humans interact with technology and how technology is designed to facilitate a meaningful and innovative interaction addressing the needs of each individual. Hence, the components of this interaction and the impact on the design of technology interface and the assessment of individual user needs have become a major part in assistive technology (Zaphiris and Siang Ang 2009). In simple computer science terms, the exchange/interaction between people and computers entails three basic aspects – input, process, and output – commonly translated into hardware and software applications. Nevertheless, Cook et al. (2008) argue that “the human/technology interface is more than hardware and inputs into the device.” Rather it entails other elements, which especially in terms of physical access, include not only hardware for input but also elements of interaction in processing and exchanging information. As Veigl et al. (2017) suggest, nonstandard human computer interfaces are required for people with complex physical and severe motor disabilities, especially when these are a combination of difficulties that challenge the selection of a single access assistive technology tool. Hence, according to the (Cook et al. 2008) model (i.e., HAAT presented later in this entry), in assistive technology for physical access elements of control interface, selection set and selection method are considered, which are examined together with the desirable output (and outcome) as well as the advances of technology.

Control interface refers to the hardware used to operate or control a device, which for people with physical disabilities often includes alternative input devices. Examples of alternative input devices are *pointing* devices, such as ergonomic mice, trackballs, joysticks, head controls, or even keyboard keys and eye-gaze technology with mouse emulation software; *keyboards*, such as one-handed keyboards, large keys keyboards, customized overlay, and programmable keyboards; *touch screens and touch surfaces*, such as external touch screens, touchpads, and touch-operated mobile devices; *switches*, which are selection and input command devices that may be operated with different body parts and control movements; *voice recognition technology*, by which the user can control the device with voice commands; *eye-control technology*, with or without mouse emulation; and even *brain control (EEG)*, which seems to create new possibilities for HCI and mostly for people with physical disabilities.

Upon decision on control interfaces, in choosing assistive technology for people with physical disabilities, selection sets and selection methods need to be considered. According to Lee and Thomas (1990) and Cook et al. (2008), selection set is the items available from which choices are made, which can be presented in visual, auditory, or tactile modalities. In other words, selection sets may be letters (e.g., in the case of a keyboard as a control interface), braille (as tactile), auditory scanning output (e.g., in the case of a switch as a control interface), and symbols (e.g., in the case of an augmentative and alternative communication system). As far as the selection method is concerned, this is defined as the basic method by which the user makes a selection that can be either direct or indirect. Direct selection (or direct access) is when the person identifies the target and goes directly to it by using voice, hand, finger, eye, or other body movement with appropriate control interface. Examples of direct selection for people with physical disabilities include the use of eye-control access systems, touch screens, pointing devices, voice recognition, etc. Indirect selection refers to selection methods where intermediate steps are involved (Cook et al. 2008). This is mostly relevant to the use of switches and scanning, where the possible targets are sequentially (in various modes) highlighted (by a visual or auditory signal or a combination) allowing the user to press a switch when the desired target is scanned. Scanning can be autonomous by the device, where speed, timing, mode, and other features can be customized or directed, where it is activated and controlled by the user through a control interface (same or other than the selection control interface) (Angelo 2000).

As the individual needs of each person with physical disabilities vary and are often complex, access devices (and control interfaces) require configuration in a number of aspects. For example, in pointing devices, adjustments include mouse control parameters such as click method, double click speed, dwell selection, pointer movement speed and sensitivity, pointer precision, size of target, pointer size, and target size (Lopresti et al. 2008). In addition, adjustment may involve other physical characteristics of the control interface such as size (e.g., of trackball) and the grip of the device (e.g., of a joystick) or issues of functionality in control and configuration through connected software (e.g., see Oppenheim 2016). Along the same lines with pointing devices, configurations are necessary for the effective use of any other control interface, and they concern size and space, activation and selection methods, effort, flexibility, and sensory and cognitive characteristics, as well as sitting, position, and coordination of the person in relation to position and mounting of the devices. For some control interfaces such as the eye-gaze technology, configurations can be complex and may require long-term piloting, training, and adaptations (Borgestig et al. 2016).

In a great number of cases of persons with physical disabilities, assistive technology for access is significant in determining technology for supporting other aspects of life, mainly communication. Hence, technology concerning augmentative and alternative communication (AAC) for persons with physical disabilities and complex communication needs is discussed in the following section.

Augmentative and Alternative Communication for People with Physical Disabilities

Augmentative and alternative communication (AAC) refers to a variety of techniques and tools, including no-tech (e.g., pictures and paper-based boards, signs, and gestures), low-tech (e.g., communication switches), and high-tech (e.g., digital devices) to help individuals with limited, not functional, or absent verbal communication/speech (ASHA 2018).

There are a great number of AAC techniques and devices that are available to individuals with complex communication needs, and most of them can be applicable for people with physical disabilities. Nevertheless, in physical disabilities, access, as discussed in the previous section, is a major parameter in the design and development of AAC interventions, as well as for the selection of relevant technology. Often AAC systems are categorized as follows:

(a) *No-tech AAC systems*, which include gestures, facial expressions, body movements, formal gestural codes, or manual sign systems (such as official sign languages). For physical disabilities, such systems can be applicable in cases where individual's physical condition allows for signing, gestures, and movement of any body part. In severe physical disabilities, the use of eye gaze for pointing (looking) at what is desired or responding to yes/no questions is very common and often effective for basic needs.

(b) *Low-tech AAC systems*, which are usually divided in nonelectronic and electronic systems. *Nonelectronic systems* include cost-effective techniques that are easy to make or obtain, and they may be *letter/words/phrases or graphic symbol displays* organized either in sets of *individual cards, boards, mats, or grids or communication books*. These may also include formal communication systems such as PECS (Picture Exchange Communication System) (Bondy and Frost 2001). In most of these systems, communication is achieved by gaining attention of the communication partner with disabilities, who expresses him/herself by giving (e.g., a card), pointing at or looking at a symbol/sentence/word. In cases of severe physical disabilities, choice can be performed by eye gaze through *visual displays such as eye-com/e-tran frame boards* which include limited number of items on transparent boards facilitating the observation of the user's eye movement toward selection by the communication partner. *Electronic systems* are devices that permit the storage and retrieval of messages, many of which allow the use of speech output, and they operate with batteries. They are also referred to as mid-tech AAC systems. These may be *communication switches of a single, dual, or sequential recorded messages, devices of multiple recorded messages, and talking albums (photo albums with recording function)*. These devices differ in size, shape, number of visual items (e.g., pictures or symbols or even objects), and recordings they can hold, as well as in fixed or changeable display. Fixed displays hold the same number of items and recordings, while in changeable displays overlays, and sometimes number of items/options and recordings, can change. Similar to nonelectronic systems, the use of electronic systems by people with physical disabilities depends on features of access. A great number of electronic systems are designed in a way that allows alternative access for physical disabilities, such as switches (with or without scanning mode), clearly separated and large cells, buttons, or ports for external access devices.

(c) *High-tech AAC systems* are also electronic devices, which are based on computer and digital technology. They can be either dedicated devices (i.e., used only for communication) or non-dedicated which are computer-based (e.g., laptop computer, iPad, tablets), which are adapted for communication use, and which are used for other functions as well. High-tech AAC systems permit the storage and retrieval of messages and allow the use of speech output. They are often called speech-generating devices (SGDs) or voice output communication aids (VOCAs). With the advances of mainstream technology and the evolvement of mobile technology, non-dedicated AAC devices are becoming more and more popular. For people with physical disabilities, the use of high-tech AAC is closely related to features of human technology interface and interaction (HCI) and more specifically control interfaces. In the past there has been a long debate between dedicated versus non-dedicated devices and their flexibility according to the needs of individual potential users, with non-dedicated devices gaining more attention. Nevertheless, nowadays dedicated AAC devices mostly run on a Windows® platform, and therefore they are becoming more flexible, than in previous years, in terms of adaptations for alternative access (e.g., eye gaze, switch, head control) for people with physical disabilities, as well as convenient for people with less complex physical disabilities due to embedded accessibility. On the other hand, new tablet-style mobile technologies hold other advantages such as availability as mainstream technology, cost, and weight, but they are in many cases challenging for people with physical disabilities in terms of physical access options for adaptations (Abbott and McBride 2014) and external accessibility. Nevertheless, the use of mainstream non-dedicated (tablet-based or other) devices for AAC largely depends on the availability and flexibility of apps or software, respectively, for communication. For physical disabilities, it is important that such apps and software also allow for the use of alternative access such as switch or eye gaze; hence this is not only a hardware issue.

A great amount of literature provides evidence on the potential of AAC for people with complex communication skills (Smith 2015; Calculator 2009; Lilienfeld and Alant 2005; Clarke and Kirton 2003), including people with physical disabilities (for instance, cerebral palsy, traumatic brain injury, neurodegenerative disabilities). On other hand, Light and Macnaughton (2014) argue that “despite the strong evidence of the benefits of AAC intervention, the potential of AAC remains unrealized for many individuals with complex communication needs” (p. 99). Individuals with physical disabilities and complex communication needs are often included in the number of people that do not benefit to the expected extent from the potentials of AAC, due to various factors relevant to personal characteristics (Smith 2015), training and digital literacy (Mavrou et al. 2017), professional support and follow-up (Mavrou 2011a), opportunities for participation, user’s own evaluation of technology function, and others (Huang et al. 2009). Hence, in following paragraphs the main characteristics and elements for successful AAC use for people with physical disabilities are discussed.

Feature matching between technology and the human/user needs, context, and activities is vital for the success of AAC in physical disabilities (and not only). To this end, input, processing, output, and other properties of technology need to be taken into consideration. Input relates to HCI and more specifically to control interface. Consequently, the use of AAC devices by users with physical disabilities requires physical skill development, whichever the selection method may be (Cook et al. 2008; Kay 2014). For physical disabilities physical skill development should specifically take into consideration not only functionality and motor constrains (Costigan and Newell 2009) but also safety and performance of the user, in order to experience success in communication efforts for developing AAC users’ self-esteem (Smith 2015). One of the key elements is reduction of physical effort, and this is why one of the breakthrough technologies currently widely used of access and communication for people with severe physical disabilities is eye-gaze technology (Borgestig et al. 2016; Light and Macnaughton 2014).

Processing is related mostly with communication competence development, not exclusively relevant to physical disabilities, but to all possible users of AAC. It is not connected solely to physical skills but also to selection sets, vocabulary, and language organization and development. Hence, issues of message/vocabulary retrieval, symbol set selection, messages coding (e.g., color or number coding), and location on device overlay are important. In addition, successful communication competence development also relates to communication partners' role and programs for language development (Smith 2015). Nevertheless, for physical disabilities, an individual may be a good communicator but a poor technology interface controller or vice versa. In such cases, the challenge is to design AAC user training programs that will address the user's profile for both access and communication (Costigan and Newell 2009).

AAC system output is also one of the features that should match user's need, activities, and context. Output issues involve visual, auditory, and maybe tactile modes of the message to be communicated, as well as issues of compatibility and interfacing with other assistive technology (e.g., power wheelchairs). Hence, in physical disabilities, decision on the output feature of an AAC system lies upon the sensory needs and abilities of the person; the context, environment, and activities she/he is involved; as well as the possibility of using other assistive technology. The latter leads to the last feature discussed here, referring to other properties relevant to physical disabilities such as portability, positioning and mounting of the device, customization, as well as training, support, and follow-up.

Bearing in mind the aforementioned, assessment and skills development for physical disabilities play an important role in effective implementation of assistive technology for access and communication. In the following section, the main assessment and support in assistive technology models and methodologies are discussed.

Methodologies in Assessment and Implementation of Assistive Technology for People with Physical Disabilities

Assistive technology assessment is a dynamic process which is conducted utilizing a variety of methodologies usually not specific to one area of AT, the outcomes of which consist the guidelines for AT implementation and plan for monitoring and measuring the effectiveness of this implementation. A number of AT assessment models are described in literature. The various models differ in certain ways, but at the same time they share the main characteristics of the fundamental assessment process (CSUN Center on Disabilities 2006). This includes identification of needs (after the person's referral), identification of desired outcomes, assessment of skills and the trial of technology, revisit of outcomes, and repetition of the process in case they are not met or acquisition and implementation of AT in case desired outcomes are met, together with a follow-up and follow-along plan. Though, no model is specific to physical disabilities, some of the most widespread AT assessment frameworks are presented here, which are largely oriented on tasks and activities linked to (among others) physical activity. Nevertheless, it is noted that AT assessment and disability assessment in general have been discussed and criticized under the various perspectives and models of disabilities (Edyburn 2001; Hersh 2010; Kay 2014). This discussion is out of the purposes of the present entry, but it is acknowledged here that application of any assessment and AT implementation process should respect the social and human rights models of disability.

Human Activity Assistive Technology (HAAT) Framework

This framework is proposed by (Cook et al. 2008) "for understanding the place of assistive technology in the lives of person with disabilities, guiding both clinical applications and research investigations" (p. 36). HAAT was developed to analyze the complexities of a person with a disability, performing an activity within a context, especially when the use of assistive technology is part of that context, and thus it has four components: the human (including physical, cognitive, and emotional elements), the activity (including self-care, productivity in all aspects, and leisure – taking into consideration the ICF model), the assistive technology, and the context (physical, social, cultural, institutional) in which the first three are integrated (Cook et al. 2008). According to Hersh (2010), in HAAT model, context is at the top with a hierarchical structure of the components, as context is considered a determining factor in whether the person (human) successfully uses AT to carry out an activity within it. Angelo (2000) argues that HAAT is widely used for emphasizing the importance of access methods, and thus it is very relevant for physical disabilities in relation to AT assessment and the identification of appropriate control interfaces and other access elements.

Students, Environments, Tasks, and Tools (SETT) Framework

The SETT framework was introduced by Joy Zabala and "is based on the premise that in order to develop an appropriate system of Tools [. . .] teams must first develop a shared understanding of the student, the customary environments in which the student spends time, and the tasks that are required for the student to be able to do in order to be an active participant in the teaching/learning process" (Zabala 2005, p. 1) (Joy Zabala, Sharing the SETT Framework, available at http://www.joyzabala.com/). The framework sets a series of questions in each of the four areas (students, environments, tasks, and tools) in order to facilitate communication and decision making, in systematic way (Edyburn 2001), and it focuses on the need for collaboration and communication among the members of multidisciplinary assessment teams. The SETT framework is not specific to physical disabilities, but it is broadly used for determining assistive technology tools for the needs of children with physical disabilities as it provides a very clear structure for identifying functional and other needs of the student, as well as determining the specific tasks (Watts et al. 2004). Specificity of task is very important for choosing and using assistive technology (tools) for physical disabilities, as identifying (interface) control devices and selection sets and methods can differ for each individual with similar characteristics and tasks, which may be slightly diversified.

Matching Person and Technology (MPT) Framework

Matching person and technology (MPT) is a framework introduced by Marcia Scherer (1998), which focuses on three primary areas: (a) determination of the environment factors influencing use; (b) identification of consumer personal and psychosocial characteristics, needs, and preferences; and (c) description of the functions and features of the most desirable and appropriate technology (for more details, see Scherer 2004, 2005). The assessment protocols suggested by MPT were developed by collaborative and participatory research approaches, and they take a personal, collaborative (user and provider working together) approach to assessing the potential technology need. Hence, components are assessed in terms of their positive or negative influence on the technology use (Scherer et al. 2005; Scherer and Craddock 2002), in order to avoid technology determinism, i.e., considering the perfect technology (artifact) while disregarding personal and environmental characteristics, resulting in misuse or even abandonment of technology (Seymour 2005). Though, similar to the above models, MPT is not specific to physical disabilities, there is an amount of research on its implementation and further development, which is based on work with people with physical disabilities (see Scherer and Cushman 2000, 2001) often with complex access and communication needs (Borgestig et al. 2016; Smith and Connolly 2008; Kintsch and DePaula 2002).

Comprehensive Assistive Technology (CAT) Model

Responding to the need for a more comprehensive approach to assistive technology assessment and consideration, the CAT model, introduced by Hersh and Johnson (2008a, b), gives a more inclusive perspective by defining all components of the *person* (social, attitudes, and characteristics), *the context* (social and cultural, national, local settings), *the technology* (activity specification, design issues, system technology issues, and end-user issues), and the *activities* (mobility, communication, cognitive, daily living, education and employment, recreation). CAT is closer to the approach of the HAAT model, as it holds a similar hierarchical structure of the human assistive technology system with the four main components at the top level of person or human, context, assistive technology, and activity (Hersh 2010). Again not specific to physical disabilities, CAT provides assistive technology and disability professionals the opportunity to consider examination of physical access for individuals with physical disabilities, from additional angles than the ones discussed above. Hence, complex physical needs and access are examined from the prism of not only the activity setting but also the social and cultural context. In addition, CAT draws the users' and the professionals' attention toward the use of new (mainstream) technologies and their embedded accessibility characteristics. It also extends the connection of (assistive) technology assessment in education beyond the physical educational environment adaptations to the pedagogy of diversity and disability for inclusive education.

The development of various different models of AT assessment (not limited to the above) highlights the multifaceted nature of the use of assistive technology (Edyburn 2001), which is even more prevalent in the case of persons with physical disabilities and more specifically when complex communication needs are present. In a certain extent, all models share similar foundation for exploring the person's needs and abilities, the environment, and the activities for which technology is required, and they also share the same ultimate goal: to identify the best technologies that will match the person's needs for improving the quality of life in all aspects. Similarities and differences of the models indicate the need for effective assistive technology assessment that will lead to the choice of technology that builds on the strengths of the person in their various environments and responds to challenges by increasing opportunities. Hence, current literature calls for the need of a holistic assessment that at the same time can lead professionals involved to considerations beyond the sensorimotor and cognitive aspects of the access assessment toward language function and interaction (Kay 2014), as well as toward pedagogy and inclusion (Hersh 2010). Thus, collaboration, teamwork, and sharing of knowledge and experience in multi-disciplinary teams (Copley and Ziviani 2005, 2007; Borgestig et al. 2013) are vital. This collaboration allows users', rehabilitation professionals', educators', and family's teams to get involved in dialogues (Watts et al. 2004) toward user-centered informed decisions in order to match the choice of both the model and the technology to the person's needs in all sectors of life and activity.

In the following section an example of a research case study of a person with physical disabilities and complex communication needs is briefly presented, demonstrating the implementation of the previously discussed technology features and models.

Example of a Research Case Study

This case study is part of a broader longitudinal qualitative research that involved several cases of persons with physical disabilities who use assistive technology (Mavrou 2011a). The present example describes the case study of a young man with cerebral palsy, during which data was collected through participatory observation, interviews, and document analysis in order to map assistive technology provisions and services in Cyprus and in attempt to understand, improve, and reform practice in relation to AT interventions. The participant is diagnosed with cerebral palsy (spastic quadriplegia), with no verbal communication and with no additional sensory or intellectual disabilities. Due to his physical disabilities and profound difficulties in verbal communication, he attended a special education unit in the mainstream school, in both primary and secondary education, until adolescence educators and professionals had difficulty to define his intellectual and cognitive abilities. His communication was restricted to yes/no questions, to which he was responding with eyes and head movement.

The first assessment for assistive technology provision was conducted in lower secondary education. Following the basic principles of the SETT model (Zabala 2005), the first assessment identified the physical access to a digital communication device as the student's main functional area of concern, taking into consideration his age and interests; the need to move around in school environment with the aid of support staff (no electric wheelchair); and communication and participation in specific school curriculum subjects as the main tasks required for active involvement. Given the resources available at the time (in the public sector), a laptop computer with switch-accessible software (Clicker5) and a large-size switch with wireless adaptor were suggested as the main technology tools (Mavrou 2016).

Nevertheless, as the participant's communicative needs and abilities increased, the equipment proved ineffective. The use of the switch and scanning demanded increased physical effort by the user and entailed the risk of AT abandonment (Seymour 2005). Hence in 2 years' time, the AT specialist requested a reassessment, which was now conducted with mixed-models approach. These involved the basic principles of HAAT (Cook et al. 2008), especially for identifying the best approach to human device interaction, regarding physical accessibility, the pedagogical aspect of CAT (Hersh and Johnson 2008a, b) in order to match the needs of the participant in terms of inclusive education, and the MPT (Scherer 2005), to best determine environmental and other factors/barriers that affected the use of technology in various settings. Thus, a new long-term assessment process followed, which involved close collaboration and teamwork among the user, family members, the physiotherapist, the school technology teacher, and the assistive technology specialist. The ultimate goal identified was the use of high-tech AAC for the participant's independent communication and learning experiences, with a technology that would reduce the physical effort load needed. Thus, in terms of *control interface*, the eye control (eye-gaze technology) was identified as the most appropriate for physical access, which is one of the reasons that long-term piloting, training, and adaptations were necessary (Borgestig et al. 2016). Eye control was considered to provide independence to the user for controlling his communication device, with direct selection as *selection method.* In addition, a grid-based augmentative and alternative communication software (The Grid 2) supported with Widgit symbols (localized in Greek) was chosen as a suitable *selection set*. Along with the matching of technology with the participant's needs and competencies, other configurations were made including sitting and position, mounting of the AAC device, and continuous adaptations of the selection set.

Following a collaborative consultation intervention model (Borgestig et al. 2013), the participant was able to develop excellent digital skills in very short time and to be become a very effective eye-gaze user of his AAC device for both communication and access to digital technology (Mavrou 2016). In addition, in terms of selection set, he further moved from the use of symbol supported short phrases for AAC to independent symbolized phrases and words and then to gaining literacy and word prediction. Hence, the design of a customized language development program resulted in successful communication competence development (Smith 2015). In a short amount of time, the communication environment for this participant extended to the online environment and to the use of the Internet, email, Skype, and much more (Mavrou 2011b), leading to the integration of AAC out of a narrow set of contexts (Smith and Connolly 2008).

Though this case study resulted to a story of success, the whole process and intervention was long term, with a number of barriers in course and a number of difficulties that both the participant and the support team needed to overcome. These involved continuous access to technology during assessment and trials, funding, and resources that were not available on time, training of professionals and family members, as well as follow-up guidance and support (Mavrou 2011a).

Conclusion

The potentials of the rapid technological advances and the impact of assistive technology in the lives of people with disabilities are highly acknowledged and discussed in the relevant literature through the years (Abbott 2007; Hersh 2010; Borgestig et al. 2013; Mavrou et al. 2017). Research provides evidence for the role of technology, as well as the barriers and opportunities (Lazar and Jaeger 2011; Mavrou 2011a; Layton 2012) for its implementation in education and learning (e.g., Alper and Raharinirina 2006; Standen et al. 2011; O'Malley et al. 2013), in employment (e.g., Wehmeyer et al. 2006; Beyer 2012), in daily life activities (e.g., Schlieder et al. 2013), and in communication (e.g., Clarke and Kirton 2003; Light and Macnaughton 2014). Often, the design, development, and use of (assistive) technology for people with physical disabilities may encounter more challenges, particularly in the case of multiple disabilities with the combination of physical limitations and other sensory, cognitive, and/or communication difficulties (Veigl et al. 2017). A quite significant percentage of people with physical disabilities, especially those who are nonverbal, become less involved in activities, and they tend to have limited opportunities for interaction, learning, and participation (Mavrou 2011a; Angelo 2000; Borgestig et al. 2016).

While assistive technology can provide opportunities for independence, in order to increase motivation and activity involvement, for people with physical disabilities, there are a number of factors that affect AT's effective implementation. A holistic approach to AT assessment (Kay 2014) is important, which may derive elements from the principles of various different frameworks. When (complex) physical limitations are in place, the use of AT is highly determined by the way the dynamic interaction between the person, the technology, and the activity (Cook et al. 2008) is supported, improved, and sustained. Hence, the role of teamwork and multidisciplinarity (Copley and Ziviani 2007; Borgestig et al. 2013), as well as the different perspectives that the various AT frameworks provide for each of these elements (person, activity, environment, technology) (Watts et al. 2004), should go beyond the assessment process. Thus, collaborative and multidimensional approaches are fundamental for continuous access to AT tools, training, guidance, technical support, and mostly opportunities for implementation in multiple contexts.

It is evident that current and future research and development trends in technologies for people with physical disabilities have already turned toward user-centered designs and participatory action research (Dorrington et al. 2016; Veigl et al. 2017), as well as the investigation of the potentials of new mainstream technologies (e.g., mobile and Internet technologies) (Abbott and McBride 2014) and robotics (e.g., Cruz et al. 2017). Nevertheless, the collective effort for the successful implementation of technology for people with physical and other disabilities and the critical elaboration on research evidence should also be put forward by policy recommendations and policy making, with inputs from many high-level experts.

The use of assistive technology and accessibility is endorsed by the UN Convention for the Rights of People with Disabilities (Convention on the Rights of Persons with Disabilities (CRPD), available at: https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities.html). Hence, no state can disregard the importance of assistive technology service delivery systems in health, social care, and educational sectors. It is therefore suggested that future research should look into new ways of collaboration among all stakeholders at national and international level, including the industry, the academia, governments, as well as international alliances and umbrella associations (e.g., the EU, the UN, the WHO, etc.).

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Assisting People with Vision Impairments Through Technology

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Synonyms

Computer based and emerging technologies; Mobile; Ocular and cerebral vision impairment; Screen access; Wearable

Introduction

Over the past three decades, a great number of technological implications have been disseminated and applied toward communication, workplace, education, and life of individuals with vision impairment (i.e., those who are blind or have low vision). It is evident that many types of technology, such as assistive technology, augmentative technology, communication technologies, and/or alternative technologies, have influenced and enhanced the quality of life of people with vision impairment through supporting mobility, transport, health, and education (i.e., instructional practices and curricula). These technologies have contributed significantly to modifications of instructional methods and teaching strategies in the education of students with vision impairment (Gerber 2003).

In fact, technology and assistive devices allow individuals who are visually impaired to have access to a range of materials though a variety of different medium ranging from electronic to printed material. In our information-based society, this appears to be an unlimited capability and provides unprecedented educational and vocational opportunities for people with vision impairment (Cooper and Nichols 2007; Kerscher 2001).

Undoubtedly, assistive technology offers many advantages to people with vision impairment. Screen readers with speech outputs, optical character recognition devices, refreshable braille displays, electronic notetakers, and closed circuit television devices make feasible blind (or visually impaired) persons' accessibility to a vast amount and range of information (Cain and Merrill 2001). This new "era" was already been highlighted by the American Printing House for the Blind (APH 2008) mentioning in their annual report that assistive technology and its applications play a crucial role for 83.6% of students with vision impairment. According to the Individuals with Disabilities Education Act (IDEA):

> "an assistive technology device refers to any item, piece of equipment, or product system, whether acquired commercially, modified, or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities" whereas the term "assistive technology service is defined as any service that directly assists an individual with a disability in the selection, acquisition, or use of an assistive technology device." (Luxton 1990; Parette and McMahan 2002; Presley and D'Andrea 2008)

Definition, Types, and Characteristics of Vision Impairment

Normal sight has a measure of 6/6 visual acuity on the Snellen test chart which consists of letters, numbers, or pictures arranged in rows of different sizes (Mason 1997). This though has now been overtaken by using the more accurate LogMAR scores (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2814576/). Visual acuity also is represented as 20/20 or 60/60 (Snellen) or by 0.0 LogMAR. Thus, if a 6 m-size letter can be read at a distance of 6 m, the normal eye has an acuity of 6/6 or if a child has a visual acuity of 6/36 in one eye, it means that what a normal eye sees at 36 m, the person with the vision impairment could only see at 6 m.

This classification about the degrees of visual acuity was defined by the World Health Organization (WHO) and is widely accepted. According to WHO, children with a visual acuity of 6/18 to 3/60 are considered "partially sighted," and those whose visual acuity is less than 3/60 are considered "educationally blind." Another parameter, which is important regarding vision, is the ability to perceive objects distinctly at distance usually measured at 20 feet (distance vision, Scholl 1986). The Snellen test still remains one of the most common methods of assessing distance acuity internationally which consists of letters, numbers, or pictures arranged in rows of different sizes (Mason 1995). On the other hand, near vision acuity concerns types of close work. It is used in tasks such as reading, writing, and drawing. The procedure of testing near vision usually is associated with reading print of different sizes. Each print size is given an N number; the larger the number, the larger the print (Mason 1995). It expresses the ability to perceive distinctly objects at normal reading distance or about 14 inches from the eyes (Scholl 1986). This classification was significantly modified for the first time, though not superseded, by a final draft of WHO (1999 version).

There are three main sites of the causes of vision impairment, which may result in a clinical acuity measure. For example, vision impairment may result from some form of ocular damage or damage to the optic nerve, and increasingly vision impairment may be as a result of damage to the brain visual pathway sometimes referred to as cerebral visual impairment (Lueck and Dutton 2015). All of these cases requires special educational arrangements (Mason 1997), but before examining the profile of children with vision impairments, there is need to ascertain what exactly it is meant by vision impairment and how it is measured. The term "visual acuity" was introduced by Donders in 1862 to describe "sharpness" of vision, although nowadays it is the ability to resolve fine detail and, specifically, to read small high contrast letters. Visual acuity is therefore the best direct vision that can be obtained, with appropriate spectacle correction if necessary, with each eye separately or with both eyes (Thomson 2005).

In a formal clinical setting, the standard measure of visual acuity is usually assessed through the "Snellen" notation. The "Snellen acuity" uses letter recognition on a Snellen vision chart. If another test is used to measure acuity, it will often have a Snellen equivalent since this is most easily interpreted vision scoring method.

The Snellen chart, although it is universally accepted, does have its flaws (McGraw et al. 1995). For example, the limited number of letters at the top of the chart does put people with very poor visual acuity at a disadvantage compared to those with better acuity. There is also the problem of irregular progression of letter sizes within the Snellen chart. The jump in difference between the letters representing acuities of 6/5 to 6/6 is an increase of 120%, whereas the difference from 6/36 to 6/60 is 167%. As Thomson (2005, p. 57) states "this is analogous to a ruler which is marked with different length graduations."

Bailey and Lovie (1976) charts, which negated some of the disadvantages of the Snellen chart, are now being introduced. The Bailey-Lovie charts convert a geometric sequence of letter sizes to a linear scale and give a LogMAR notation of vision loss. LogMAR vision testing offers a consistent and scientific method of recording vision scores. Although LogMAR is seen as the gold standard in measuring visual acuity, it is still common parlance to use the Snellen notation and to convert it using similar table. However due to the reasons just explained, these conversions are only approximate, and good practice dictates that comparisons between LogMAR and Snellen should not be made.

A more analytical spectrum in the classification of vision impairment is the WHO International Classification of Disease and Related Health Problems (ICD) Version 10 (2016) although as Ravenscroft 2017 has highlighted, cerebral visual impairment is not listed within ICD 10 coding system. In addition to the above classification, the element of visual functioning is equally highlighted by the Resolution of the International Council of Ophthalmology (http://www.icoph.org/downloads/visualstandardsreport.pdf) and the Recommendations of the WHO Consultation on "Development of Standards for Characterization of Vision and Visual Functioning (2003)."

It is interesting to present the recent key facts addressed by WHO (http://www.who.int/mediacentre/factsheets/fs282/en/) because it provides a global overview of the present situation regarding the population of individuals with vision impairments (VI).

- 285 million people are estimated to be visually impaired worldwide: 39 million are blind and 246 have low vision.
- About 90% of the world's visually impaired live in low-income settings.
- 82% of people living with blindness are aged 50 and above.
- Globally, uncorrected refractive errors are the main cause of moderate and severe vision impairment; cataracts remain the leading cause of blindness in middle- and low-income countries.
- The number of people visually impaired from infectious diseases has reduced in the last 20 years according to global estimates work.
- 80% of all vision impairment can be prevented or cured (cited from http://www.who.int/mediacentre/factsheets/fs282/en/).

In conclusion, there are many differences among people who have severe VI. They are a heterogeneous group with a wide range of educational, developmental, and physical abilities and needs, which require specialized supports and services (Candlin 2003; Huebner 2000; Scholl 1986). The element of heterogeneity is reinforced by the fact that even when two individuals have exactly the same degree of vision loss, they may have tremendous differences because the way in which an individual uses whatever vision he or she has is unique (e.g., individual characteristics of people with vision impairment, vision loss, low vision, chronological age of visual loss). It is the so-called functional vision and plays crucial role in all aspects of life (Best 1992; Corn et al. 2000).

Assistive Technology and People with Vision Impairment: Challenging Limitations

When the person has a residual vision and can use his/her functional vision, then there are specifically designed technologies to meet the needs of those with vision impairment and maximize their residual vision. The vast majority of computers, for example, have accessibility features, such as magnification and speech output. Nowadays, many persons who have vision impairment (low vision) use computers, and they need a combined set of settings, devices, and software to facilitate their functional vision. For example, large monitors (21-inch screen) with accessibility features such a built-in magnifier and contrast enhancement settings are common. Computer programs such as ZoomText can be downloaded to allow for an even greater range of magnification and contrast enhancement (http://www.aisquared.com/docs/zt2018/ZoomText_2018_User_Guide_English_UK.pdf).

The Multidimensional Function of Screen Access

Access to screen is made feasible through two different functions: (A) amplifying visual information through magnification and (B) translating or transforming the visual information into alternative sensory information (sound such as speech outputs or touch such as braille).

High-Tech Optical Devices

Optical magnifiers have been the backbone of visual rehabilitation for many years and nowadays are enriched by high-technological optical devices bringing impressive outcomes regarding reading and clarity in image recognition (Virgili et al. 2013). There are near vision devices such as handheld magnifiers and spectacle-mounted magnifiers. The baseline of these devices is usually twofold: (a) improved lighting and (b) contrast. On the other hand, there are the distance vision devices, such as handheld monoculars (one telescope) and bioptic telescope systems (two telescopes). The aforementioned implementations often include a zoom function, brightness and contrast controls, and color inversion. In essence, the above technological implementations fall under the umbrella of the computing process of magnification (Corn et al. 2000).

Closed Circuit Television (CCTV)

These devices, closed circuit television systems, are considered to be the "ancestors" of electronic magnification and contrast in the contemporary history of assistive technology for people who have residual vision. Two strands can be distinguished regarding these devices: (a) desktop CCTVs and (b) portable CCTVs.

Desktop CCTVs were the "groundbreakers" in electronic magnification and constitute the pillars for the systems that are used today. Flat screens are used, and apart from the traditional black and white contrast technologies, all up-to-date CCTVs have expanded this capacity into offering all the colors and saturations in order to design a great variety of contrast settings (Bennett 1997; Markowitz 2006). In addition, many models have cameras whose focus can be adapted for distance viewing and optical character recognition (OCR). These capacities enable the person with vision disability to read a page because the camera takes the photo, the OCR in turn converts the letters on the screen, and hence the user can read the page adjusting the magnification and contrast or listen to a computerized voice that reads aloud text on the screen (Holbrook and Koenig 2000).

Portable CCTVs have the same properties as the desktop CCTVs plus the property of portability, which give users the freedom to travel or work away from their home desk system. Some of the more common units available are the Zoomax Snow and Zoomax HD 7, Pebble HD preis from Enhanced Vision, SmartLux Digital Portable Magnifier from Eschenbach, and Ruby from Freedom Scientific.

B. Translating or Transforming the Visual Information into Alternative Sensory Information.

This path of alternative sensory information needs at least two types of specialized software, which are usually embedded in computers, tablets, or smartphones. One is reading the text, namely, a screen reader, and the other one serves as a speech synthesizer. A screen reader "reads" what is displayed. In essence, a screen reader is software that is now commonly pre-installed in PCs, tablets, phones, etc., which reads aloud the text that appears on screen, such as documents, menus, icons, web pages, dialog boxes, phone numbers. The screen reader interprets the text on the screen (either on computer screen or on mobile phone) and uses electrical signals to activate the synthetic speech (Sherwin 2015). Through this software, people with vision impairment can access Internet resources, all texts contained in files, digital libraries, email, forums, etc. Some popular representatives regarding screen readers may be "JAWS" of Freedom Scientific (http://www.freedomscientific.com/products/fs/jaws-product-page.asp.), "Windows Eyes" of GW Micro (http://www.gwmicro.com/Window-Eyes/), "SuperNova" of Dolphin (http://www.yourdolphin.com/productdetail.asp?id=1), or "VoiceOver" of Apple products (http://macfortheblind.com/What-is-VoiceOver) and the like. All the above apps or software provide speech output and screen magnification as well as refreshable braille displays can be connected and used.

The general term which encapsulates the process of transformation from visual format into aural format is called text-to-speech (TtS) technology (Dutoit 1997). Through this technology, digital text is rendered aloud conveying all the meta-data of the text (i.e., lists, bold, italic, etc.; see Argyropoulos et al. 2015). The TtS can be used as stand-alone software, be built-in applications or operational systems, and be embedded in screen readers. TtS is much more effective than human narration, because the latter is time-consuming and requires much cost and effort (Peters and Bell 2007).

Sometimes the output may not only be speech but a tactile format such as a braille display. Through a specialized software, the system converts the content into braille characters. To transform the content into braille, an electronic refreshable braille display is needed which is hardware and is usually attached to the computer and driven by a specialized software. This particular braille display consists of a series of six- or eight-dot braille cells made up of small metal or plastic pins arranged in a rectangular context. The pins are raised and lowered depending on the electric signals, which are created due to the piezo effect of some crystals, whereby they expand when a voltage is applied to them. Each crystal is connected to a lever, which in turn raises the dot from a braille cell (Quick 2010).

Finally, the output may be a combination of tactile and aural stimuli. For example, technologies known as accessible pedestrian signals (APS) aim to assist people with vision impairment to cross streets through tactile arrows and audible signals. For example, poles with crosswalk buttons are placed within specified distances of the curb and crosswalk, and pushbuttons (the buttons used to request a walk signal) are placed on the side of the pole closest to the corresponding crosswalk (Carter et al. 2007).

Wearable Technological Devices

As mentioned above, the underpinning qualities that are essential for any technological implementation (software or hardware) regarding individuals with vision impairment are pertinent (a) to enhancing visual information via a variety of methods and techniques and (b) to transforming visual information into alternative sensory information, such as sound or touch. Another branch of assistive technology relevant to the above qualities and related to ubiquitous computing (Velázquez 2010) is modern wearable technology. Wearable technological devices make technology pervasive by incorporating them into daily life. Devices worn on many parts of the body – such as the finger, hands, wrist, tongue, head, chest, abdomen, and feet – have been designed and tested over the last decades to provide wearable solutions to the problems of reading and mobility when it comes to navigation (i.e., indoors navigation, outdoors navigation) (Ramadhan 2018; Tsukada and Yasumrua 2004; Velazquez et al. 2009). In all the aforementioned devices, there are common patterns but differences as well. For example, outdoor navigational apps are usually designed differently than apps for navigation indoors because the former includes a GPS system, whereas this is not the case for the latter (indoor environments always change their reference points; therefore there have no stable structure over time).

Electronic eyeglasses constitute excellent example of wearable devices for improving vision (such as read books, distinguish street signs and objects from far away, and know what friends' and relatives' faces actually look like). Each of these electronic eyeglasses houses a high-speed, high-definition camera that captures what the user is looking at. The device through a series of algorithms enhances the video input and in turn displays the video through appropriate screens in front of the user's eyes (or even through auditory input). The cameras in real time enhance the footage that beams across two screens, one in front of each eye (Hwang and Peli 2014). In addition, a magnification process takes place combined with contrast. Lastly, as a wearable device, there is the capacity of a hands-free operation, which is of great importance for people who have significant vision loss, even up to 20/200 vision.

OrCam My Eye wearable technology, for example, constitutes an integrated portable device with smart camera reassigned to help individuals with vision impairment. The camera is attached to the glasses of the person who is visually impaired and transmits information converting the visual information into an auditory format in real time. Labels, documents, banknotes, products, and other images, including faces and names, can be quickly and efficiently converted into spoken words. The device has multiple readable features that are compatible with headphones and speakers as well (https://www.orcam.com/en/myeye2/).

Mobile Technological Devices

Mobile assistive technologies constitute another platform for conveying and transforming information through accessible formats. Similarly, as it happens in wearable technological devices, smartphones and tablets – the main representatives of mobile assistive technologies – are now produced with accessibility options to allow magnification or contrast enhancement (Hakobyan et al. 2013). Many of the apps developed in mobile technological devices, which aim to support people with vision impairments fall roughly into three categories:

(a) Navigation: Global Positioning Systems provide the person with vision impairment auditory instructions to streets and intersections, business names and addresses, public transportation or schedule appointments, and web searches (Chandana and Hemantha 2014).
(b) Identification: specialized detectors provide the person with vision impairment feedback about the color of clothes, currency identification, products in supermarkets, and so on (Hild and Cheng 2014; Sangami et al. 2015).
(c) Reading: text readers and barcode scanners provide the person with vision impairment audible formats or enhanced images (screen reader or screen magnification) to have access in large databases, such as national libraries, or in vast repository containing nearly every work of literature available in the public domain (such as the Project Gutenberg – Free ebooks, http://www.gutenberg.org/).

All the above share the same operation principle: they all scan the environment – using different technologies – and display the information gathered to other sense (mainly hearing and touch) (Velázquez 2010). Specifically, the wearable systems are considered to be of high importance because they leave the users' hands free increasing in this way his/her degrees of independence and mobility.

Other Computer-Based Assistive Technology

Braille Embossers

These devices are hardware, which started to print text documents in the form of braille text. They use specialized software to convert text to braille. The evolution of the embossers continues to become more and more sophisticated, leading to new developed software applications, which in turn result in better-raised and recognizable dot tactile graphics. Nowadays, tactile graphics can be produced simultaneously with the braille text in the same hard copy sheet and by the same braille embosser (Kouroupetroglou et al. 2016).

Electronic Notetakers

Electronic notetakers are portable devices equipped with a speech synthesizer, a braille display, and a braille or typewriter keyboard. They are extremely useful in storing information, keeping track of appointments, and taking notes. They can be connected to braille or laser printers, and the latest electronic models of notetakers provide advanced word processing, web browsing, and other functions (Kapperman and Sticken 2000).

Specialized Keyboards

Users with vision impairment may benefit from keyboards with a high-contrast key legend or from the addition of high-contrast labels. Also, large key keyboards (with high-contrast lettering or color-coded keys) may enhance the residual vision of people with vision impairment and enable them to be efficient at work or at home (https://www.techsilver.co.uk/large-print-keyboard-best/).

Other Emerging Breakthrough Assistive Technology

In general, emerging technologies are characterized by radical novelty (i.e., have the capacity at least to challenge the status quo), relatively fast growth, coherence, prominent impact, as well as uncertainty and ambiguity (Rotolo et al. 2015). Transforming emerging technology into assistive technology provision requires an ongoing effort, which includes collaboration with people with disability and discussing goals, needs, and functional links between capabilities offered by new technology and functional capacities of the person. One example of such innovative and breakthrough assistive technology for people with vision disability is the iBeacons protocols. These implementations constitute a special class of Bluetooth low energy devices that broadcast their identifier to nearby portable electronic devices. This technology enables smartphones, tablets, and other devices to perform actions when in close proximity to an iBeacon. Hence, people with vision disability through iBeacons can identify shelves in a supermarket, rooms in a campus or in a hotel, streets, areas, or points of interest (Stinson 2015).

Ultrasonic technological implementations in conjunction with Global Positioning Systems constitute up-to-date navigation systems where people with vision disability can detect obstacles and nearby vehicles, identify a place, provide information about traffic conditions and suggest alternative directions, monitor a direction, and/or cross-reference with other streets (Shahu and Shinko 2017).

In addition, high-tech learning spaces equipped with differentiated learning platforms seem to accommodate the changing dynamics of current education in order to meet at a global level all persons' educational needs including those who have vision impairments by appropriate hardware and software. The aim here is to promote web-accessibility and to provide differentiated e-content to learners with vision impairment and in the end enable them to learn and progress in an autonomous way (Kishore and Raghunath 2015; Ramakrishnan et al. 2017).

Finally, the use of robotics at the service of assisting people of vision impairment has been gaining ground in recent years. Indoor navigation involving multipurpose robots seems to prevail in human-robot interaction, and robot hardware learning environment has already been embedded in educational practice and application (Marques et al. 2017).

This entry has not covered new technologies in bionic eye development, as while this could be seen as the latest advancement in assistive technology, it has been excluded as the technology is not yet available to all who need it while those described above are all available through the open market.

Conclusions

As mentioned above assistive technology, devices, and services have been developed to "increase, maintain, or improve functional capabilities of individuals." In specific, there are different types of access such as the physical access, sensory, intellectual, emotional/attitudinal, financial, cultural, digital access, etc. (Dodd and Sandell 1998), and hence there are corresponding technological implementations which enhance and/or facilitate this accessibility. Regarding individuals with vision disability, all barriers have a common denominator (i.e., access to information in general) and significant differences as mentioned above about heterogeneity. For this reason, there is a big range of technological devices and services which are embedded in a bigger network including the person with the vision impairment (i.e., user), specific implementation(s) of relevant assistive technology, and the activity in conjunction with the environment in which it is being used (e.g., home, workplace, leisure).

Because of the universal design, there is a trend that the accessibility is not depended on the visual acuity of the person; rather the advances and all technological implementations are based on relatively new approaches and theories such as universal design or universal design for learning (Follette 2001). This means that the evolvement in technology resides more on a global basis of "thinking" and design rather than on specific needs. The needs of a person with vision impairment may change over time just as the site of vision impairment has, and as a consequence of this, a technological device should be adaptable, up to date, and flexible to the person's needs (Stephanidis et al. 1998).

People with vision impairment should be systematically trained in using assistive technology devices and software, by specialist professionals who have the expertise to properly exploit the technology (Guerette 2014). Furthermore, students/people must be assessed before trained in order to choose the assistive technology equipment that is suitable for them. The ultimate goal of assessment should be the selection of a device or equipment that meets the student's needs. Technological advances should be conducive to blind students/peoples' development, and assistive technology should be considered as an educational tool and not as an educational end (Abner and Lahm 2002). This is to say that assistive technology should be adapted in the schooling of students with vision impairments as indispensable means, promoting their literacy skills and enhancing their access to the full curriculum.

Anything that prevents or limits the inclusion and active participation of people with disabilities to social life constitute barriers. The accessibility of the common resources of the community (facilities, services and products related to housing, health and rehabilitation, education and vocational training, work, politics, sports) for the use of people with disabilities in conjunction to social awareness represents the essence of an open society (Male 2003; Ravenscroft 2016). The scope of the strategy sustains the increase of quality of life of people with disabilities in respect with independence, security, dignity, decision, and personal responsibility. With such advances in technology, people with disabilities – especially those with vision impairment – now have more options to visually enhance their daily lives and maintain independence.

Cross-References

▶ Assistive Technology and Inclusion, Philosophical Foundation
▶ Games, Simulations, Immersive Environments, and Emerging Technologies

▶ IT on Teaching and Learning Process of Visually Impaired Students
▶ Mobile Computing and Mobile Learning
▶ Mobile Learning
▶ Mobile Learning and Ubiquitous Learning

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Assisting Students with Attention Deficit Disorder Through Technology

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Synonyms

Computer-based instruction; Students with ADHD-related difficulties; Technology-aided attention training; Technology-aided self-regulation training

Introduction

Identified as the most common disability in childhood and adolescence, attention deficit hyperactivity disorder (ADHD) is characterized by developmentally inappropriate levels of inattention, impulsivity, and hyperactivity (Barkley 2014). The prevalence rates of this high-incidence and neurologically based disability range from 5% (APA 2013) to 11% (Ogg et al. 2015) with increasing rates being reported in recent years. The diagnostic criteria for ADHD involve persistent and severe difficulties in the aforementioned areas, the onset of which occurs in childhood and persists into adulthood (Steiner et al. 2011). However, variations exist with respect to the nature and severity of the difficulties experienced by young people with ADHD across developmental phases and also between sexes (Ogg et al. 2015).

Young people with ADHD often face functional limitations in their academic and social skills that cumulatively lead to diminished learning motivation, difficulties in completing academic work, and problems in developing positive interpersonal interactions with peers and adults (Barkley 2014; DuPaul et al. 2011; Lewandowski et al. 2016; Ogg et al. 2015; Polderman et al. 2010). Students with attention difficulties often encounter learning problems that hamper their academic progress and as such are more likely to be provided with special education services (Loe and Feldman 2007). These children are also more likely to terminate compulsory schooling early and not pursue post-secondary education (DuPaul and Weyandt 2009). Impaired inhibitory control has been suggested, in theory, to be a core deficit underlying ADHD and is associated with disruptive, off-task, and generally undesirable behavior (e.g., school rules infringements) that often warrants special attention and intervention by teachers (DuPaul et al. 2011). Thus, young people with ADHD are likely to display various emotional and behavioral difficulties (e.g., disobedience, aggressiveness, etc.) that adversely affect their interpersonal relationships and contribute to their social marginalization within schools.

School-based interventions targeting the learning and social needs of young people with ADHD are regarded as key primary support provision (DuPaul et al. 2011) that fosters their educational and social inclusion in mainstream educational environments. A new era of technological development has opened up ways of providing education to students with ADHD which are expected to facilitate their learning, improve their academic and social performance, and promote their social inclusion in schools. Technological applications and devices have been found to be helpful in securing access to the mainstream curriculum and in accommodating the divergent learning needs of students' with ADHD within mainstream classrooms (Dolan et al. 2005). Digital devices, auxiliary computers, and electronic applications are beneficial for teachers, assisting them in the implementation of approaches tailored to the unique learning and social needs of students with ADHD, thus helping these students overcome the learning barriers they face (Schuck et al. 2016). More specifically, computers, various digital applications, and portable online devices have recently been identified as being promising in supporting the learning process of students with ADHD and facilitating in their training in the areas of attention and self-management skills.

Computer-assisted teaching provides students who experience attention-related problems with various alternative ways of accessing knowledge, which maximize their skills for the assimilation and generalization of new concepts. Accordingly, technology-aided learning can be useful in helping students monitor their attention and on-task behavior, thereby improving their overall academic performance as well as their social behavior in the classroom. However, computer-aided learning, technology-based attention, and self-regulation training used for teaching and assessing students with ADHD in a natural learning environment often produce mixed results, and hence further research is needed to clarify their effectiveness. These issues are briefly discussed below.

Computer-Assisted Instruction and Technology-Aided Learning

Over the past few decades, the use of computer devices, digital platforms, software applications, and hypermedia has proliferated, and they are increasingly being used to provide learning support to students experiencing attention-related difficulties and ADHD (Fabio and Antonietti 2012; Ok and Kim 2017). Computer-aided teaching provides students with flexible interactive learning environments that enable them to highlight and summarize easily, access vocabulary, and test multiple ways of dealing with mathematical problems (Lewandowski et al. 2015, 2016). Despite its promising potential, research on computer-aided instruction for students with ADHD has been relatively limited (Lewandowski et al. 2016). Yet, the available data showing positive results is challenged by other existing studies that question the overall effectiveness of technology-based teaching for students with ADHD, making it difficult to develop a clear picture and draw conclusions. Therefore, further studies need to be carried out to substantiate the outcomes of technology-based teaching in specific academic areas and skills.

One of the strongest advantages of hypermedia tools is that they present learning concepts in a network structure and through a variety of perceptual channels, thereby facilitating access and encouraging assimilation (Mayer 2001). They facilitate the avoidance of distractions by presenting new concepts in such a way that relationships between these concepts are clearly demonstrated. They allow for increased incentive and learning as a result of the flexibility they provide in allowing students to access new ideas. As indicated in the findings of the experimental study conducted by Fabio and Antonietti (2012) on a sample of Italian adolescents with and without ADHD, the students facing attention problems were receptive and benefitted more when the teaching was presented in a hypertext format compared to conventional teaching. The data revealed that the participants who were exposed to the hypermedia-learning environment performed better in the acquisition and retention phases of learning than the control group. Their evidence is further endorsed by an earlier study demonstrating that computer-aided learning facilitates the development of new ideas and the creation of links with pre-existing knowledge while minimizing the typical counterproductive behaviors of students with ADHD that undermine their learning outcomes (Solomonidou et al. 2004). Similarly, some other studies have found computer-based teaching to be effective for improving the learning skills and on-task behavior of students with ADHD (Mautone et al. 2005; Rueda et al. 2005; Shalev et al. 2007).

In spite of the positive results pointed out above, researchers highlight some methodological issues that raise concerns over the overall effectiveness of computer-based instruction. These issues are mainly related to the small sample sizes of available studies, the lack of control groups, and the limited sustainability of long-term effects (Lewandowski et al. 2016; Rabiner et al. 2010). For example, Rabiner and his associates (2010) conducted a randomized controlled trial research on the impact of computerized attention training and instruction on first grade American students with attention-related difficulties, including ADHD. Their intervention yielded positive outcomes on learning (e.g., reading fluency) and attention, as documented in the assessment conducted by class teachers. Nevertheless, the effects of the intervention program were of a modest magnitude, and attention improvements were not sustained in the following year. Thus, the researchers argued that interventions targeting the difficulties associated with attention and learning, which are experienced by students with ADHD, are in need of improvement, as is the method of evaluating the outcomes of such interventions.

In addition to the limitations highlighted above, the evidence available points to differential effects of computer-aided teaching on different curriculum subjects suggesting that ADHD students may be more likely to benefit from science and problem-solving teaching as opposed to reading (see for a review Lewandowski et al. 2016).

Some studies highlight the potentially positive results of available IT applications, mobile devices, and software targeting the learning difficulties related to ADHD and the improvement of the academic skills and on-task behavior of students (Cullen et al. 2013; Mautone et al. 2005; Rabiner et al. 2010). More specifically, mobile devices (e.g., iPad, iPods) have recently gained prominence in education and have become popular tools used to enhance the learning experience of students with ADHD, mainly because of attractive and beneficial features such as touch screens, built-in cameras, Wi-Fi connections, and download capabilities. In today's world, an ever-increasing number of young people have access to mobile devices and are connected to the Internet (Common Sense Media 2011). Despite this, the use of such technology and its impact on students experiencing attention problems have not been thoroughly investigated by relevant research (Douglas et al. 2012). Indeed, available relevant studies often reveal mixed results in terms of the overall effectiveness of technology on improving and maintaining the academic skills of ADHD students (see Lewandowski et al. 2016). Within the context of the limitations outlined above, computer-based learning is anticipated to deliver a better outcome for students with ADHD if integrated as complementary training aimed at developing cognitive skills, such as attention, a skill that students with ADHD usually face major difficulties with.

Technology-Aided Attention Training

The rapidly evolving electronic world has encouraged the construction of various interactive computer-based games and applications that are easy to use and available to children and adolescents with ADHD (MeMotiva game 2013). These digitalized applications usually provide attractive virtual learning environments and platforms that integrate games targeting the development of various cognitive skills (De la Guia et al. 2015). Indeed, there are several digital computer-based game-type exercises available to young people with ADHD that aim to develop their attention, working memory, and task completion skills (e.g., *Home Routines*, *Attention Exercise*, *Play Attention*, *Cogmed*) (see http://appcrawlr.com/ios-apps/best-apps-adult-adhd and www.playattention.com and https://www.cogmed.com). Nonetheless, many of the available online applications and electronic game programs have not been tested yet, nor have their results been thoroughly evaluated (Lewandowski et al. 2016).

In addition to the abovementioned game programs, computer-based training focusing on attention skills is recommended for young people with ADHD as a means of improving their attention and further developing their thinking and problem-solving skills (Klingberg et al. 2002). Nevertheless, computer-assisted interventions targeting attention, and delivered to students with ADHD, have generally yielded mixed results in terms of their overall effectiveness and long-term sustainability. A case in point is that of Steiner and her associates (2011) who conducted a pilot study to test the results of a computer-based attention training intervention that was delivered to school-aged students with ADHD. Their sample consisted of 41 American middle school students with a formal diagnosis of ADHD and also included a control group. More specifically, of the 41 students participating in the study, 11 were included in the attention training program, with a further 15 serving as a control group and the rest receiving a different intervention. Their intervention program included sessions of auditory and visual exercises of increasing complexity targeting the students' impulsivity and their attention to the tasks presented. The study was carried out over a 4-month period. Once the participants demonstrated attention and achieved goals quickly, they received immediate feedback, and the accumulation of scores allowed them to move on to subsequent levels, which were more demanding. However, the data collected from teachers, parents, and students themselves showed mixed results. Although the parents of the participating students reported positive results regarding attention and other ADHD-related behaviors, their assessments were not consistent with those given by their children or their children's teachers, who did not detect any significant relevant improvements.

In another similar European study, De la Guia and her associates (2015) conducted experimental research to assess the outcomes of a novel interactive multi-device learning system based on a set of collaborative games and targeting the attention skills of young people with ADHD. Their sample comprised 12 Spanish children and adolescents with ADHD aged between 5 and 16 years who were receiving relevant support at a therapeutic clinic. The aforementioned system used software that controlled the interconnection and operation of various integrated computing devices (e.g., laptop, computer, tablet, mobile phone) allowing participants, who, without any prior knowledge of computer use, were able to interact by touching familiar objects. These interconnected devices were programmed to handle the input received from the participants and to indicate whether the task had been performed successfully. This attractive interactive platform encouraged students to develop ownership of the learning environment by manipulating a set of cards displaying images of animals. The participants were asked to indicate the correct set of images that appeared on the screen based on a growing level of difficulty. Once the embedded system reader had recognized the cards, it responded immediately, indicating whether the sequence presented by the students was correct. The evaluation results showed that the participants had demonstrated improved memory and attention and had enjoyed using the application. Nevertheless, as the researchers argue, the sustainability of the outcomes of this intervention and its applicability to larger samples, in particular, those in non-clinical educational settings, are certainly an issue that needs further examination.

As has already been mentioned, in addition to the significant difficulties experienced by young people with ADHD in the areas of academic and cognitive skills, their various counterproductive behaviors may place them at a high risk of social marginalization within education institutions. Consequently, technological applications and devices may be considered to be extremely promising tools in assisting young people to improve their social performance and mitigate the constraints they face in this area. Further, the combination of learning and self-regulatory interventions is likely to contribute to the long-term maintenance of improvements in the academic and social behavior of the students (DuPaul et al. 2011).

Technology-Aided Self-Regulation Training

Self-management and self-monitoring programs have been among the most popular interventions for young people with various disabilities, including ADHD (Briesch and Chafouleas 2009; Reid et al. 2005). In contrast to the narrowly defined behaviorist approaches that are largely based on the external manipulation of the social environment, self-management programs focus on the learners themselves by encouraging them to monitor and evaluate their own learning and social behavior (DuPaul et al. 2011). Self-monitoring has been identified as a self-management strategy aimed at enhancing students' awareness of their own behavior through recording when a specific behavior has taken place. Typically, at regular intervals students report on their performance using a scale provided. Their teachers also complete a similar scale, and then the student concerned is reinforced depending on whether their assessments match those of the teachers' ratings (DuPaul et al. 2011). Some researchers comment on the positive outcomes of teaching meta-cognitive self-monitoring skills to young people with ADHD, mainly in promoting on-task behavior, academic completion, and work performance (Carter et al. 2011; Gureasko-Moore et al. 2007).

Various types of devices and online applications (e.g., iPod touch, iPad, smartphones) are considered useful in helping students with ADHD to self-monitor their attention and on-task behavior. However, their use in educational settings has not been systematically evaluated by research. Thus, despite the fact that some of the available studies show positive results (Laurice and Elisha 2011; Wills and Mason 2014), these positive effects may be of limited duration and may not be maintained when electronic devices are removed (see Lewandowski et al. 2016).

This is illustrated in the study carried out by Bruhn and her associates (2015). Experimental research was carried out by them to assess the effects of an iPad application (SCORE IT) designed to assist two American middle school students (one with ADHD) to self-monitor learning as well as disruptive behaviors. This particular application stores the results of monitoring, carried out by the students and their teachers, in the form of scores based on the student's compliance with the rules of the class. These scores are then displayed in chart format at the end of each day. As soon as the participants' goals for each day are met, the students are reinforced by their teachers. The collected data can be stored and examined for up to five consecutive days, thereby allowing students and teachers time to review and track their progress. Although the results showed improvements in the participants' on-task behavior and engagement in learning, these were not sustained in the long run.

In line with the reasoning above, Schuck and her colleagues (2016) conducted a pilot study to test the feasibility of using a web-based application (iSelfControl) that was designed to evaluate student self-control and compliment traditional classroom behavior management approaches. More specifically, the pilot testing included 12 fifth grade American students with ADHD attending a clinical facility where a universal behavior management program had been implemented. Each student had their own iPad, and their application prompted them to evaluate their behavior every 30 min on three behavioral goals, namely, paying attention, following the rules, and behaving appropriately toward others. At the same time, teachers rated the students' behavior on another iPad. The application was designed in such a way that allowed staff to complete entries for many students within a very short time. The students could check their progress charts, on their iPads, throughout the day and receive feedback accordingly. This pilot intervention lasted for six consecutive weeks, and data collected consisted of a total of 141 teacher-student paired observations. The results indicated that by using this particular application, the students' awareness of their behavior improved, as did their ability to regulate their behavior effectively. Despite these positive outcomes, the researchers recommend that these results need to be further substantiated by complementary studies involving larger samples of students and testing the iSelfControl in natural learning environments (e.g., classrooms).

Conclusions

This entry comments on the use of technology in assisting students with ADHD in their learning and in improving their on-task and social behaviors. In particular, we focused on technology-assisted instruction as well as attention and self-management training, which have been found to ameliorate the difficulties that this particular group of students faces in academic and social settings. Therefore, within this new evolving electronic era in education, computers, mobile devices, and digital platforms appear to be promising tools that may be used in promoting the academic and social skills and performances of students with ADHD. Despite their promising potential, however, we could argue that their application in natural learning environments and schools has not been thoroughly examined by relevant research in the field. Thus, some of the studies available suggest mixed results in terms of overall effectiveness, while others highlight methodological limitations that prevent researchers and practitioners from reaching clear-cut estimations and drawing conclusions.

Nevertheless, one of the strongest advantages of digital applications and electronic devices is that they can respond directly to the complex needs and interests of students and are therefore likely to contribute to providing specialized support within mainstream educational settings. Consequently, available evidence needs to be further substantiated by future studies that involve larger samples of students with ADHD as well as complementary data from natural educational environments, in addition to that collected in clinical settings. Educators and researchers need to work together on the implementation of technology-aided support interventions within mainstream classrooms. Teachers may need guidance from researchers and technology specialists to address the complex needs of ADHD students, as well as receive training to successfully implement these promising technology-led educational support services.

Cross-References

▶ Teaching with Computing, Educational Games

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Assisting Students with Intellectual Disability Through Technology

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Synonyms

Assistive and instructional technology; Intellectual disability

Introduction

Intellectual disability (ID) refers to limitations in intellectual functioning and adaptive behavior, with onset during the developmental period (AAIDD 2018; Papazoglou et al. 2014). Moreover, ID is characterized by heterogeneity in terms of etiology, and it pertains to a variety of behavioral profiles in terms of relative strengths and weaknesses through an array of domains including the cognitive, language, social, and socio-emotional domains (Bertelli et al. 2018).

Over the last decade, there has been an increasing emphasis on adaptive functioning and the consequent support needs of people with ID. In the latest (5th) edition of the *Diagnostic and Statistical Manual of Mental Disorders* (American Psychiatric Association 2013), the severity of ID is specified on the basis of adaptive functioning which is considered indicative of the supports needed by a person with ID (Papazoglou et al. 2014). Even in earlier years, it became evident an increased emphasis on the development of individualized supports to address the unique needs of a person with ID within an inclusive environment, along with the development of relative measurement scales and tools (Thompson et al. 2009). This special emphasis was consistent with a turn toward the social-ecological model of disability (Shogren et al. 2017; World Health Organization 2001), while an even broader modus for viewing, understanding, and addressing intellectual disability has stemmed from the "social and human rights perspective" on disability (Bach 2017).

Within the context of such a broader perspective, a tendency toward more individualized or person-centered support services has been generated in pursuing the enhancement of inclusion and achievement without ignoring at the same time information on the unique challenges related to ID (Bach 2017). Furthermore, the concept of "support" is becoming the central part of interventions and policies that target the promotion of educational, social, community, work, and economic inclusion for people with ID. In this realm of "adequate supports" and "support services" to prevent marginalization and promote active citizenship, quality of life and self-determination for people with ID, technology has been progressively recognized as a crucial enabler of these goals and of inclusion in general.

Connecting Technology with Support Provision and Inclusion

It is widely acknowledged that technological developments and resources have a catalytic role and effect in almost all aspects of our daily life. In light of this fact, the provision of opportunities for technology use by people with ID is a sine qua non situation in order for the modern societies to be considered inclusive; moreover, technology resources are among the critical supports for people with ID as they can assist them, under the appropriate conditions, in achieving independence, participation, and progress into inclusive societies.

In the context of providing personalized supports tailored to each person's with ID needs, strengths, choices, and goals, technology – in terms of devices, tools, systems, and solutions – (Lancioni 2017) can assist people with ID in improving their functioning in a variety of areas related to adaptive behavior, promoting their personal and interpersonal development, and enhancing their participation in school, work, leisure activities, and community (Wehmeyer et al. 2004). In other words and in light of a social-ecological point of view, technology, either instructional/educational or assistive, is considered a crucial part of the supports that should be provided to people with ID on the basis of their individual strengths and support needs to address the contextual/environmental challenges encountered within the school and the community in the course of their participation in inclusive settings in general (Thompson et al. 2016).

Today, there is an increased emphasis on inclusive education and in specific the inclusion of students with ID in general education classrooms (Thompson et al. 2016). Considering possible indicators of quality inclusive education, it has been suggested that they are related, among others, to the promotion of students with disabilities participation, progress, and achievement in general education contexts and settings and to the implementation of curricula grounded in the principles of universal design for learning (UDL) (Loreman et al. 2014; Ryndak et al. 2014). Moreover, access to and availability of assistive technology are among the critical considerations relating to indicators for the measurement of progress in inclusive education (Loreman et al. 2014). In this vein, the provision of opportunities to use universally designed technology can facilitate all students, including those with ID, in meeting both the structured (i.e., academic) and informal (i.e., social) processes taking place into an inclusive school. Consequently, at the school level, technology could be conceptualized as a pivotal system of support for students with ID, in terms of enabling them through the pathway of their individual strengths to deal with an array of challenges in various key areas such as participation, independence, learning of new skills, academic achievement, and social functioning and inclusion.

A central issue in the process of assisting people with ID to increase their independence and foster inclusion through technology concerns the "means" by which the variety of available technological resources would be actually, purposefully, and fruitfully used by people with ID. This process of resolving the "what, how, and why" challenges – related to the application of technology to the field of ID – is translated into adequate interventions that enhance technology usability, as well as learning, motivation, and success by the students with ID (Lancioni 2017; Thompson et al. 2016). Selecting the appropriate technological solutions for a student with ID in light of a holistic understanding of the interaction between his/her strengths and weaknesses and the environment, without ignoring the user's opinion, and then teaching the student to effectively use these solutions consist important considerations in the process of bridging the gap that usually emerges between availability and actual and effective use of technological devices (Alper and Raharinirina 2006; Thompson et al. 2016; Zabala 2005). An actual turn toward the development of universally designed technological solutions is considered beneficial for all students with ID, and it could result to positive outcomes in the areas of availability, utility, and usability (Wehmeyer et al. 2008).

Technology Use Benefits in Within-School and Out-of-School Contexts

In the relevant literature, technology use is characterized as instructional or assistive according to the particular purposes that it serves, although these two categories may have overlapping roles (Ayres et al. 2013; Thompson et al. 2016). Instructional technology refers to supporting students with ID toward their progress and skills enhancement in academic areas, and it applies, generally, in teaching of specific skills, while assistive technology aims at helping students to "participate in settings and activities in ways that they otherwise could not" (Thompson et al. 2016, p. 45).

Technology has become a key component of educational programs for all students and also a central consideration in the development of Individualized Education Programs for students with low-incidence disabilities (Lee et al. 2011). There are an increasing number of studies in the field of technology use by students with disabilities, indicating that both assistive and instructional technology solutions can be used in teaching students with ID and supporting them in various domains. Life skills, including daily living and social skills development, improvement of academic performance and engagement, enhancement of communication, and promotion of self-determined behavior, all of which can contribute to the educational, social, and community inclusion, are central to interventions involving technology use by students with ID. Moreover, positive outcomes for adults with ID in the area of employment-related skills and behaviors can be potentially achieved through interventions based on the use of technology devices (Wehmeyer et al. 2006). However, on the grounds of the heterogeneity issue in the field with ID along with the tendency toward the application of UDL principles, there are still suggestions for further evaluation of educational interventions pertaining to technology use in relation to the abovementioned areas to strengthen their role as evidence-based practices (Bouck and Bone 2018; Wehmeyer et al. 2008).

The application of universal design (UD) principles in designing technology devices, along with an emphasis on cognitive access, can be beneficial for people with ID as regards the functional use of technology in a variety of domains and contexts (Wehmeyer et al. 2004). In their meta-analysis of single-subject design studies, Wehmeyer et al. (2008) examined the degree to which UD features, namely, "equitable use, flexible use, simple and intuitive use, perceptible information, tolerance for error, low physical/cognitive effort, size and space" (p. 23), were identified in the studies with regard to the technology device used. The results indicated that, with the exception of "flexible use," every other UD feature was reported only in few studies (less than 10%). Nonetheless, it has been suggested that recent advances in the field of assistive technology, including mobile technology, are more likely to have the potential to meet the basic principles of UDL, i.e., "provide multiple means of representation, provide multiple means of engagement, and provide multiple means of action and expression" (Cumming and Draper Rodríguez 2017, p. 165). However, there is still a need for more research evidence with regard to the use of mobile technology in interventions to support students with disabilities across different areas (Cumming and Draper Rodríguez 2017).

Related literature includes numerous studies which demonstrate that educational software can assist students with ID in both academic and everyday skills. Moreover, recent tablet and smartphone devices offer a new user experience both through their mobility (in classroom-centered, outdoor, or home activities) and their multi-touch, direct manipulation interaction (Gunderson et al. 2017; Hetzroni and Banin 2017). This new user experience can have a direct effect on the acceptability and effectiveness of learning applications for students with ID.

With respect to research findings, assistive technology devices and in particular mobile technology were found to have beneficial effects for students with ID in life skills development and consequently in the domain of independence (Ayres et al. 2013). It should be highlighted though that the notion of independence in relation to technology use can be viewed as a result of both skills (e.g., life skills) acquisition and reduction in external adult help during task completion. For example, in previous studies, self-prompting procedures with video, photographic, and auditory prompts using a personal digital assistant (PDA) were successfully implemented for the instruction of daily living skills, such as cooking and independent pedestrian travel, to high school students with ID (Mechling et al. 2010; Mechling and Seid 2011).

Taken an inclusive perspective, schools are to ensure meaningful opportunities for all students to learn and achieve (Florian et al. 2017). However, students with significant cognitive disabilities (e.g., moderate or severe intellectual disability) still face a high likelihood of placement in separate educational settings than in general, inclusive, education classrooms (Kleinert et al. 2015). Nonetheless, according to research findings, students with ID may have benefits not only in the social domain but also in academic learning within general education classrooms (Hudson et al. 2013). Technology has the potential to support students with ID on their performance, meaningful participation, and engagement in inclusive learning environments. For example, assistive technology solutions and especially the use of augmentative and alternative communication (AAC) systems (e.g., modern devices and applications based on tablet and mobile technologies) by students with ID having limitations in the area of communication are related to both within-school and out-of-school positive outcomes (Davies et al. 2018; Fossett and Mirenda 2007).

In respect of the provision of academic content instruction and the promotion of access to the general curriculum for students with disabilities, including ID, it has been suggested that the utility of advanced mobile technologies could enhance their academic achievement (Ok and Kim 2017). For example, Creech-Galloway et al. (2013) used a simultaneous prompting procedure and delivered video via a tablet showing real-life situations with applications of the Pythagorean theorem to teach geometry skills to secondary students with ID and specifically the use of the Pythagorean theorem. Furthermore, technology (e.g., speech-to-text) has been utilized to academic skills instruction, such as writing skills, in students with ID (Cannella-Malone et al. 2015). Writing skills have been also taught in the context of promoting independence and functional skills. For example, the implementation of a computer-based instruction package in combination with a teacher-directed forward chaining procedure provided in a small group structure resulted in improved performance in manual spelling of grocery store words for students with ID attending a high school transition program (Purrazzella and Mechling 2013). In another study, written expression in the context of text messaging on a smartphone and in particular the inclusion of specific socially appropriate statements or phrases within text messages was successfully promoted in young adults with ID by involving a robot in the instructional procedure (Pennington et al. 2014).

The recent trend to extend mobile learning applications with augmented reality (AR) features offers additional opportunities for students with ID. AR has the potential to radically change the nature and effectiveness of digital learning material and activities, through a new 3D interactive experience (Reardon et al. 2016; McMahon et al. 2016). Another recent technological development with a clear potential to students with ID refers to educational robotics (ER), through their new interaction and communication capabilities and the facilitation of a stable environment for experimentation, creation, and learning.

To summarize, it is well documented that technology constitutes a promising avenue for supporting students with ID in educational contexts. However, taking into account the rapid advancements in technology, more empirical research evidence is needed on how and whether students and young adults with ID incorporate advanced technology into their lives (or have the opportunities to do so), across a range of contexts including academic tasks and learning, and everyday living (home, interpersonal, leisure, and community activities).

In the relevant literature pertaining to technology use in people with disabilities, the potential role of technology on decreasing marginalization and assisting students with disabilities to enhance their autonomy is highlighted. In this case, a probably dynamic linkage between technology use and aspects of self-determination may be acknowledged (Ayres et al. 2013). Enabling a student with ID to effectively utilize technology either in academic or nonacademic contexts could have beneficial effects on student's self-determination. For example, previous intervention studies reported a positive impact of the use of microswitch technology on promoting communication skills in students with profound and multiple disabilities and specifically demonstration of responses related to access to preferred stimuli and choice making, both of which are considered aspects of self-determined behavior (Roche et al. 2015). Technology (multimedia) has been also used in promoting self-determination and self-advocacy in secondary students with intellectual and developmental disabilities in the context of enhancing their active participation in the Individualized Education Program and transition planning process (Van Laarhoven-Myers et al. 2016). Furthermore, the results of a previous study have also shown a positive effect on self-determination of an intervention involving technology use that aimed to promote the involvement of students with disabilities, including ID, in transition planning (Wehmeyer et al. 2011).

In light of the above, it could be suggested that technology has promising prospects for the improvement of people with ID functioning, participation, and progress in various domains, including education and everyday life activities. On the grounds of the implementation of inclusive practices, there is an increasing interest in developing strengths-based interventions targeting the effective and meaningful use of technology devices by people with ID on the one hand and on the other in successfully integrating instructional and assistive technology in education in order to promote positive school and post-school outcomes for students with ID.

Conclusions

Quality of life, self-determination, and social inclusion are among the prospective outcomes of supports provisioned for students with ID, and technology is considered as having a substantial role in the process toward their acquisition. However, a critical issue regards the students with ID sufficient training in using assistive technology devices in order to avoid its abandonment or low use (Alper and Raharinirina 2006). Training and preparation of students with ID on the use of technology devices should be a substantial part of broader interventions targeting the organization of the decision-making process with regard to the selection of personalized technology supports (Ayres et al. 2013). The cognitive and adaptive behavior characteristics of students with ID and the related heterogeneity call for interdisciplinary teamwork involving the collaboration between experts in the field of ID, psychology, education and those with expertise on technical issues (Lancioni 2017; Wehmeyer et al. 2004). Nonetheless, the preferences of the students with ID should be a vital consideration during the development of assistive technology services and interventions (Taber-Doughty et al. 2008). On the other hand, rapid technological advancement induces a need for the school staff, practitioners, and professionals in the field of ID to pursue professional development on technology supports for people with ID (Ayres et al. 2013).

Technology seems to be quite promising in offering benefits to students with ID in terms of learning opportunities and educational and societal inclusion. However, there are critical challenges that need to be effectively addressed pertaining to the quality of technology supports, such as solutions tailored to individual needs and strengths in relation to environmental characteristics, and quality of technology usage, such as student's and teacher's knowledge, instruction, and positive experiences in using technology tools (Thompson et al. 2016).

Within an inclusive society, it is imperative to provide appropriate supports to people with ID to enhance their independence and quality of life, and within this context, technology constitutes a promising pathway to this end. However, it is also imperative to assess and consider the experiences of people with ID by hearing their "voices" and asking for their opinion, besides preferences, on the perceived personal and social outcomes of technology use, and on the perceived parameters that could make more fruitful to themselves the use of technology and enhance their positive personal and social experiences as well (Tanis et al. 2012). Technology could be used as a vehicle for accomplishing such a perspective, since it may provide to people with ID opportunities not only to learn and achieve in a variety of fields but also to express themselves through various solutions.

Within inclusive settings, multimodal systems and material, including low- and high-tech solutions, should be available and used in combination with evidence-based instructional strategies to enhance active learning and engagement of students with ID in academic content (Hudson et al. 2013). The utility of advanced technology devices, especially mobile technology solutions (e.g., tablets), has opened new perspectives in supporting students with ID. The effective and appropriate use of mobile technology can be beneficial to students with ID in terms of educational, personal, and social goals and is considered a potential way of developing more inclusive classroom environments, promoting students' participation, independence, and social interactions, increasing learning and self-expression opportunities, and decreasing stigmatization (Burke and Hughes 2018).

The utility of advanced technology on assisting and supporting students with ID is a rapidly evolving research area. Undoubtedly, the relevant findings can inform educational practice and intervention development efforts. In the current literature, a need for further research evidence to shed more light on several challenging issues is highlighted, such as the incorporation of assistive technology into classroom on the basis of UDL principles, the implementation of relevant strategies in inclusive rather than separate education environments, the development of evidence-based strategies and interventions concerning technology use, and the ways to facilitate the utilization of technology by people with ID in terms of availability and usability (Bouck and Flanagan 2016; Cumming and Draper Rodríguez 2017; Ok and Kim 2017; Wehmeyer et al. 2008).

As discussed in the beginning of the entry, some of the key concepts behind the understanding of ID are *person-environment/context interaction*, *social and human rights perspective, social-ecological perspective,* and *strengths-based and personalized supports*. Information and communication technologies (ICT) and industry have identified the objectives of *adaptation* and *personalization* for their applications and services, as a means to meet the demand for a better user experience through technology. The e-learning industry has also adopted the "anyone, anytime, anyplace" motto, to underline the fact that barriers are increasingly overcome through the flexibility offered by technology. At the research level, personalized learning environments, which are capable to adapt to the profile of each individual learner, have been the focus for more than 50 years. The complexity of the problems involved limits the generalization and commercialization of respective results. Nevertheless, the emergence of the *ubiquitous* computing and learning era calls for more inclusive applications, to cater for the diversified usage scenarios of *all* users/students. In the knowledge society, users/learners are expected to access learning applications in different settings, which have profound effects on the understanding of disability. This fact has been acknowledged by the technical literature, as reflected in specifications of the IMS Global Learning Consortium (2004): "The term disability has been re-defined as a mismatch between the needs of the learner and the education offered. It is therefore not a personal trait but an artifact of the relationship between the learner and the learning environment or education delivery. Accessibility, given this re-definition, is the ability of the learning environment to adjust to the needs of all learners." In this context, it can be expected that future learning applications and services will become progressively more inclusive to cover the needs of potentially *all* users/learners, including students with ID.

Cross-References

- ▶ Assistive Technology and Inclusion, Philosophical Foundation
- ▶ Computer-Assisted Instruction, Changes in Educational Practice as a Result of Adoption of ICT
- ▶ Computer-Assisted Learning
- ▶ ICT-Based Inclusive Education

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Assisting Students with Learning Disabilities Through Technology

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Synonyms

Actor-network theory; Education; ICT; Job opportunities; Learning difficulties; Learning disabilities; OECD; PISA; Social and collaborative technology; Special needs; Special needs students; Special schools; Students with learning difficulties

History and Definition of Learning Disabilities (LD)

The terms learning difficulties and learning disabilities are usually referred to as LD. The history of LD has been well documented with respect to the nature of particular problems (specific language and reading disorders and the behavioral correlates of brain injury) and the structure of special education at the time; a compelling case was made for the need for a category like LD (Kavale and Forness 1995). It should be noted that given the sensitive nature of this problem, and the wide range of special needs, one must be very careful when applying the definition as inferences could be drawn that could lead to negative results.

The history of LD in Australia has been documented in several studies, including Jenkinson (2007), Elkins (2000), and Rivalland (2000). In fact, the definition of LD that is adopted and accepted in a significant way in this important field is also debated, and according to this analysis, the definition hinges on the following main terms that are used in Australian schools:

- Learning difficulties
- Learning disabilities
- At educational risk
- Special needs

These terms are used to describe children who have difficulties with literacy and numeracy learning.

It should be clear to the reader that the meaning of these terms varies from state to state and from school to school in Australia. In fact, the author came face to face with the main actors of a special school where it was not the protocol to refer to students with learning difficulties as LD students, but instead, these students should be referred to by the term “special needs” students. Although these perceptions may be present, the term that has been universally adopted is LD as it is used globally and refers to students with learning disabilities; it should be noted that in the UK, the term Special Needs Education (SNE) is used in a formal context to distinguish students with learning difficulties and other disabilities. In some publications, the term “learning disabilities” was used by the Department of Education, Employment Training and Youth Affairs (DETYA 1999) and was also used to classify funding categories for special needs students:

> a student, who has been assessed by a person with a relevant qualification, as having intellectual, sensory, physical, social/emotional or multiple impairments to a degree that satisfies the criteria for enrolment in special education services provided by the government of the state or territory in which the student is located. (DETYA 1999, p. 2)

The definition of LD appears to be a little vague, and evidence from previous studies in the literature indicates that the normal mainstream curriculum appears to disadvantage this category of students. The question “What is LD?” has been a long-standing source of controversy, conflict, and crisis. Although research in LD has experienced unprecedented growth and has had significant impact on special education, it remains among the most problematic classifications because of the vagaries and antagonisms surrounding the definition (Shakespeare 2005).

Over time, a number of LD definitions have been proposed, but none had emerged as an unequivocal favorite. Currently the two definitions that dominated this area are the legislative definition found in the Individuals with Disabilities Education Act and the one proposed by the National Joint Committee on Learning Disabilities (NJCLD 1994), a consortium of representatives from organizations interested in LD.

The definition of learning disabilities (LD) is a very strongly debated matter. Organizations, such as the National Joint Committee on Learning Disabilities (NJCLD 1994) in the USA, and Australian government groups, such as MCEETYA (2005), have considered and debated the relevant definition of LD or special needs.

The definition of LD which has been adopted in this entry is the one presented by Kirk (1962) and is quoted here for completeness:

> A learning disability refers to retardation, disorder, or delayed development in one or more of the processes of speech, language, reading, writing,

> arithmetic or other school subjects resulting from a psychological handicap caused by a possible cerebral dysfunction and/or emotional or behavioural disturbances. It is not the result of mental retardation, sensory deprivation or cultural and instructional factors. (Kirk 1962, p. 263)

An issue that has concerned education authorities around the world is whether students with learning disabilities should receive their education in mainstream classrooms or in some form of special schools. A number of researchers support the view that students with LD require an alternative approach to their learning, while others claim that it is best to integrate these students with mainstream classes (Bulgren 1998; Kavale and Forness 1995). Overall, however, there is considerable evidence to support the existence of special schools to cater for the needs of LD students. These schools often exist on a small amount of funding support from the government; however, they cater for individual differences in a significant way through their own fundraising and budgeting efforts.

In a national Australian study that was conducted in 2000, it was found that particular schools demonstrated their comprehensive curriculum through the integration of ICT (Cormack et al. 2000). One of the schools included in that study was Concord School, Bundoora, Victoria; that school maintained its philosophy and belief that ICT provided a lifelong learning and skills for students with LD.

Early researchers concentrated on the learning difficulties of a single primary area or field like English, Mathematics, or Science. Their work and analysis depended on the identification of some criteria or factors like IQ, which did not adequately demonstrate the full scale of the learning problems and disabilities (Bulgren 1998).

From the early days of computers and technology, teachers and researchers were keen to explore computer-based tools in order to enhance learning outcomes. In particular, some of the computer-based software on dyslexia in the 1980s was developed by people who were closely related to students who suffered from dyslexia. For example, Stanovich (1980) used dyslexic software programs to aid students in this area. It should be noted that similar software application programs were used in the UK and in particular people with dyslexia were assisted with ICT (Becta 2005). Other computer-based software involved mathematical problem-solving, games, and simulations. The latter is a significant area that involves ongoing research about the way games can stimulate and engage students with learning disabilities.

While these approaches may have provided an environment for work and stimulated the students' own interest, there was insufficient evidence to support that the learning outcomes had improved to a significant extent through these approaches (Newhouse et al. 2002 and Becta 2005). The entry will discuss and compare the participant observations from the special schools, and in particular, it will provide evidence of the impact that games have on self-esteem, engagement, and learning outcomes for LD students.

How Big Is It: Prevalence?

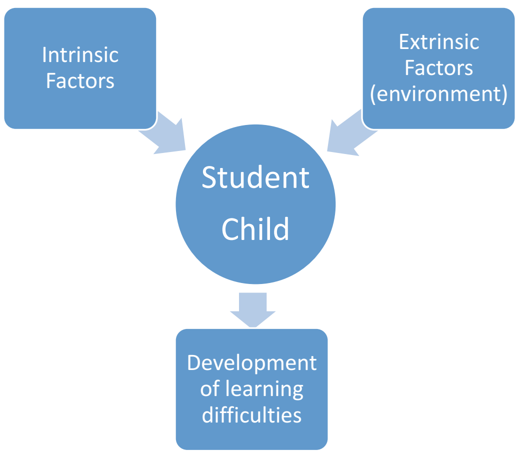
It should be noted that globally, the students with LD (OECD 2005) are a unit of interest for researchers, and in some cases, they appear as a sub-unit (subset) of a larger group of people who are disadvantaged in life – for example, the Australian Indigenous people, the Aborigines. In the UK, the House of Commons Education and Skills Committee, 2005, report summary states that:

> In 2005 around 18% of all pupils in school in England were categorised as having some sort of special educational need (SEN) (1.5 million children). Around 3% of all children (250,000) had a statement of SEN and around 1% of all children were in special schools (90,000)—which represents approximately one third of children with statements. With such a large number of children involved, it is important to recognise that many children are receiving the education they need in an appropriate setting. It is equally important, however, to highlight the difficulties faced by a large number of parents for whom the system is failing to meet the needs of their children. (HC: 478 I 2005-06, p. 5)

The Australian literature identified a study by Elkins (2000) where an analysis of learning difficulties and disabilities was reported (Fig. 1). The sections below provide a summary of the main findings about this important area. The prevalence and identification or reference to special needs is also extracted from a study by Rivalland (2000) (Fig. 2).

The prevalence data were analyzed state by state in Australia in a study by Rivalland (2000) in “Policies and Practices: Students with Literacy Difficulties” case study in Elkins (2000) “Mapping the Territory” vol 1.

What is important here is quoted in the following paragraph from the report by Rivalland:



Assisting Students with Learning Disabilities Through Technology, Fig. 1 Learning difficulties: factors. (Source: Elkins 2000)

> The many differences in definition and identification across the systems and sectors make it very difficult to make generalisations about prevalence. However, the case study schools do tend to reflect the findings of the Survey of Schools. Most of the case study schools, like the schools in the survey, reported a range between 10 percent and 30 percent. Many of the case study schools clustered between 15 percent and 25 percent with three schools reporting prevalence data below 15 percent. (Rivalland 2000, p. 51)

The terminology of learning difficulties and learning disabilities is further reflected in a survey (Rivalland 2000, p. 69) where principals referred to these categories by the following percentages listed in Table 1.

The term “learning disabilities” was more likely to be used by teachers with special education training and by school psychologists. The term LD is widely accepted in the psychological field in the USA, but is usually qualified in Australia to specific learning needs.

The definition that has been used for the term LD by MCEETYA (1999) is similar to one from the USA and is provided here to assist the discussion:

> A generic term that refers to a heterogeneous group of students who have significant difficulties in the acquisition of literacy and numeracy and who are not covered in the Commonwealth’s definition of a student/child with a disability. . .Learning disability is believed to be a difficulty that is intrinsic to the individual and not a direct result of other conditions or influences. (MCEETYA 1999)

Western Australia	Victoria	New South Wales	South Australia	Queensland
Crestwood (20%)	St Bernadette’s (5%)	Lake Hewitt (25%) estimated by principal	Messiah (13%)	Bennetts Hill (24–25%)
Rivergums (30%)	Hilltop (10–20%)	Grisham (15%)	Franklin Landing (15%)	Durie (25%)
St George’s (22%)	Mountain Ash (10–15%)	ST Philomena (15%)	Beachcliff (17%)	St Evangeline (32%)
District High (10%)	In Victoria, very high estimate of at risk students were shown at the start of Year 1			Thornburn not applicable Learning disability program

Assisting Students with Learning Disabilities Through Technology, Fig. 2 Prevalence data. (Source: Rivalland 2000)

Assisting Students with Learning Disabilities Through Technology, Table 1 Reference to learning difficulties. (Source: Rivalland 2000)

Factor	%
Learning difficulties	47
Children at risk	37
Special needs	17
Learning disabilities	10

Assisting Students with Learning Disabilities Through Technology, Fig. 3 Venn diagram for learning difficulties

Range of Special Needs

Given the complexity of the definition of learning difficulties, one way to represent these differences is with the following Venn diagram shown in Fig. 3.

The term "learning difficulties" is used to refer to a large group of children who need extra assistance with schooling, while "learning disabilities" refers to students who are a small sub-group who exhibit severe and unexplained problems. In fact, in the USA, it is also referred to as "learning educational disabilities."

The research presented here originated with an interest in dyslexic students. A federal government report on students with disabilities – "Technology for Learning: Students with Disabilities" – reported 21% prevalence (Cormack et al. 2000). In a study by Miles (2004) in the UK, a number of issues were discussed that might account for the difficulty of assessing the prevalence rate with dyslexia around the world. Among these are the issue of resources to carry out the analysis and dyslexia variants. The prevalence rate varies between 5% and 17% (Wikipedia), and Miles (2004) arrived at the conclusion that in the UK, there are approximately 4–6% people who are dyslexic. All that can be said with any certainty is that in every English-speaking country, a significant percentage of the population has reading and spelling difficulties varying from mild through to severe. A parliamentary report titled "Helping People with Dyslexia: A National Action Agenda" shows that the prevalence rate across all states in Australia ranged from 5% to 10%. These facts show that the prevalence rate of dyslexia has not changed by a significant amount over the last two to three decades.

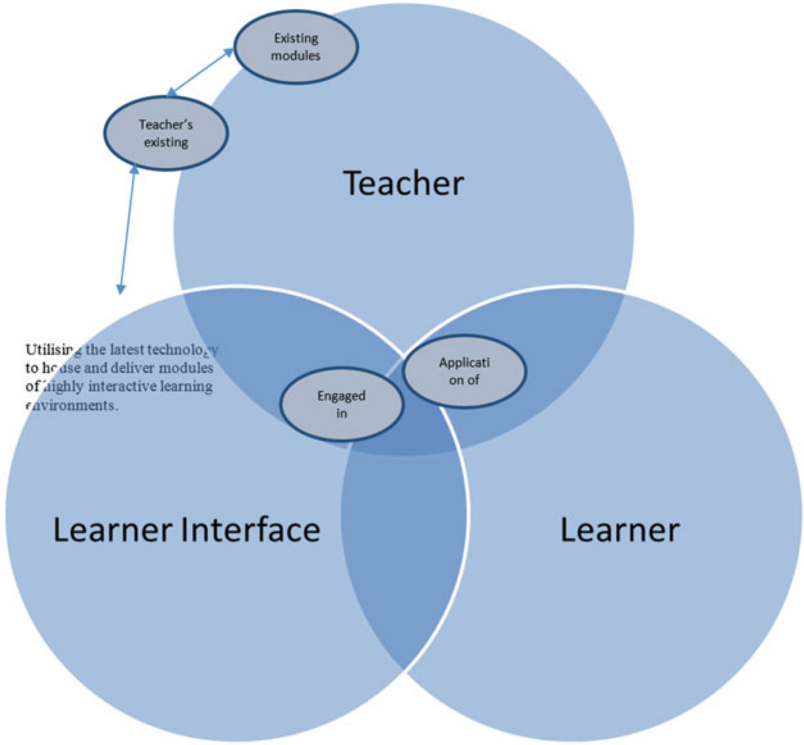
Models for Education and Technology for Disability

A starting point in modelling learning with ICT is the Learning Interface Model (Adam et al. 2006) – see Fig. 4. In this model, teaching can be thought of as an interaction between teachers, students, experience, and knowledge (Schunck and Nielsson 2001). How these entities interact can be seen in different teaching/learning paradigms, ranging from one characterized by a verbal flow of information streaming from the teacher directly to the students to the model shown in Fig. 5.

In this model, the teacher acts as a catalyst or consultant for students to show them where information can be obtained from. Next, we can consider the model from Schunck and Nielsson (2001) as a starting point to examine what changes are needed to the traditional teaching model as we move toward the adoption of technologies in the curriculum. These changes are captured in Fig. 6; this is a reproduction of the model in a study reported by Schunck and Nielsson (2001).

From Traditional Teaching and Learning Models to e-Learning

In their study, Schunck and Nielsson (2001) examined three different scenarios to describe pedagogic developments from a historical perspective. These perspectives primarily focused upon the interaction between teachers, students, and given subject matters (domains). In proposing

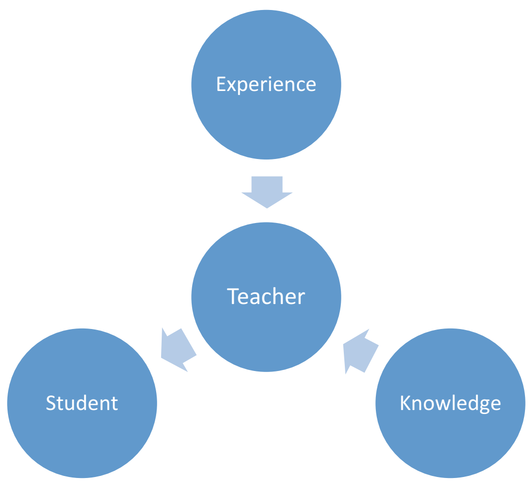


Assisting Students with Learning Disabilities Through Technology, Fig. 4 Learner Interface Framework – Adapted from Brusilovsky and Papert. (Source: IEFTS 2001)

their model, they considered the following paradigms:

The paradigm of yesterday
The paradigm of today
The paradigm of tomorrow

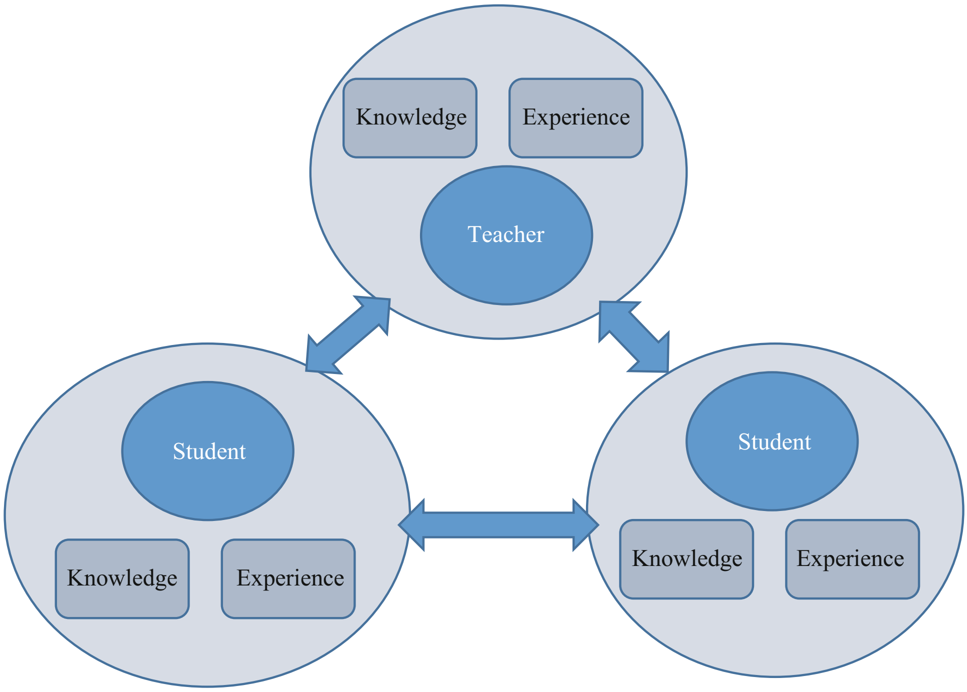
Naturally, the structure and the developments in the surrounding society as well as the political dimensions play an important role as far as the models' individual lifetime and the transition from one model to another are concerned. The models may be looked upon as changes of paradigms, assuming new forms in connection with the implementation of new discoveries or theories and new decisions or changes in views and attitudes.



Assisting Students with Learning Disabilities Through Technology, Fig. 5 Paradigm of yesterday. (Source: Schunck and Nielsson 2001)

Adopting the Schunck and Nielsson e-Learning Model for LD Students

The study adopted the above e-learning paradigm to determine the impact of technology on the educational outcomes of LD students. The model in Fig. 7 illustrates the facilitating role of the teacher and the independence of students in working and sharing their knowledge through experiential learning. The early research was



Assisting Students with Learning Disabilities Through Technology, Fig. 6 Paradigm of today. (Source: Schunck and Nielsson 2001)

proposed at Macedon Ranges where this model was applied to the main actors, like the school principal and the IT coordinator. Fortunately, the model was accepted, and the research study was facilitated through the exploration of the policies and infrastructure that was available at the school level.

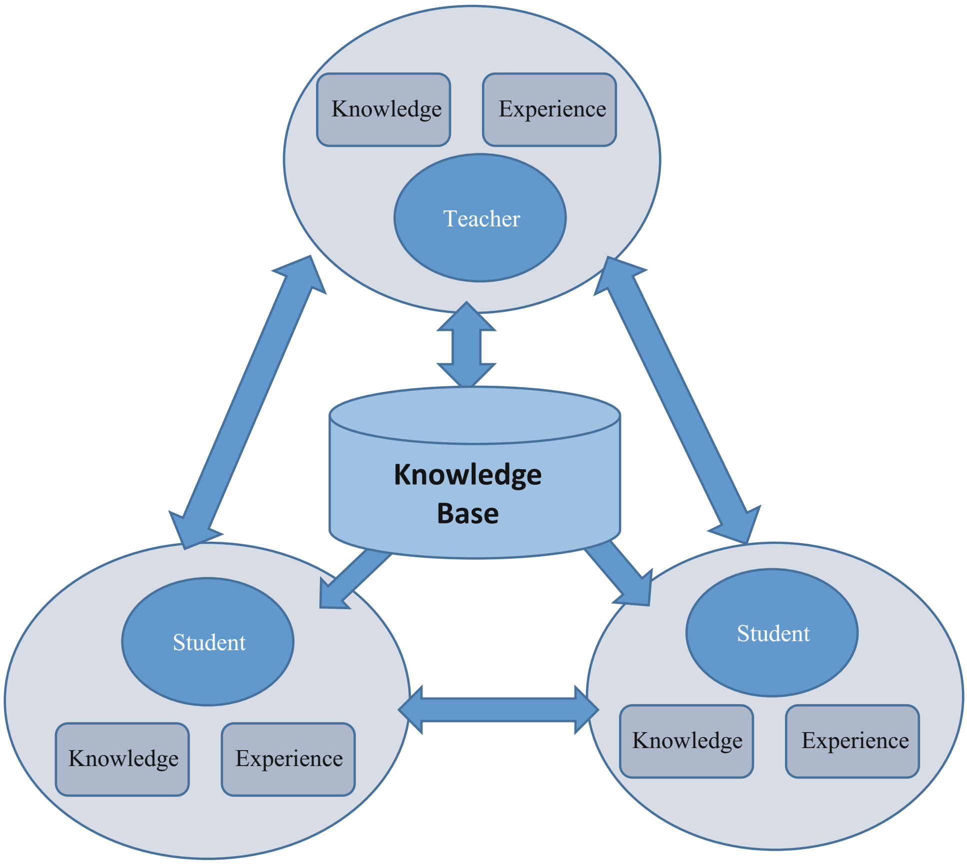
Technology Enablers and Inhibitors for Disability

Earlier research explored issues regarding both the adoption and impact of ICT in teaching and learning. The main regions that were considered were Australia, the UK, the USA, and Africa. In addition, studies were found from some other countries like Turkey, Nepal, and Malaysia, where technological, political, and socio-technical factors were investigated. The main findings from these studies relate to school leadership, professional development, and perceptions from parents. In a study by Elliott (2005), the main factors that were identified were in fact divided into two categories, structural and process barriers, and are summarized in Tables 2 and 3.

According to Elliott (2005):

> ICTs have not had the widespread impact on teaching and learning processes envisaged a decade or so ago is disappointing but not surprising. Most educational innovation happens slowly and ICT is in itself continually transformed by new developments and market conditions. It is not a discrete subject and its applications in education are the subject of considerable debate, informed by a combination of scholarly discourse, opinion and research. (Elliott 2005, p. 8)

Elliott further provides a summary of the literature for barriers to effective ICT learning in schools. The following are highlighted in several contexts (White 2005), and calls for national ICT standards, greater institutional support and infrastructure, and better professional development for teachers have been addressed to varying degrees in all states and territories.



Assisting Students with Learning Disabilities Through Technology, Fig. 7 Paradigm of tomorrow: the e-learning paradigm. (Source: Schunck and Nielsson 2001)

Assisting Students with Learning Disabilities Through Technology, Table 2 Structural barriers for ICT adoption. (Source: Elliott 2005)

Structural barriers
Limited classroom space
Lack of computers and/or internet in classrooms
Unreliability of the technology
Lack of leadership and support from principals
Lack of institutional support and encouragement
Poor technology infrastructure
Class timetabling difficulties, short lessons

Elliott further proposed the following factors should be considered for the adoption of ICT in schools: school leadership, teacher competency, level of support, teachers of LD and ICT ongoing,

Assisting Students with Learning Disabilities Through Technology, Table 3 Process barriers for ICT adoption. (Source: Elliott 2005)

Process barriers	
Poor teacher attitudes toward technology, lack of teacher confidence	Lack of professional development or inappropriate PD
Conflicting information on the value of ICTs in learning	Lack of time for planning and preparation
Limited teacher skills and competence especially in the face of rapidly changing technology	Lack of involvement in computer room and/or classroom layout/planning
Classroom management difficulties	
Difficulty to adjusting to new pedagogies	

teacher awareness, and teachers' view of ICT (Soderstrom 2009).

In a study by Bates et al. (2007), models of early adoption of ICT innovation in education were considered. In particular, the characteristics of early adopters were reviewed, and these basically related to the following main areas:

- Experienced microcomputer users
- Individuals displaying opinion leadership qualities
- Individuals more likely to investigate new developments

Elliott (2005) further argued that in order for technology to be accepted and incorporated in learning and communication, the following three main areas must be considered:

1. Encouragement of teachers to embrace ICT in their teaching and school culture.
2. Investigation of how ICT can best support and improve the learning outcomes.
3. Analysis of the impact of the digital divide.

In general, Australian teachers felt that they did not have adequate support for effective ICT use and integration of ICT in the curriculum. This view was also supported in research studies by Becta (2005). Moreover, research studies by OECD (2005) and Meiers (2009) provided similar arguments and concerns from the teachers.

Environment for Technological Innovation

National and other studies on the use of technology by Newhouse et al. (2002), Shaddock (2007), Meiers (2009), and White (2005) established that ICT has a positive effect on teaching and learning. In the UK, Becta carried out several research studies to determine the impact and adoption of ICT in schools.

The movement and acceptance by schools of technology is summarized by Ertmer et al. (1999):

> Despite the fact the number of the computers in teacher's classrooms has increased dramatically in the last 20 years, researchers and educators alike report that integrating technology into classroom curricular is not easily accomplished. (Ertmer et al. 1999, p. 54)

Undoubtedly, technology has been adopted and integrated successfully in the administration of schools. In Victoria, for example, this was promoted and progressively rolled out through policy initiatives between 2000 and 2006. The aim is to provide a standardized platform for Victorian government schools in order to help them manage their core administrative and finance functions. The software, called Computerised Administrative System Environment in Schools (CASES21), is an integrated school administration and finance system that supports approximately 1600 government schools. It is designed to facilitate schools with data reporting to the Department of Education and Early Childhood Development (DEECD). Although the Auditor General's 2008 Report findings show that the system has improved school administration for a broad range of schools, there are a number of large schools that have reported that the perceived benefits have not yet been fully achieved (Auditor General's Report 2008, CASES21 2008).

A report by Cuttance on school innovation concluded that school classrooms were adapting to the needs of students so that they can develop skills and knowledge to use information, to collaborate, and to communicate effectively with others through ICT (Cuttance 2001). The report further stated that there is no unequivocal evidence about the impact of ICT on the learning outcomes of students although a significant number of studies had indicated that there is potential for ICT to improve the learning outcomes.

In addition, similar to the findings from Becta (2005), the report supports the view that computers in classrooms increase student motivation and increase student control over learning and access to information (Shaddock 2007; Meiers 2009).

The last example to innovations and projects in this section is the Innovation and Best Practice Project (IBPP) from the Cuttance (2001) report. The report included a study on the impact of laptops with 20 schools in the special project (IBPP). For one of the groups where the students had their own laptop, the research evaluation for the innovation program did not produce evidence of their impact to be as strong as the group that used desktop computers. The innovations were based on constructivist learning principles because contemporary learning theorists argued that this was the most appropriate way to facilitate the students learning outcomes and allowed them to control their progress in ICT integrated classrooms (Shaddock 2007, and Cuttance 2001).

The Value of Using ICT in the Education of School Students with Learning Difficulties

Children with Learning Difficulties

The Good Schools Guide (2016) points out that: "Some students who have no obvious physical or mental impairment can have trouble managing tasks necessary for learning, such as concentrating, keeping still, making themselves clear or understanding tasks set in class." The term "learning difficulties" (LD) is used to refer to this quite large group of children who need extra assistance with schooling that arise from a vast range of cognitive and physical impairments.

Several related terms are "special needs students," "students at educational risk," and "students with specific learning disabilities." While the terms "special needs students" and "students at educational risk" mean essentially the same as "students with learning difficulties," the term "specific learning disability" refers to a distinct handicapping condition for a small sub-group of students who exhibit severe and unexplained problems. In this entry we will refer only to "students with learning difficulties."

Learning Difficulties Australia (LDA 2016) notes that in Australia, the term learning difficulty refers to those students "who experience significant difficulties in learning and making progress in school, but who do not have a documented disability such as an intellectual disability" and that about 20% of students (LDA 2016) have some form of learning difficulty in some aspect of learning. Most schools are able to help these students in some way by setting up special classes, by working with teachers and parents to help them in ways of coping, or by the use of specialists. In other cases special schools offering greater support and a specialized learning environment exist to cater for these students.

Many countries have tackled the dilemma of school membership for students with learning difficulties considering whether these students should be kept in mainstream schools or moved into special schools designed to cater for their needs (Adam et al. 2006; Laabidi et al. 2014). Although many researchers claim that it is best to integrate these students into classes within mainstream schools, numerous "integration" or "remedial" programs in mainstream schools have proved ineffective for the total learning of this group of students. There is strong evidence to support the existence of segregated special schools, and there are around 35 special needs schools in metropolitan Melbourne (Australian Schools Directory 2016). Many previous studies on LD have focused on only one or two specific factors such as IQ, but the literature shows that IQ does not yield valid results or assessments here. The literature also provides examples of where these students in normal classroom settings achieve little success in situations where technology was not regarded as an integral part of the curriculum (Meiers 2009).

The research underpinning this entry was primarily undertaken in two special schools in metropolitan Melbourne, Sunbury and Macedon Ranges Specialist School and Concord School, concentrating on their use of ICT and computers in classrooms. Discussions were also held with two local polytechnics and an industry training organization on the possible further education of these students.

The study reported here was highly motivated due to work with students with learning difficulties over a long spanning teaching career. Special school programs were coordinated such as the school's federal government funding for special schools program (DSP). This program was set up for the allocation of resources for students with special needs in the 1980s. This interest and motivation culminated in the present research study. It led to the close participation and observation of students with special needs in two outer suburban (regional) special schools (Macedon Ranges and Concord) and, in addition, an individual case study to apply some of the early findings and make a comparison. One of these schools provided a basic ICT infrastructure for its staff and students, while the other provided a more enhanced "state-of-the art" ICT environment that was integrated into the school's curriculum.

These two schools provided two distinct geographical groups of students and were observed over a significant time period. During this time various government departments and agencies were also visited so as to gain an insight into the level of ICT support for students with learning disabilities (or special needs). These included Technical and Further Education (TAFE), the Royal Children's Hospital (RCH), and also some private individual consultants. These consultants worked with a significant group of LD students on a regular basis on language skills and speech pathology at RCH.

In closing this section it should be observed that an investigation on the infrastructure provided a strong link with the Department's IT services. This link enabled the study to determine the level of support that existed for school projects including those that involved ICT with video-conferencing. Furthermore, the Department provided the necessary support for the investigation and analysis of the infrastructure; indeed, this support was essential for setting up the link between the special schools through the Local Area Network (LAN) of the Department.

Methodology

This research was qualitative, framed by actor-network theory, and involved case studies at two special schools in suburban Melbourne over several years by one of the authors who attended and observed specific classes at these schools on a regular basis. Due to the sensitive nature of this area, special approval needed to be obtained from the Victorian Education Department. This allowed a single researcher to enter and observe activities in the school classrooms. The case study data described in this entry was collected mainly between 2003 and 2008 (Adam and Tatnall 2012) and consisted of interviews with the school principal, teachers, and parents (Adam 2011; Adam and Tatnall 2014) on student learning, attitudes to learning, and overall progress. (School pupils could not be formally interviewed under Education Department ethics rules, although informal discussions with some students were held.) As this was exploratory research and the data sample was not large, no claim was made to the generalizability of the findings although it was suspected that further research would confirm them.

Special schools are especially complex socio-technical entities, and research into their infrastructure, organization, and curriculum needs to take account of this complexity. A significant difficulty arises in framing research in a situation like this that involves both technological and human actors ranging from students and teachers to software and broadband connections. When dealing with the related contributions of both human and non-human actors, actor-network theory (Callon 1986) provides a useful framework. Actor-network theory (ANT), or the "sociology of translations," is concerned with studying the mechanics of power as this occurs through the construction and maintenance of networks made up of both human and non-human actors. It attempts to allow for the socio-technical nature of research of this type by giving due and equal treatment to the interactions of both the human and the non-human actors that are involved in each situation and to deny that in regard to technological innovation, purely social or purely technical actions are possible. ANT reacts against the idea that characteristics of humans and social organizations exist which distinguish actions from the inanimate behavior of technological and natural objects, instead offering a socio-technical approach in which neither social nor technical positions are privileged (Adam and Tatnall 2012).

The actors involved in the adoption of this technology to assist students with special needs were found to include the students, their parents, their teachers, school principals, school ICT specialist teachers, the school council, the Web, microcomputers (Windows and Macintosh), laptops, iPads, software, Education Department policies, learning technology policy, the school environment, classroom environments, learning approaches and paradigms, delivery methods of instruction, engagement methods, thinking processes, technology infrastructure-bandwidth, curriculum, Internet resources, digital libraries and other related mainstream, and special schools (Adam and Tatnall 2010).

The methods employed in this research come from those of case study. Yin (2014) regards a case study as the preferred method for examining questions that ask the how or why of contemporary events or when the relevant behaviors cannot be manipulated. He believes that case studies use many of the same techniques as a history, but add direct observation and systematic interviewing. Case study evidence can come from documents, archival records, interviews, direct observation, participant observation, or physical artifacts. In this research study, key (human) actors – teachers and parents – were identified and interviewed about the use of ICT in the school. Questions to the teachers were broad and asked whether, and if so how, the use of ICT in the school had made a difference to the students' learning outcomes. Parents were asked to identify any changes in their child's attitude to learning and ability to perform educationally. The computers and software (non-human actors) were "interviewed" by examining their operation, instruction manuals, and facilities.

Following the main data collection period, contact was kept with Concord School through ongoing conversations with the principal and attendance at a Concord Conference in 2008. After completion of the initial research project, although access to these special schools was no longer possible (under Education Department ethics rules), follow-up discussions were also held over several years with principals and teachers from nearby and feeder schools to see if anything had changed from their perspective. These discussions suggested that what was observed during the case studies was still continuing, and perhaps even accelerating, after this period.

Case Study: Sunbury and Macedon Ranges Specialist School

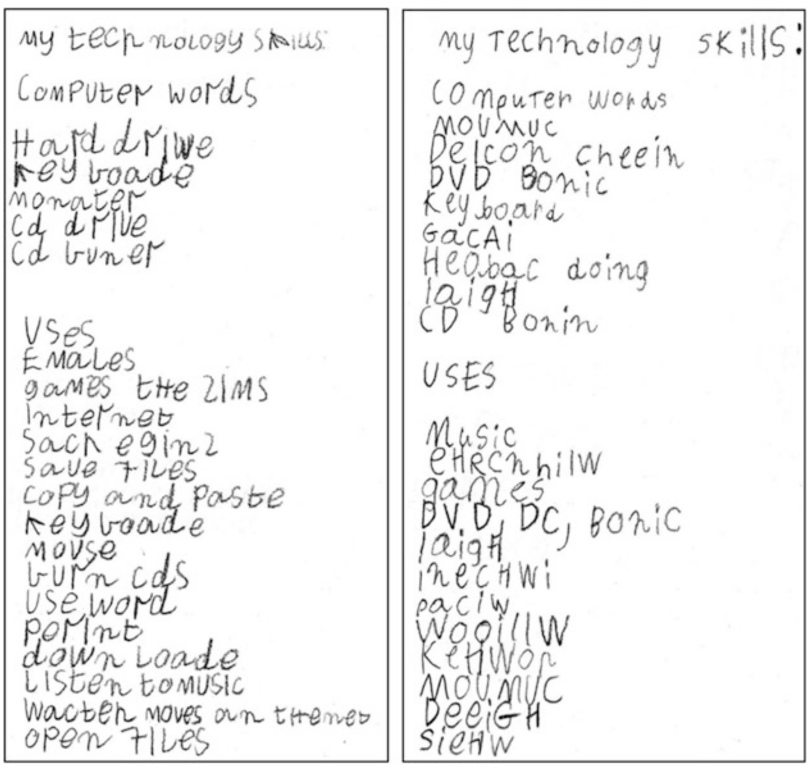
Sunbury and Macedon Ranges Specialist School is a purpose-built school for students with learning disabilities. It has around 180 students with 70 teaching and support staff and provides a range of educational programs for students who present with special learning needs including global development delay, autism spectrum disorder, and physical, social, and emotional disabilities and provides an extensive curriculum consisting of Arts, English, Technology, Health and Physical Education, Studies of Society and Environment, Science, and Maths. In addition to delivering the key learning areas as part of the curriculum, the school provides a broad range of programs that are designed to further enhance the independence of its students. The school motto of "Consistency, Credibility and Continuity" is reflected in the curriculum delivered and underpins all that the school's website claims the school represents (Sunbury and Macedon Ranges Specialist School 2016).

At Sunbury, ICT was used predominantly to reinforce language and numeracy skills. An examination of the school's technology policy and curriculum showed that the use of ICT was an integral part of classroom teaching and learning (Adam 2011) but that access was rather limited.

The reported research involved a small-scale project of observations and discussions with the principal and several teachers as well as a small group of students aged around 14. The students were of mixed cognitive and physical disabilities and in general were keen to use computer games (AbilityNet 2013) that reinforced certain skills like language or numeracy and literacy. The researcher chatted with a few students, Ben, Barry, and Teagan, and watched them play the Magic School Bus on Mars. This showed how puzzles were used in this setting to engage students and help them to improve their perception of space, time, age, and personal attributes (Adam 2011). The students investigated were heterogeneous in LD as there were both physical and cognitive disabilities present in the group. At the school there were certain students with severe physical disabilities. Several students needed help with the CRTL-ALT and DEL keys on the keyboard, and a few needed directions as to how to shut down the computer and the order that the various keys had to be used.

Overall though the students were familiar with their environment and were able to relate to and use technology in a comfortable manner. Parents were generally supportive for the initial ICT study and infrastructure. One technical task was setting up the infrastructure for links between different classes at the local level. In working between classes, the students showed a tremendous level of enthusiasm and immediate engagement when they began to communicate via web cams. The students were provided with an opportunity to respond to the researcher's open-ended questions relating to "My technology skills" and "Uses of technology." Figure 8 shows the list of skills and uses of technology from two of the students at the school.

Sunbury and Macedon Ranges provided a gateway into this research and facilitated an investigation of the infrastructure for school ICT. The results were very significant, enabling identification of the level of support both at the local school level and from the Education Department. The school was also instrumental in



Assisting Students with Learning Disabilities Through Technology, Fig. 8 LD students' skills and uses of technology: early adopters identifying Concord School, where a significant part of the study was conducted.

Case Study: Concord School

Concord School is a special school located in metropolitan Melbourne that caters for special needs students with mild to moderate intellectual disabilities from Primary (elementary) to Year 12 (senior secondary) levels. The students come from diverse socioeconomic backgrounds and are between 5 and 18 years of age. The vision of this school community encompasses a commitment to achieving excellence in education for students with additional learning needs through a curriculum which integrates learning technologies with best practice in teaching and learning. The values embraced by the school community are “Respect, Personal Best, Happiness, Cooperation, and Honesty.”

Concord has a teaching and educational support staff of 110 with an enrolment of about 400 students. The school’s website (Concord School 2016) proclaims that “Concord School is a government P-12 specialist school for students with additional learning needs. It provides a safe and supportive learning environment where students are challenged to achieve and reach their full potential.” It indicates that Individual Learning Plans are used to specifically tailor the educational pathway of each student to meet their targeted learning needs (Adam 2011). This is done through the use of good resourcing, class sizes of 8–12, and education support staff in each classroom. There is also specialized staff consisting of a school nurse, occupational therapists, speech pathologists, and student well-being coordinators. The school has an excellent IT Resource Centre housing the latest technological equipment for use by its staff and students. Classrooms are equipped with an electronic whiteboard, and each student has access to a notebook computer and iPad. The students at Concord School are encouraged with the school motto: “To be the best that they can be.”

For senior students in the school, the curriculum offers alternative studies such as the Victorian Certificate for Applied Learning (VCAL). ICT was clearly seen as a driving force for students with special needs. Concord had a One-to-One (121) Information and Communications Technology initiative in its Transition Centre. In simple terms this required the school to invest in a computer (laptop or desktop) for each student, as well as other accompanying software and hardware (including a classroom interactive whiteboard) for VCAL students. The 121 ICT project offered opportunities for students to use technology that would improve their literacy output, access and exposure to technology, as well as increasing engagement (Adam et al. 2006) and provides evidence that scaffolding with a direct teaching approach enhances the learning outcomes of LD students.

In addition, the study further demonstrates that infrastructure is a significant factor in the successful adoption of ICT in these schools. A major part of the reported research was related to VCAL studies, where the students’ daily work was aimed at completing the set tasks. In addition this program provided access to work and further study with the assistance of local organizations and programs from tertiary institutions. In terms of learning outcomes, the students were involved in activities that allowed them to become familiar with current events, national issues, and disasters (Adam 2011). The ICT programs and environment were reflected in the attitude, motivation, and communication skills of the actors.

Overall, observations and discussions at the school found that a strong focus on the use of technology in teaching and the curriculum can lead to stronger engagement by students and teachers. Although in some cases students faced difficulties with motor skills including writing, drawing, spatial perception, and speech, it was observed over a significant time period that these handicaps were often overcome with the use of ICT. For example, folding a blank sheet of paper to make an envelope and then writing their address on the front of the envelope were very difficult for some of the students. However, almost every student was able to use a laptop and a Word Processing program to do this. It was also apparent that some of the students demonstrated ICT skills beyond what was required in class, and because of this, they tended to show frustration with the teacher in class. The activities appeared to be commensurate with the standard of the students, and the main activities observed included personal development, office skills, and ICT studies (Adam 2011).

The school principal fully supported the research and felt that the school could only benefit from an independent examination of the way ICT was used and how it could be further used to support the 121 project. This was a key actor who displayed very strong leadership, and this was recognized and respected by the school staff, students, and other stakeholders. He was an early adopter of the technology and held the belief that students with LD could be assisted by the use of technology or ICT in the classroom. This actor saw the strength of the school in the strong bond that it had with its students. Everyone in this school community – teachers, parents, assistants, students, and ancillary staff – all had access to the principal who was active and involved in the affairs of the school and very supportive of ICT projects implemented. This was a very enthusiastic actor about innovation with technology and organized work on the infrastructure to get the classrooms ready. His interview comments included the following (Adam 2011):

- "I want to see the students to be active participants in their own learning that leads to specialization in technology."
- "This empowers students (disabled or not) to control and self-manage their own learning at school and at home and hence become lifelong learners with access to technology and skills."
- "Technology provides skills so that they can be seen as normal workers and have gained an understanding to take on the role beyond school."
- "The focus is on collaborative learning with students becoming social and collaborative learners."

A number of teachers were observed and interviewed on a regular basis, and all demonstrated full support for the school leadership and vision in regard to ICT. They were all very strong users of ICT, having their own laptop, used email, and also accessing the school's internal resources through a shared medium (SharePoint). They worked well with the students and implemented school policy, agreeing that ICT was an enabler for the students and that it would improve their learning outcomes, particularly since it was integrated into the curriculum. They showed adequate technical skills and willingness to adopt new technologies. The following comments displayed their belief in ICT:

- "This is an exciting step for students, teachers, and classrooms as it is social and collaborative technology – it is never boring."
- "Yes and they are growing in an environment where the world is at their fingertips."
- "It is a whole new classroom that is not contained to that physical building of the school."
- "It's not just about playing with a new toy – it's exciting because it connects you with others."

Parents of students from several classes were asked to respond to a questionnaire, and the response rate was very high and showed a positive attitude for the use of ICT in the classroom. Several parents indicated an awareness of the use of ICT in the curriculum by the school, and their responses showed that they felt there were still gaps in how technology could assist their child in both school and life. However, they indicated that they had identified a positive gain from ICT and acceptance of the school's work and curriculum. Parent responses included (Adam 2011):

- "Provides confidence, very useful information, spelling, solving problems, skills for the job, and skills for the home."
- "Ability to use laptops and programs not at home."
- "Gain independence in writing and money skills."
- "Have good understanding of various computer programs, source information, look up

bus tables, concert tickets, movies, starting times, etc. independently."

- "My daughter's limitations reduce the degree to which she can use ICT, great learning tools as she is a very visual child, and she likes to be alone often."

Concord School, Transition Centre

The Transition Centre caters for approximately 60 to 70 students from Years 10, 11, and 12 with the aim of facilitating their transition from school to further education or to work, through learning programs that offered an applied learning curriculum. This could be followed up through courses at a local training organization. The practical and pragmatic approach adopted by Concord was that its Transition Students are provided with a curriculum with a strong focus on ICT. In Year 10, students complete the pre-transition learning program designed to prepare them for their post-compulsory schooling. In Years 11 and 12, students complete either their VCAL or a Special Needs Learning Framework program designed by the school. This ensures that learning continues during and after the transition process and is recognized for employment and educational purposes. It also provides a safety net for school leavers.

The practical and pragmatic approach adopted by Concord is that its Transition Students are provided with a curriculum with a strong focus on ICT. And this subsequently can be seen as a vehicle that allows the students to build lifelong skills. From the USA, the "Individuals with Disabilities Education Improvement Act" mandates equity, accountability, and excellence in education for children with disabilities and provides recommendations in regard to the assessment of standards of LD students in the preparation and continuity beyond college. Concord's Transition Centre echoes these ideas. ICT is embedded in the curriculum and the beliefs of staff and school community at Concord. It is a strong vehicle and enabler for good pedagogy as it reinforced the communication skills and engagement and is a clear indicator and facilitator for school to work transition (Adam 2011).

This study provided strong evidence that ICT can equip LD students with adequate skills which allow them to continue with further study through pathways to higher education at a local polytechnic or university. This subsequently can be seen as a vehicle that allows the students to build lifelong skills. The research also showed that LD students can increase their job opportunities as the ICT skills they learn can minimize the impact of their disability or learning difficulty and thus enable them to attain a normal work environment.

At an academic conference in 2007, the ICT coordinator described how Concord School had introduced and trialed the use of social software and networked learning activities and practices. He described the use of relevant software at the time such as Lumil, WordPress MU, ccHost, Urdit, Gregarius, Scuttle, and Firefox by the students at all levels in the school. Table 4 gives a summary of the activities undertaken and what they achieved. Understandably, these have been superseded by more recent programs and tools, but the presence of these strongly demonstrates the significance of this actor.

An Actor-Network Analysis of the Use of ICT for Students with LD in These Schools

Any analysis using ANT deals not so much with the actors themselves as with the interactions between actors and their networks, so ICT is only important here in its interactions with the LD students. Both schools only had significant ICT programs and provided good ICT facilities and student encouragement due to the interactions of their principals with teachers, parents, and the Education Department. The classroom computers are only able to interact with students due to their prior interactions with the school ICT coordinators to prepare workstations, software, and Internet connections. The most important interaction here though is between the students and ICT facilities. We will discuss the data, primarily from Concord School as this was most significant, in accordance with ANT innovation concepts, namely, problematization, interessement, enrolment, and mobilization of actors (Callon 1986) similar to Shaddock (2007).

The leadership of key actors, including the principal, ICT coordinator, and several leading

Assisting Students with Learning Disabilities Through Technology, Table 4 Trialed social media activities undertaken at each section of the school

	Junior	Middle	Secondary	Transition
Using photo-sharing social software to locate suitable photos for use in other work by searching with tags	X	X	X	X
Using photo-focused social software (tagging and comments) to share artwork created with GIMP			X	X
Using photo-focused social software to annotate photos to identify key information and demonstrate learning about horticulture				X
Using photo-focused social software to share sound notes recorded at when the photo was taken to demonstrate learning and understanding				X
Using photo-focused social software to create albums to identify and celebrate a range of learning activities and experiences		X	X	X
Using photo-focused social software to comment on successful learning				X
Using photo-focused social software to easily locate photos for student blogs (digital portfolios)			X	
Using blogs to celebrate and reflect on student learning			X	X
Using ccHost to share scratch sprites, backgrounds, and projects to encourage remixes and collaborative work				X
Importing scratch sprites and reusing and modifying the work of others	X			X
Using ccHost to share audio samples to encourage networked and collaborative learning				X
Using music-focused social software to develop social software skills and activities and create an online presence			X	
Searching music-focused social software using tags to find suitable music for use in other work		X	X	X
Using a web-based feed reader to read aggregated student blog content to facilitate interaction			X	X
Using social bookmarking software to share web resources and encourage networked learning			X	X
Using shared scripts to scaffold use of social software and other internet sites				X

team teachers who worked in the 121 ICT project, all problematized (Callon 1986) the vision of integrating ICT in the curriculum. The most important actors and their interactions were:

- Ten students of mixed cognitive and physical disabilities at Concord were observed working and interacting with teachers and assistants from the senior class in the 121 pilot project. Their main interactions were with their teacher and the school computers, and they were all keen to use computer games. These acted to reinforced skills like language, numeracy, and literacy. They were also able to exchange email with the principal.
- Parents as actors had their own voice and networks and problematized their own way via the school council and supported funding.
- The principal is very much a leadership actor, gatekeeper, strong voice, and power in the school council. He insisted protocols were followed and held a very strong view on the technology, users, and role of technology on learning.
- The ICT coordinator was another leading actor who was recognized for his skills and knowledge. He was assigned the task to enroll other actors and extend the 121 ICT pilot to the rest of the school. He was an innovator who introduced modern technologies and was

very highly regarded by other actors. He problematized ICT curriculum by applying his ICT skills. He also possessed previous experience from working with specific Education Department projects to train others.
- Leading teacher (1) was a key instigator for the 121 project in 2005 and a willing user of ICT in classrooms. This actor problematized the 121 ICT project and the necessary infrastructure for its delivery, possessed high communication skills, and was very capable in mobilizing other actors.
- Leading teacher (2) was highly trained in special needs work and an engaged ICT user. This actor problematized curriculum studies by integrating ICT in general VCAL studies.
- Computers and other technical objects (in ANT, known as immutable mobiles) and their interactions with students were highly significant. For instance, it was amazing to notice the students' reaction to the tablet PC when they saw it for the first time.

The interactions between the students and computers indicated their considerable interest in ICT and showed that their teachers were able to help them in catching up with schoolwork, looking up words in the dictionary, preparing oral presentations, working on the computer, working out things together, and similar activities. They were clear and accurate about who managed the school and the class they belonged to and clearly identified with their home group teacher. In some classes, they were given responsibility to check the attendance roll and organize orders for the store and lunches. They also collected and distributed laptops and trolleys between classrooms in an orderly manner and appeared happy to go from one class to the next and participate in the activities on hand.

The school learning model developed and changed in response to need and the availability and type of resources. It was proactive, and its focus was on addressing the current needs of students, parents, and teachers. For example, inclusion of social networking concepts like blogs was introduced in 2007. This enhanced the way ICT was used in the classroom with students engaging and producing work of higher standard and displaying stronger skills. All this curriculum development was done within the frame of Education Department policy.

Conclusion

The research showed that use of ICT enhances LD students' independence and equips them with adequate skills which should allow them to continue with further study through various pathways and to move into a normal work environment. It also demonstrated the importance that key actors, such as the Concord school principal, have in facilitating the adoption and use of ICT with these students. It was observed that in certain activities that required physical or motor skills, some students were able to overcome these with the use of ICT.

Although Concord did use some performance indicators internally and externally through the number of students completing VCAL, in this entry, it has not been argued that test results and better educational outcomes in the commonly used sense of the term were necessarily improved. It has been argued, however, that ICT can be seen to be an enabler for good pedagogy with these students.

The research found that the most effective manner for teachers to implement programs using computer-based technology is to integrate the technology into the curriculum. In doing so, the special needs students gain lifelong skills and enhance their self-esteem and communication skills. ICT is shown to be an enabler for good pedagogy that can also set a pathway for the transition from school to work or further study for these LD students. It does not change the nature of a subject but has the capacity to integrate and consolidate several areas from the field of study or curriculum. This study found that ICT was applied to teach image refinements, certificate designs, or artifacts in office skills at Concord.

The research data from the case studies demonstrate the power of both human and non-human aspects of the socio-technical network that staff and students construct around LD and the benefit of using ICT in their education. The study provides evidence that for LD students, a significant attainment in skills and academic knowledge is facilitated by the adoption of ICT. This data showed that a strong focus on the use of technology in teaching and the curriculum can lead to stronger engagement by students and teachers. The study strongly supports that ICT increases the motivation, independence, self-esteem, and communication skills of LD students and aids in facilitating transition to work. At least in this respect, producing a different result to that reported in the OECD study, made this research study very worthwhile. The results support the view that ICT has the power to interest, enthuse and inspire these students. This result is illustrated by the comment of one student who proudly said: "We were the first to use a laptop and a smart whiteboard in the school."

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Assistive and Instructional Technology

▶ Assisting Students with Intellectual Disability Through Technology

Assistive Listening Devices

▶ Assisting People Who Are Deaf or Hard of Hearing Through Technology

Assistive Technology

▶ Assisting People with Physical Disabilities Through Technology
▶ IT on Teaching and Learning Process of Visually Impaired Students

Assistive Technology and Inclusion, Philosophical Foundation

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Introduction

Recently the World Bank reported that out of the 1 billion population (15% of world's population) experiencing some form of disability such as one-fifth of the estimated global total, or between 110 and 190 million people experience significant disability (WHO 2018). Technology plays a vital role for Inclusion as it increases the participation of individual and community at large in all walks of life. Various revolutionary innovations such as artificial limbs, robotic assistance for feeding, Speech Generating Device (SGD), etc. enables individuals with disabilities more functional capacities.

In general, definition of assistive technology comes from the Assistive Technology Act of 1998, which was amended in 2004. The amendment defined assistive technology as “any item, a piece of equipment or product system whether acquired commercially off the shelf, modified, or customized that is used to increase, maintain or improve functional capabilities of individuals with disabilities” (Cook and Polgar 2014, p. 2). But there is also myth regarding thinking aspect of assistive technology, namely, “technology panacea myth,” that means a psychological state when individuals with disabilities and other related person think that technology itself enables an individual with disability function as without disability (Quist and Lloyd 1997). However, this may not be rightly defined and may actually be the outcome of lack of knowledge regarding the philosophical view of technology and fundamental design principle.

Therefore, this chapter mainly focuses on two different sections: *firstly*, the chapter discusses the philosophy of technology and shows how in the context of philosophical orientation, theoretical and conceptual frameworks of assistive technology are being developed. *Secondly*, it focuses on universal designing aspects of assistive technology. The chapter intends to redefine assistive technology based on these two aspects in the context of inclusion and tries to answer some questions related to mainstream technological design. In a major aspect, this chapter seeks to explore some of the basic questions related to technological design and its use in the context of assisting the people with disabilities in the context of inclusion such as – how an assistive cab be defined in the context of inclusion? Besides, this chapter will also explore an overview of how the knowledge of philosophy for technological design is crucial to designing an assistive technology device for inclusion.

Philosophy of Technology for Inclusive Accessible Design of Augmentative and Alternative Communication (AAC)/ Assistive Technology (AT)

This is a relatively new concept in terms of Augmentative and Alternative Communication (AAC)/Assistive Technology (A.T). This section will reflect the philosophical overview of technology. This is important because technology itself is not a miracle which can bring change and enable people with disability function like without a disability. The success of any AT always is based on design and functions of the specific device with respect to the context be it environmental, cultural, psychological, etc. Therefore, in order to understand technology properly in the real sense, there is poignant need of understanding the underlying philosophy. Any designer, user, or family member of user and practitioner needs to know more about the nature of technology through the lenses of philosophical inquiry to understand the essential approaches needed to use AT in inclusive settings.

This section is organized through different domains of the philosophy of technology which is mutually interrelated in the context of AT design and inclusive accessible viewpoint. Next part provides an overview of the philosophy of technology as a contribution on a theoretical and conceptual basis of AT and at the end draws some conclusion from the point of view of design and application of AT.

Researchers are very much interested in the philosophy of science rather than the philosophy of technology. However, quite recently philosophy of technology is also getting an increasing amount of interest and attention among the researchers. The most comprehensive viewpoint of philosophy has been given by Carl Mitcham (1994) in his book “Thinking Through technology” where he conceptualizes it from three aspects/angles: “technology as artifact,” “technology as knowledge domain,” and “technology as social values” (Vries 2010b).

Technology as Artifacts

Mitcham believed that every technology is an outcome of "Artifact." But generally, people are not aware of the artefact and think that everything can be technology. In any circumstance everywhere is an artifact, but people associate them with technology. In the field of technology for people with disability, in many ways people just assemble amount of artifact to diminish the specific obstacles for people with disability and called it as a technology. Therefore, artifact is one of the direct ways of connection with technology. Another way we can define "artifact" is as a functional nature of "natural object." So here one needs to clarify the complimentary concept of "artifact" and also explain why artifact is different from "natural object." According to Meijers (2000), artifacts incorporate two different natures with specific properties:

(a) **Physical/structural properties**: Physical or structural properties of artifact refers to the element of an object. For example, think about ones' smartphone, one can describe the phone based on its elements (such as plastic), size (5 in.), color (black), weight (5 gm.), shape (square), etc. But one who is not familiar with a phone or its function, may think it as an object for dressing hair or even digging soil.
(b) **Functional properties**: Alternatively, "smartphone" can be described based on its functional aspect such as one can talk through it from a distance or the Internet can be surfed by it etc. Now, who is not familiar with this can imagine some of the basic images such as how the object looks like, or its shape, and so on and so forth.

Furthermore, these two descriptions of an artifact are incomplete without a combination of both. Such as only physical/structural properties cannot give the whole image of an object or vice versa. So now if one tries to know about "natural object," there is only physical/structural properties and no functional properties. It is the human who defines the functional properties of an object and makes it an artefact. This concept will be further analyzed by providing examples from the assistive technology point of view. For instance, suppose when one thinks about a "rubber" while someone uses it as a pencil grip for the student with Tourette syndrome (i.e., who has difficulty controlling motor pattern for writing). In that situation, "rubber" is a natural object and that is the human who ascribes "function" aspect to it (viz. use it as a gripper). In that way, natural object (here rubber) can have many "function" such as it can be used for hair binding or pencil griper and many more ways. However, in that situation, natural objects will be treated as an artifact. Therefore, size, weight, or color doesn't depend on the idea of rubber, rather "function" does (Vries 2010b).

Moreover, from the functional view of artifact, Hendrik van Riessen (1938) discussed about "aspects of reality." "Aspects of reality" means functions of artifact from different aspect. He also elaborated that every artifact may have 15 aspects of reality. Some of them are as follows:

- **Spatial aspect of reality**: Every artifact occupies a certain amount of space. So, designer of any artifact must take this into account.
- **Economic aspect of reality**: Every artifact has its own value (from the economic aspect – the price tag). This value depends on what "function" someone ascribes for it.
- **Social, judicial, aesthetical, ethical, and belief aspect of reality**: This aspect means belief or distrust in any technology.

Another viewpoint that may be important to discuss here is that every artifact will have subjective as well as objective functions. Such as in the physical interaction point of view, pencil griper, as an assistive artifact, can function as both subject and also object. Subjective in the sense, pencil gripper can itself diminish the problem of writing for Tourette syndrome and objective in a view that human beings can change or modify pencil grip for his/her own convenience. Therefore, designer of any assistive technology or better to say who ascribes function to any artifact must reflect its various aspects such as passive, active, or both in order to function it as desired.

Now another important aspect necessary to explore here in order to get a sound view about designing any AT are the following:

- **Proper function**: Proper function refers to a specific function which designer (or any human) had in mind when he/she ascribed functions on it. Such as pencil gripper can be used in many ways but the designer who designed it, ascribed function of writing as a pencil.
- **Accidental Function**: But the element or physical property of pencil gripper can be used in several ways such as someone can use it to resist the pen falling down from the table. That is the accidental function of an artifact. It is very common that the accidental function may work properly because physical elements of specific artifact are fit to do that.
- **Improper function**: Suppose someone wants to use pencil gripper for breaking the glass but it doesn't work because physical properties don't allow doing this. Therefore, it may be considered as improper function.

From the functional aspect, Van Riessen also discussed two distinct functions of an artifact such as foundational function and qualifying function.

- **Foundational function**: The foundational function of any artifact refers to the origin of an object. Such as a stone was formed by many physical processes that is why one can say that a stone has its foundational function in the physical aspect (Vries 2010a).
- **Qualifying function**: Qualifying function refers to ultimate contribution of any object to the meaning of reality. For instance, for a pacemaker the qualifying function of reality is that to produce the correct electric pulse. This can be characterized as technical function. Varies (2010b) described that the qualifying function of a train is in the social aspect such as carrying people together. But this "social aspect" can only take place when train fulfills the technical function that is the "spatial aspect," i.e., going from Place A to B.

In the view of the previous example of pencil griper as an assistive technology, the element of rubber gripper or wood for pencil has had its own foundational function separately.

Apart from all foundational or operational functions, there is another crucial aspect of an artefact which corresponds to "operation" or "functioning in a specific action." It means that application of multidisciplinary way to derive knowledge about physical and functional properties to predict how a specific artifact behaves in a certain action. In that situation, effective design of an artifact should reflect the desired function. Additionally, an artifact can be consisted of many parts; in that case, artifact denotes a "system." A system is a combination of many parts of an artifact working together.

Here an overall discussion about the philosophy of technology as artifact provides background knowledge about how philosophical reflection of technology can influence the design of any assistive technology. This knowledge is pertinent to design an assistive technology for an inclusive setup. Many times it has been observed that poorly designed assistive technology stigmatize student with peers without disability (Hayhoe 2014). Only awareness or academic setting through assistive technology doesn't contribute to the process of inclusion of people with disability (Krüger and Berberian 2014), there is necessity of ascribing function to it. Many assistive technologies mainly focuses on hardware or software function rather aesthetic aspect of reality, the cultural aspect of reality, and social aspect of reality (as discussed in the previous section) in context of mainstream settings. The subsequent section of the chapter is going to discuss another important aspect, namely, design principle of AT for inclusion.

Design Principle of AT for Inclusion

The concept of "inclusiveness" refers to equitable or equal opportunity or participation of the "people with disability" by providing them a platform where they can exhibit their different abilities with their neuro-typical peer (Ahmad 2015). Though various AT has been developed to assist the "differently abled" community, there are always emerging needs and challenges to tailormade or personalize the design of AT device to increase more participation in an inclusive setup (Carmien 2016).

This section focuses on the designing principle provided by Quist and Lloyd (1997). Quist and Lloyd (1997) portrayed six standards of AT which are needed to taken into consideration when designing any assistive devices. The six standards are as follows: (a) Principle of parsimony (b) Principle of minimal effort (c) Principle of minimal energy (d) Principle of minimal interference (e) Principle of best fit (f) Principle of practicality and use, and (g) Principle of evidence-based practice.

Principle of Parsimony

> *Everything should be made as simple as possible, but not simpler* – Albert Einstein (Reader's Digest in July 1977)

"Principal of Parsimony" refers to that a design of AT should be simplest to increase effectiveness and efficiency (Quist and Lloyd 1997). Complex design can be a very effective solution but that can also create barriers for users, especially those who have struggled with various physical and mental challenges. Therefore, when designing or selecting any technological devices, the designer and end-user should be concerned about unnecessary complexity and implement easy to understand approaches (Jones 2002). Generally, in daily life activities, people are intended to use various complex solutions which can easily be substituted with the simplest solution (viz. inexpensive, reliable, and easy to transport) (Lee and Johnson 2017). For example, those who have "Tourette syndrome" or difficulty in a motor pattern for learning, one of the major struggles is "writing." Therefore, he or she can easily buy "voice recognition software" for writing or can use low technology such as "pencil grips." But if both this technology helps in writing then choosing simple one is the less expensive, easy to transport, and less time consuming (Quist and Lloyd 1997). By diminishing complexities, active participation may be enhanced and hence inclusion can be improved.

Principle of Minimal Learning

> *Don't Make Me Think* – Steve Krug (2006)

Another hindrance for active participation or inclusion of people with disability is the use of poor design while developing AT devices that require additional thinking or mental effort to use or understand the function (Malcolm and Roll 2016). The principle of minimal learning refers to less cognitive load aspects when using devices. For example, in 9th grade, the teacher gifted a new design pen to all the students in the class. There were various instructions given by the pen company regarding how to open the pen and write. However, after sometime classroom was getting too much noisy and lots of queries were poured in to the teacher, lots of broken pen in hand for the inappropriate opening and lots of frustrated faces. So, why this situation happened? The answer is as the designer of the pen company did not maintained the principle of minimal learning. Therefore, to use or understand the function of pen, the users required more mental effort which increased the cognitive load and decreased the motivation to use it (Malcolm and Roll 2017).

Therefore, in the context of designing AT devices, designer should be concerned about less instruction on how to use it. King (1999) pointed out it as "operational knowledge," knowledge regarding "how to use" or "operate" any devices. Quist and Lloyd (1997) noted that if any device required more "operational knowledge,'" it likely reduces the use of the device over and over time by the user.

Principle of Minimal Energy

> *Minimum effort means maximum comfort* – Cited by Aarts (2006)

Minimal energy refers to the least necessary mental and physical effort for any task performance. Research has shown that task which required huge energy for task performance, there will be less motivation about specific task completion (McDonnell et al. 2003). This can be worst in context of people with disability. Quist and Lloyd (1997) found that AT user most likely to avoid any task performance if there is need of too much energy. Therefore, designer of AT must take into consideration this principle to increase performance for long period of time. From the designing perspective, the Center for Universal Design at North Carolina State University (1997) provides some guidelines to minimize effort in task performance. Some of those are natural body position of user which should be maintained in any design. Those are the following:

- Reasonable operating forces should be executed.
- Repetitive action should be minimized.
- Sustained physical effort should be minimized.

In the context of AT device, this principle can be utilized for motivation or to execute a behavior. Any user can be withdrawn from any task related cognitive load or mental effort and physical effort that is more than the motivation of user.

Principle of Minimal Interference

> *Stop brothering me!* – Cited by Quist and Lloyd (1997)

This principle emphasizes that any design of AT should create a distraction-free environment. This principle is important to take into consideration as if any AT design has more complex or multiple features then attention of any user will be engaged in operating the device rather the task performance (Shaffer 2017). In such situation extrinsic cognitive load will be increased; therefore, the user may experience low motivation from the required task such as learning activities or communication.

Principle of Best Fit

> *Is it me?* – Cited by Quist and Lloyd (1997)

This principle emphasizes on individualized design of any AT. A designer should be aware of the target group or individual to design a "best fit" device based on personality or need of individual or community to the maximum extent possible. Quist and Lloyd (1997) stated that design which is compatible with user need and the personality of a user AT becomes more effective for people with disabilities. Ergonomic or understanding the human factor is major study area in the field of any technological design. King (1999) claimed that 75% success of any AT device is related to the human factor.

Principle of Practicality and Use

> *Never forget why you started* – Cited by Quist and Lloyd (1997)

This principle supports feasibility and practicality of any AT device. Design of any device needs to be consistent with the availability of resources. Therefore, this principle emphasizes to apply previously mentioned all the principle from the practical ground. For instance, mental effort, cognitive aspect, physical or environmental aspect need to be taken into consideration based on the availability of resources. In a simple way, this principle encourages to develop a solution which can actually use in real-world context. Therefore, designer should keep in mind economic, social, mobility, psychological aspect, etc., while designing devices (Hayhoe and Simon 2014; Yu and Liang 2013).

Principle of Evidence-Based Practice

> *Stand on the shoulders of giants* – Isaac Newton on Letter to Robert Hooke in the year of 1676

Another important principle for designing an AT device is Evidence-based practice (EBP) (Thistle and Wilkinson 2015). Schlosser (2003) stated three aspects for EBP such as (a) use of best and most current research as a reference for design (b) focus multidisciplinary team or expert approach (c) need to take all the stakeholder perspectives in consideration for best services. EBP is the most critical aspect of AT development for any technological design for the following ground:

- Research-based pieces of evidence can help educator or designer towards effective implementation of AT for assessment and intervention (Schlosser and Raghavendra 2004).
- EBP increase accountability through a literature survey and help to find out effective strategies and interventions for present and future design of AT (Logemann 2000).
- EBP helps to provide insight regarding equal weight to unique client (Schlosser and Sigafoos 2009).

In this particular discussion, it has been observed that for designing effective AT devices the designer should know the fundamental aspect of technology from the philosophical viewpoint. Besides, a designer needs to know design principles to develop new forms of mainstream technology through innovation. In fact, we are living in an innovation era, where every nanosecond we are witnessing innovating some or the other new technologies. This is also true in the field of AT devices. This is privilege for us, however may not be every time. Because this may create a problematic situation in the context of inclusion, therefore, we need a serious (Re) philosophical evaluation of any AT so that it can contribute most effectively and purposefully to the mainstream technology or inclusion. Based on the reflection above, the next section is going to conclude assistive technology in the context of inclusion and intends to answer some relevant philosophical question in the context of design and functions of assistive technology.

Conclusion

Now coming to the end of the whole discussion, after providing general knowledge about the philosophy of technology in the context of AT including knowledge about design principle for designing effective AT device, the final section intends to link together and try to redefine technology as an assistive approach in the context of education. Here one tries to answer two specific mutually exclusive questions; (a) What is meant by assistive technology in the context of inclusion? (b) How designers can use the knowledge of philosophical aspect for designing such inclusive technologies?

A straightforward approach to answering the first question is no people with disability should separate from his or her nondisabled peers by using any AT device. As discussed earlier that poorly designed assistive technology stigmatize student with nondisabled peers (Hayhoe 2014). Therefore, technology needs to be inclusive. Hayhoe (2014) also discussed inclusive technology is such technology that encourages social inclusion in the context of communication and interaction for the people with disability. The philosophy behind the inclusive approaches in AT technology and design is that it is our fundamental right that everyone should have social and cultural equality in the context of education and communication.

Consequently, the second question can be answered from several points of view. One of major important aspect needed to be taken in to consideration is (re)shape and (re)define the terminology "assistive technology" (Hayhoe 2014). This can only be done when designers of assistive technology shift their focus from the design of AT for people with disability to inclusive designs by addressing the social and cultural inclusion issues in their design. Additionally, need to design any device, not customer-led rather the intention to assist for whom the technology is created. To make a drastic shift in the context of assistive technology for inclusion, there is poignant need to provide encouragement and training to people with disability so that they are skilled to make their own devices (Simon 2014). Furthermore, it needs to be emphasized that people with the disability still have human capital that is valuable to their society.

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Assistive Technology and the Gifted Learner

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Synonyms

Acceleration; Distance learning; Gifted; Online learning; Web-based learning

Assistive technology is generally defined as piece of hardware, software, or other product that is used to help individuals perform tasks that might otherwise not be possible – especially those with cognitive and physical impairments (ATiA 2018). In the USA, a federal definition for assistive technology exists and policies and regulations provide protections and exclusive rights for those with disabilities needing certain technologies. Though not legally binding, some individuals have broadened the definition to include anyone who needs special accommodations in order to access appropriate learning, including gifted learners (Ellsworth 2018). Some states and higher education institutions in the USA consider gifted students within the special education umbrella and require that districts write Individualized Educational Plans for them. While the same federal legal rights do not apply, the individualized plan within a state allows gifted students to access learning tailored to their needs. Still, it may seem counterintuitive to consider gifted learners as a population that requires or benefits from assistive technologies. When one does think of assistive technology and gifted together, generally it is because a student is twice exceptional, meaning they are identified as gifted and also have a cognitive or physical impairment.

It may be argued, however, that gifted children differ from the general population in ways that require special accommodations and services not typically provided in the general classroom in order to continue learning at an expected pace and as to not impede their rate of learning. Gifted learners differ from their same-aged peers in a variety of ways. They are more likely to make complex connections within and across disciplines, learn (and retain) information more quickly, and understand abstract and theoretical ideas at deeper levels. They require accelerated instruction with appropriate levels of challenge and pacing in order to excel (Thomson 2010). Without the necessary accommodations, gifted students are less likely to show learning gains that are commensurate with their abilities and to achieve at expected levels (NAGC 2010). Consider, for example, a 6-year-old gifted student who already understands plot development, characterization, and how language impacts a story but has not yet developed fine motor skills to write down all of her ideas because her physical development is not synchronized with her cognitive development. She may benefit from assistive technology to help her convey her ideas and continue learning and practice new concepts at a pace necessary for her until her fine motor skills develop enough to write the stories independently. As such, the use of assistive technology supports her cognitive development and eliminates the fine motor development concern that could have impeded her learning.

Evidence suggests that the use of technology in gifted classrooms offers benefits to both students and teachers (Housand and Housand 2012) although there are limited empirical studies on the topic. Strategies such as acceleration, interaction with like-ability peers, in-depth study with authentic learning experiences, and access to opportunities, mentors, or more knowledgeable others are effective ways to increase academic achievement and develop expertise (Rogers 2007; Subotnik et al. 2011). Technology may be used as a tool to implement such strategies to help gifted students perform tasks that might not otherwise be possible making it, in the broadest definition, assistive. In particular, the use of hardware, web-based approaches, software, online collaboration and discussion forums, and online coursework are the most studied interventions that have positive results for accommodating gifted student learning needs.

Hardware

The use of technology to develop content expertise, coupled with becoming more proficient in a variety of technology platforms, programs, and hardware can enhance gifted student learning and critical thinking. The use of graphing calculators, simulation tools, and digital drawing tools at earlier ages serves as a way to accelerate learning, allowing gifted students to become proficient in using advanced tools in a discipline at earlier ages consequently increasing conceptual understanding and spatial skills (Duda et al. 2010; Gadanidis et al. 2011).

Web-Based Approaches

Liu (2004) found that using specific hyperlinks (i.e., links to videos and online lectures and other advanced resources) increased gifted students' higher-level thinking skills and attitudes toward learning. The use of specific hyperlinks for independent learning also allows gifted students to adjust the pacing of their own learning and learn at a pace and depth more commensurate with their abilities, showing higher self-regulation skills (Greene et al. 2008).

Software

Software programs support individualized learning and advanced pacing so that gifted students can pursue areas of interest in depth (Sanderson and Greenberger 2011). In one study, e-publishing software allowed gifted students the opportunity to develop and showcase their talents at a pace appropriate for them and consequently they showed greater gains than those not identified as gifted (Gentry 2008). In another study, the deliberate use of game-based software allowed students to increase their problem-solving approaches and strategy development (Steiner 2006).

Discussion-Based Forums

Online platforms and discussion boards as well as collaborative games and software programs allow gifted students opportunities to develop social connections and interact with other like-ability peers. Students can engage with other like-ability peers to promote social-emotional health, share unique perspectives, and connect with others who have similar interests, regardless of age. Shin et al. (2013) found that the use of a software program that incorporated collaboration through sharing ideas about content and story designs increased the reported levels of friendships in gifted students. Students participating in online or virtual forums may also find a sense of belonging not otherwise enjoyed or accessed in their schools (Cross 2004). Similarly, when educators used online discussion boards, students were more likely to collaborate and communicate with each other, thus developing more advanced thinking skills (Gadanidis et al. 2011). In another study, students who participated in online learning courses reported that one of the positive aspects was the socialization. Further, gifted students reported being more open-minded to different perspectives (Blaire 2010) although students still wanted face-to-face or voice interaction with instructors (Olszewski-Kubilius and Lee 2004; Gadanidis et al. 2011); they also preferred online resources with hard copy textbooks as opposed to strictly online work (Gentry et al. 2007).

Online Coursework

The use of online coursework allows educators to individualize and tailor learning to each learner's unique strengths and needs in ways that are not typically provided in the general classroom. Teachers of gifted students might lack the qualifications to teach courses in the subjects their gifted students are interested and proficient in. Moreover, schools may not offer the number or types of advanced courses necessary to support the unique needs of gifted students at a pace or depth necessary for them to continue learning. With the help of computer-aided instruction and online courses, teachers can provide students with the resources needed to continue to learn and develop expertise. Specially designed online courses for gifted students led by content experts as well as adaptive software programs that progressively increase in difficulty provide accelerated opportunities that may not otherwise be afforded. Access to websites such as museums, ask-an-expert forums, and virtual tours of historical places and related websites can be a powerful tool for finding answers to many student questions. Free courses and lectures such as MOOCs, Ted ED, or Khan Academy allow access to accelerated content calibrated at a level commensurate with gifted students' unique abilities. However, teachers must be careful when selecting online forums for gifted students and ensure that the courses are tailored for gifted learners and appropriate for student use. When online courses are designed specifically for gifted students, they report greater interest in a learning (Wallace 2009), show advanced problem-solving skills, acquire more in-depth content, and score higher on Advanced Placement exams (Olszewski-Kubilius and Lee 2004). Gifted students also reported that the online courses served as a positive way to actively pursue areas of interest in deeper ways, participate in courses not typically offered at their school, to learn at a pace commensurate with their abilities (Olszewski-Kubilius and Lee 2004), and to enjoy more personalized instruction not typically found in face-to-face settings (Thomson 2010; Wallace 2009).

A few cautions must be noted when examining technology and gifted students – especially assistive technology. First, the literature on this topic is extremely limited. In a review of the literature, Periathiruvadi and Rinn (2012) found 24 empirical studies focused on technology and giftedness although 157 descriptive or conceptual articles were found. Many believe that technology can be used to help gifted students access and perform tasks not otherwise available, but there are a few clear empirical studies on the effects. Information on assistive technologies for gifted students who are twice exceptional (i.e., have cognitive or physical disabilities and are labeled as gifted) is almost nonexistent of the few that were available. One article makes recommendations for particular apps that build upon twice-exceptional students' strengths (Stewart 2009) while another highlight ways to use translation devices for gifted students, particularly those who are deaf or blind and from rural areas (Belcastro 2004) arguing that geographic limitations complicate access and technology can assist in equalizing this access for those in remote populations who are also in need of assistive services due to a physical impairment.

Second, teachers may have an inaccurate understanding of differentiated instruction. It is not enough to apply technology with gifted students as a general instructional strategy. The use of technology alone does not make instruction differentiated. Technology, when used as a differentiation tool, is carefully selected and deliberately applied to help students accomplish or access opportunities not otherwise available. Merely giving gifted students access to technology is not adequate. Differentiation with technology for gifted learners is individualized and targeted to their unique learning needs and strengths.

Finally, professional development and training for teachers and students is required. Students need to know how to effectively and safely use and participate in technology (Siegle 2003; Siegle 2007) and carefully select appropriate sources (Housand and Housand 2012). Not only is it important for students to know how to navigate the world that technology opens for them but teachers also need to be trained to use technology in their classrooms; technology cannot be used effectively if teachers do not know how operate or integrate it into classrooms and lesson plans (Periathiruvadi and Rinn 2012). Students need to be trained to effectively conduct online research and use the tools at their disposal while teachers need to be trained so that technology can be seamlessly integrated into classroom settings. Competing priorities, high stakes testing, little to no planning time, wide ranges of abilities in one classroom, lack of access to appropriate resources, and lack of pedagogical and content expertise can inhibit a teacher's ability to differentiate instruction for gifted learners in the general classroom (VanTassel-Baska and Stambaugh 2006). Technology's benefit cannot be realized if students and teachers are unable to use it properly or current systems and policies are not in place to necessitate use. Moreover, not only do teachers need to realize how to use technology and keep up with the fast-paced and ever-changing developments in technology but they also need to know how to apply it effectively as a differentiation tool (Shaunessy 2007; Zimlich 2015). Teacher attitudes, access to appropriate technology, student responses to new approaches, and funding approaches all impact the effective use of technology in the classroom for gifted learners.

In summary, the research on assistive technology and the gifted learner is nonexistent. Accepted definitions of assistive technology are narrowly defined and do not include gifted learners as a special population that requires assistive technology. This may be due in part to federal guidelines for funding as well as philosophical beliefs. Regardless of the definitions, it is well documented that gifted students have learning needs that necessitate attention and accommodation (NAGC 2010) in order to develop at a pace commensurate with their abilities. Moreover, gifted students can benefit from the use of technology in ways that allow access to accelerated learning, like-ability peers, and other opportunities not otherwise provided in their school to support their pace and depth of learning. Access to appropriate supportive software and hardware, discussion forums, and online courses improves gifted students' reported interest, critical thinking skills, test scores, self-regulation strategies, and social interactions. In this way, technology does assist students in performing tasks based on their ability in ways that may not otherwise be available, especially if they are from geographically remote or under-resourced areas or homes where access to advanced opportunities are not available. As future research emergences in this area, perhaps definitions can continue to be expanded to look at students on both ends of the learning continuum. One cannot forget to include gifted learners, including those who are twice exceptional, as another population whose learning needs require assistance in order to fully invest in human capital and harness ways in which technology assists in performing tasks for which one is fully capable if provided the appropriate resources.

Cross-References

▶ Distance Learning
▶ Learning Strategies and Achievement of IT Students in Higher Education
▶ Teaching with Computing, Educational Games

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Attendance Marks

► Attendance Records, Educational Management

Attendance Records, Educational Management

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Synonyms

Attendance marks; eAttendance; Register; Roll book

Definition

Attendance can be defined as the physical or virtual presence at a learning environment either real or online. It can be measured as daily, morning/afternoon, or lesson based and has a variety of subclassifications as discussed in this entry.

Attendance is a key component of the educational management process as clearly learning can only occur when the learner is present in the learning environment and this normally requires attendance at a specific location. It may be mandatory through a legal framework or merely a requirement for the successful outcome of a course or exam.

Attendance records are a key part of all phases of the educational process from early years, primary, secondary, further, and higher education. They can take the form of handwritten documents, machine-readable records, biometrics, or automated through near field or similar technology.

Attendance can be recorded online, in person or by any other mode that indicates that the learner has been present in the learning environment.

However, it should be noted that although attendance may be linked to educational advancement and learning in its most simplistic form, it has no necessary relation to this. While a student may attend 100%, they may not learn anything, while one who attends 0% may still pass a final exam. This, however, would not be true for some courses that require a minimum attendance to pass something which has an increasing popularity for educational institutions.

Recording Attendance

Historically attendance has been recorded by hand in a register or ledger. It is normally a legal requirement for statutory education although is likely to still be an institutional requirement where this is not the case.

In its most basic form, it is recorded as a binary mark either attended or not attended. However, a large number of additional statuses have evolved as reporting has become more prevalent.

For example, in England (DfE 2016), the USA (Marblehead Public Schools 2017), and New Zealand (Ministry of Education New Zealand 2015, attendance Code List 2015), the following are all used for various attendance types. These are shown in Table 1.

One of the obvious trends here is the number of different codes and absence marks that are available. This is often as a direct result of government reporting requirements as well as the desire for more management information made more accessible through the electronic collection and storage of attendance. In addition the distinction between authorized and unauthorized absence has also become prevalent as the reporting of truancy rates (unauthorized absences) has become more of an educational issue.

Since the year 2000 has started to be recorded electronically, this started with the use of Optical Mark Readers (OMR) in which preprinted register sheets are marked manually by the teacher and then fed into an OMR reader and the marks transferred electronically to a computer as shown in Fig. 1 (SIMS 2017).

However, as Strickley (2007) observes that although these forms were always filled in at the appropriate times, often they were not read into the management information system (MIS) until the end of the day and at worst the end of the week. This meant the attendance records could not be used for truancy detection and prevention but merely as statistical records. This was, to some extent, due to the issues around the process of importing the sheets which could be quite time consuming.

The advent of whole school computer networks, Wi-Fi, swipe cards, and handheld appliances has meant that attendance can be recorded in real time at the point of entry into the learning environment enabling real-time recording, reporting, and remedy.

Finger prints and even retina scans have also been used for the purposes of recording attendance although there have been some legal and privacy issues here that make this method less attractive.

Key to any method is the requirement to cut down on administration in recording and the ability to monitor in real time.

To a greater extent, the advance of electronic attendance recording led to a more report-led model which in its own way created these complex attendance code systems as illustrated in Table 2 (Ministry of Education New Zealand 2015).

Legal Issues

In many countries attendance at schools is compulsory, enforced by law. As such the recording of attendance is a legal requirement, and the registers themselves are legal documents and therefore need to be accurate, secure, and held for a period of time. This requirement originally applied to manual records but now is applicable for electronic records as well.

In addition there are a number of statutory statistical and public reports that involve the use of these records and consequently their accuracy is paramount.

A result of the public publication of attendance records has, to some extent, resulted in the increase in the definition of absence above and beyond its original concept as illustrated in Tables 1 and 2.

Attendance Records, Educational Management, Table 1 Example attendance codes and meanings

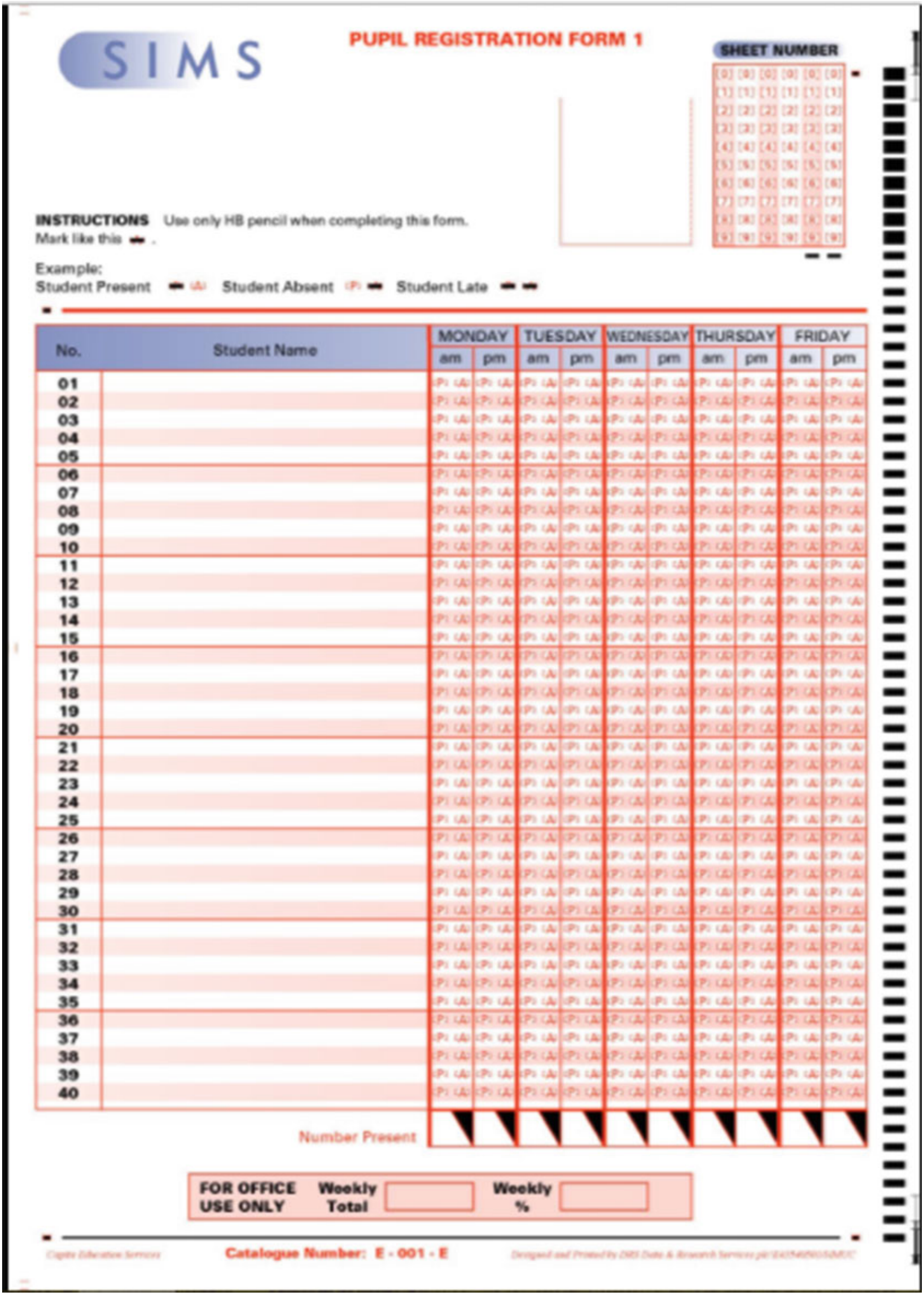
Code (England)	Description	Meaning	Code (USA)	Description	Code (New Zealand)		
/	Present (AM)	Present	ABS	Absent excused	?	Not in class	Unknown reason
\	Present (PM)	Present	ABU	ABSENT- UNEXCUSED	P	In class	Present
B	Educated off-site (NOT dual registration)	Approved educational activity	ACI	ABSENT- CALLED IN	L	In class	Student is late to class
C	Other authorized circumstances (not covered by another appropriate code/description)	Authorized absence	COL	ABSENT- COLLEGE	S	Not in class	Sickbay
D	Dual registration (i.e., pupil attending other establishment)	Approved educational activity	DA	DISMISSED-ABSENT A.M.	D	Not in class	Medical appointment – doctor or dentist
E	Excluded (no alternative provision made)	Authorized absence	DM	DISMISSED- MEDICAL	I	Not in class	Internal school appointment
F	Extended family holiday (agreed)	Authorized absence	DP	DISMISSED-ABSENT P. M.	E	Not in class	or activity – dean, DP, sports administrator, coach, attendance officer, etc.
G	Family holiday (NOT agreed *or* days in excess of agreement)	Unauthorized absence	FT	FIELD TRIP	M	Not in class	Student absent due to short-term illness/medical reasons
H	Family holiday (agreed)	Authorized absence	GYM	OPEN GYM	J	Not in class	Justified absence – the reason is within the school policy
I	Illness (NOT medical or dental etc. appointments)	Authorized absence	HM	HOME and HOSPITAL	T	Not in class	No information provided – truant (or throw-away explanation)
J	Interview	Approved educational activity	LIB	LIBRARY	V	In class	Examination or unsupervised study – student is on the school site
L	Late (before registers closed)	Present	SIS	SUSPENDED- IN-SCHOOL	X	Not in class	Exam leave unsupervised study – student is off-site
M	Medical/dental appointments	Authorized absence	SOS	SUSPENDED- OUT-OF-SCHOOL	G	Not in class	Holiday during term time
N	No reason yet provided for absence	Unauthorized absence	SPD	SPORTS DISMISSAL	N	Not in class	On a school-based activity
O	Unauthorized absence (not covered by any other code/ description)	Unauthorized absence	SRP	SENIOR PROJECT	Q	Not in class	Attending an off-site school – organized activity such as trip/camp

(continued)

A

Attendance Records, Educational Management, Table 1 (continued)

Code (England)	Description	Meaning	Code (USA)	Description	Code (New Zealand)		
P	Approved sporting activity	Approved educational activity	TA	TARDY-ABSENT- P.M.	W	Not in class	Work experience
R	Religious observance	Authorized absence	TD	Tardy dismissed	R	Not in class	Removed (temporarily) from regular class (internal school student isolation)
S	Study leave	Authorized absence	TDA	TARDY-DISMISSED-ABSENT	Z	Not in class	Secondary and tertiary program (including trade academies)
T	Traveler absence	Authorized absence	TEX	TARDY-EXCUSED- A. M.	O	Not in class	Justified overseas
U	Late (after registers closed)	Unauthorized absence	UTD	TARDY-UNEXCUSED	K	Not in class	Attending a teen parent unit
V	Educational visit or trip	Approved educational activity	UTR	TRUANT-UNEXCUSED	A	Not in class	Attending alternative education
W	Work experience	Approved educational activity	V	FAMILY ABSENCE	Y	Not in class	Attending an activity center
X	Non-compulsory school age absence	Not counted in possible attendances			F	Not in class	Attending an off-site course/ class
Y	Enforced closure	Not counted in possible attendances			H	Not in class	Attending a health camp/ regional health school/ residential school
Z	Pupil not yet on roll	Not counted in possible attendances			C	Not in class	Involved in justice court proceedings
#	School closed to pupils	Not counted in possible attendances			U	Not in class	Student is stood down or suspended



SIMS

PUPIL REGISTRATION FORM 1

SHEET NUMBER

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INSTRUCTIONS Use only HB pencil when completing this form.
Mark like this ▬ .

Example:
Student Present ▬ (A) Student Absent (P) ▬ Student Late ▬ ▬

No.	Student Name	MONDAY		TUESDAY		WEDNESDAY		THURSDAY		FRIDAY	
		am	pm	am	pm	am	pm	am	pm	am	pm
01		(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)
02		(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)
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12		(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)
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15		(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)
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20		(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)
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22		(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)
23		(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)
24		(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)
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27		(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)
28		(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)
29		(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)
30		(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)
31		(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)
32		(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)
33		(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)
34		(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)
35		(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)
36		(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)
37		(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)
38		(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)
39		(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)
40		(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)	(P) (A)
	Number Present										

FOR OFFICE USE ONLY Weekly Total Weekly %

Catalogue Number: E - 001 - E

Attendance Records, Educational Management, Fig. 1 OMR sheet for SIMS attendance

Attendance Records, Educational Management, Table 2 Attendance codes and meanings New Zealand

Attendance Code List 2015

MINISTRY OF EDUCATION
Te Tāhuhu o te Mātauranga

Key
- Present for half day calculations
- Unjustified absence
- Justified absence

School Code	Classroom	Reason (Business Rule)	Explanations – The following explanations are provided as common reasons why a student may be absent from school. The *Truancy Code* column indicates if the absence is **Justified** or **Unjustified**. This does not preclude the Principal from using discretion over any specific student absence	Truancy Code	½ day calc
?	Not in class	Unknown reason (A temporary code)	This is the initial entry for a student not in class and the reason is unknown. It will be edited as relevant information becomes available about the reason for the non attendance. If required, the SMS can be set by the school to automatically change the '?' code to a T after a configurable number of school days (eg 7)	U	A
P	In class	Present	Student is in his/her regular class (This includes supervised study)	P	P
L	In class	Student is late to class	School policy will determine when this code is used. Eg. School policy may recommend that a student more than 10 minutes late is coded "L". Note this code does **not** contribute to the student's or school's absence or truancy rate.	P	P
S	Not in class	Sickbay	Student is known to be in the schools sickbay	P	P
D	Not in class	Medical Appointment – doctor or dentist	Current legislation means this type of absence is counted as present for ½ day summaries. There must be documentation verifying the appointment. This code is not to be used for a stay in hospital. Use code "M"	J	P
I	Not in class	Internal school appointment or activity – Dean, DP, sports administrator, coach, attendance officer etc	This can include students who are out of class for various school appointments including: form teacher, dean, senior management, counsellor, sports administrator, coach, nurse, careers, as well as students on an administration activity such as messenger, collecting attendance etc. It does not include a student who has been removed from his/her regular class and sent to the administration area for disciplinary reasons. This student would be coded P in the class and the code would probably be changed to R by the senior staff member dealing with the student.	P	P
E	Not in class	Student is absent with an Explained, but Unjustified reason	The explanation for the absence is accepted by the school as the reason for the absence. But the reason does not fit within the school's policy as a justifiable reason to take the student off school. (Even though the parents may consider the absence was justified and may have provided a written explanation). E.g. "Molly had to stay home to look after her younger brother". For New Zealand and overseas holidays use code "G" – see below.	U	A
M	Not in class	Student absent due to short-term illness/medical reasons	Student is at home, or in hospital, because of illness or other medical reason. Depending on school policy a medical certificate may be requested for prolonged illness. eg three days, or as policy requires.	J	A
J	Not in class	Justified absence – reason for absence within the school policy	• Unplanned absences such as a bus breakdown, accident, road closure, extreme weather conditions etc • Planned non attendance such as national/local representation in a sporting or cultural event in New Zealand or overseas. • Approved absence (including overseas) can also include bereavement, visiting an ill relative, exceptional family circumstances or a Section 27	J	A
T	Not in class	No information provided – truant (or throw-away explanation)	An absence where either no information is provided, or the explanation is trivial (throw-away): • I didn't feel like Maths so I took the period off • I had to finish an important assignment • I went down to the river • I went to the shops • we had a test and I wasn't ready for it	U	A
V	In class	Examination or Unsupervised Study – student is on the school-site	Students sitting examinations at school (if the SMS can provide attendance marking during exams.) Unsupervised study – school process verifies student is on the school-site. Note that **supervised study** is recorded as a regular timetabled class.	P	P
X	Not in class	Exam leave Unsupervised study – student is off-site	Code X will count as a justified absence and contributes to ½ day absence summaries. Note that **supervised study** is recorded as a regular timetabled class.	J	A
G	Not in class	Holiday during term time	When a student is on a New Zealand, or, Overseas holiday during the school term, the absence is **U**njustified. A parent's note does not provide justification.	U	A
N	Not in class	On a school based activity	A school-based (on-site) activity. • cultural/sporting presentation/practice including swimming/athletic sports • one to one tuition either as tutor or tutored	P	P
Q	Not in class	Attending an off-site school-organised activity such as trip/camp	A school-organised off-site activity **including overseas** • school trip (sporting, cultural or academic) • school camp	P	P
W	Not in class	Work experience	Student is working for a recognised employer as part of their course (Gateway is an example)	P	P
R	Not in class	Removed (temporarily) from regular class (internal school student isolation)	This code is for students who for a time period had an arrangement for alternative supervision. This may be in the administration corridor or in another teacher's class, instead of the student's regular scheduled class	P	P
Z	Not in class	Secondary Tertiary Programme (including Trades Academies)	The student is participating in a part-time (off-site) approved Secondary Tertiary programme that includes Trades Academies. The school is not entitled to be funded.	P	P
O	Not in class	Justified Overseas	A student accompanying, or visiting a family member who is on an overseas posting. (Up to 15 weeks) Eg military or diplomatic.	O	A
K	Not in class	Attending a Teen Parent Unit	The student is not in class, is on the school roll but funded elsewhere	J	P
A	Not in class	Attending Alternative Education	The student is not in class, is on the school roll but funded elsewhere	P	P
Y	Not in class	Attending an Activity centre	The student is not in class but in an approved environment for which the school is entitled to be funded	J	P
F	Not in class	Attending an off site course/class	The student is not in class but is on a legitimate off-site school-based course	P	P
H	Not in class	Attending a Health camp/Regional Health School/Residential School	The student is not in class but in an approved environment for which the school is entitled to be funded	J	P
C	Not in class	Involved in Justice Court proceedings	Under existing legislation this type of absence is deemed to be Present when calculating ½ day summaries	J	P
U	Not in class	Student is Stood down or Suspended	Student is Stood Down or suspended according the conditions of Section 14 of the Education Act 1989 (This code is for the period of the stand down/suspension. It does **not** include the day the stand down was imposed)	J	A

Key
- Present for half day calculations
- Unjustified absence
- Justified absence

Code not used: B

Rules for Truancy Codes:
J = Justified Absence
U = Unjustified Absence
P = Present
O = Overseas (justified)

School closures

A Board of Trustees can close the school (for instruction) for reasons including:
• an emergency (earthquake, flood, etc); or
• strike closure

It is usual that ½ days lost do not have to be made up, but schools should confirm this when informing their local Education Office of the closure. The School calendar should be adjusted in the SMS to show such days (or ½ days) as a non-school day and this means the students' attendance cannot be marked. If the school's SMS cannot make a ½ day adjustment in the calendar, then students should be marked J (justified absent). In the case of a strike closure, although the school is closed for instruction, the Secretary expects boards to consider providing supervision for those students who do turn up. Note that Boards have ongoing responsibility for the safety of students while under supervision at the school, whether or not the school is also open for instruction.

Keeping the school open

Depending on the circumstances the Board, while not closing the school, may ask parents to keep children (of specific, or all year levels) at home where possible, but if they send them to school they will be supervised. If the school remains open then students not attending are J (justified absent) and those attending are P (present).

Effectiveness

The electronic recording of attendance has had some significant effect on educational policy.

1. It has become one of the benchmarks of a successful school.
2. It has resulted in an expansion of the definition of absence.

3. It has to some extent resulted in a manipulation of absence as a result of 1.
4. It has resulted in legislation punishing parents who take their children out of school in term time.

Attendance reports are collected via the annual government censuses or equivalent and published at least annually.

In educational institutions such as further and higher education where attendance is not mandatory, the above have become less prevalent although are still monitored for the purposes of student satisfaction, etc.

Previous empirical literature indicates that student performance is inversely correlated with absenteeism. Studies in the USA (Roby 2004; Marburger 2010) would suggest that that attendance policies do improve performance. The authors investigate the impact of enforcing an attendance policy on absenteeism and student performance. The evidence suggests that an enforced mandatory attendance policy significantly reduces absenteeism and improves exam performance.

Reporting

As well as public and government accountability attendance data can be used within the institution to improve teaching and learning.

Firstly it is important that the data is available in real time and secondly that it is available in a management information system (MIS) that enables it to be linked to other collected data.

There are a number of ways that attendance data can be used in this way.

Using alerts the institution can be alerted to absences almost as soon as they occur.

The Future

In addition to the so-called am-pm attendance at the institution, the use of lesson attendance has become more prevalent in recent years. This can look at patterns of attendance within the day as well as detecting students who register at the start of the day and then do not participate in any lessons. In addition it can be used to look at attendance in specific subject areas and with particular tutors as well as against gender age, etc.

Real-time recording and reporting with preset alerts can be an enormous aid to preventing unauthorized absence, and it can also be used to better allocate resources and track student patterns.

Summary

The recording of attendance has developed from a manual mark at the start of each morning and afternoon to a sophisticated electronic system using a multitude of codes to describe the type of absence recorded.

The increase in the publication of attendance particularly as a result of its collection through pupil-level census resulted in attendance records becoming a key indicator to the performance of an institution. In addition the role of attendance in the inspection process also increases its importance within educational institutions.

The use of attendance to manage the resources and management of a school is however still lacking in sophistication and development.

The future is undoubtedly going to see an increase in the recording of attendance both as a result of improved recording techniques and the desire for more management information. Whether this will result in an increase in performance remains to be seen.

Cross-References

► Data Mining for Educational Management
► E-Portfolio in Higher Education
► Support for School and Institutional Improvement and Accountability

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Audience Response Systems

► Clicker Interventions, Promoting Student Activity and Feedback at University Lectures

Augmentative and Alternative Communication

► Assisting People with Physical Disabilities Through Technology

Augmented Intelligence in Education

► Artificial Intelligence in Education

Augmented Reality

► Augmented Reality in Education, Scope of Use and Potential

Augmented Reality and Its Use in Education

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Introduction

Educational content is increasingly being delivered through learning environments that are digital or technologically enhanced. One such technology-enhanced application is the evolving medium of augmented reality (AR), a technology that integrates interactive computer-generated data with the user's environment within a display interface. AR has the ability to enhance the real environment and perceptually enrich the user's experience, hence "augmented." This makes AR an enticing technology for educators to use as a tool since the real environment gets "annotated and informative" through the overlay of virtual objects in AR. Students construct new meaningful situational experiences with these augmented virtual objects that are brought to life in the backdrop of the real environment.

History of AR

The history of augmented reality spans over half a century. The term augmented reality was thought to be coined by former Boeing researcher Thomas Caudell who used this technology to assist in assembly of a jetliner in 1990 (Lee 2012). However, its first ever use was earlier in the 1960s, where Ivan Sutherland demonstrated simple wireframe drawings in real time via the first see-through head-mounted display (Lee 2012).

AR is used to display information that is beyond our senses which is used to guide us in the real world (Azuma 1997). Since the late 1990s, this ability attracted attention to utilize its potential and applicability in diverse fields including commercial, maintenance, and education industries.

Virtual fixtures are one of the earliest functioning AR systems designed for the air force. A superimposed exoskeleton provides a guide to perform tasks from a remote space. In 1999, ARToolKit, an open-source software library for the creation of AR applications, became freely available to the public and revolutionized its accessibility (Azuma et al. 2001), thus allowing educators, trainers, and educational designers to be able to design AR objects and use them freely. This remains one of the most widely used libraries for current AR designs.

For training, the car manufacturer, Volkswagen, in 2013 started to use AR to assist their service technicians to foresee the repair process virtually on the physical vehicle. AR technology had remained in the purview of the corporate world; until in 2014, wearable AR devices for the public was made popular with the availability of Google Glass, thus making searchable information available "on the go" and contextualized to the perceived environment. Thereafter, AR applications have grown in leaps and bounds with AR and virtual reality (VR) investment reaching more than $1.1 billion in terms of business importance.

Definition of AR

AR is defined as a technology that enables users to engage with virtual information augmented (usually superimposed) by computer-generated sensory input, e.g., graphics on the *live* direct or indirect view of a physical, real-world environment. This mediated immersion places digital resources throughout the real world, thus, augmenting the users' experiences and interactions. Augmented reality is a subset of immersive technology that accounts for various computer-generated sensory information augmented onto the real world. Commonly, the sense augmented is usually sight but may be applied to other senses such as olfactory, haptic, and auditory.

AR is a system that possesses the following properties (Azuma et al. 2001):

1. Combines real and virtual objects in a real environment
2. Interactive and in real time
3. Registers (also aligns) real and virtual objects with each other

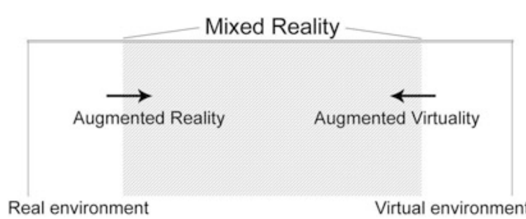
Thus to follow these criteria, not only do the virtual objects are to be placed in a real environment (e.g., as the virtual objects that were presented in the *Jurassic Park* movie) but also will these virtual objects need to be interactive to be considered as an AR (Azuma 1997).

AR belongs to one part of a spectrum of immersive technologies – the reality-virtuality continuum as illustrated by Milgram et al. (1994). At one end of the spectrum, as illustrated as the left side of the spectrum in Fig. 1 is the real environment – a physical space without any added virtual stimuli. At the other end is a world that is completely virtual with no involvement of physical elements.

The difference between augmented virtuality and AR is that it is more computer-mediated than AR as it adds real objects into virtual environment. Some examples of such real stimuli are such as texture mapping of videos onto virtual objects.

In the realm of AR, artificial intelligence is applied for its recognition of the "real world" to project the virtual information, thereby rendering virtual stimuli onto the real world and allowing user interaction. In contrast to VR, AR enables the user to experience real-life situations that are not readily or commonly accessible to the user (Rodriguez-Pardo et al. 2015).

Learning affordances of this form of mixed reality delivery of education include contextual skills development, tangible manipulation,



Augmented Reality and Its Use in Education, Fig. 1 Diagram adapted from Milgram et al. (1994)

exploration, immersion, ubiquitous and situated learning, collaborative learning, reflection, analysis, and assessment.

AR Technology

The goal of AR is to integrate the computer's virtual object into the real environment or recognition of 3D virtual object space (objects, location, etc. within it) and so guiding the human user's visualization and knowledge of the same space. Because of this, AR requires enhancement of basic technology to create this complex integration. These enhancements are called enabling technologies, sensory interfaces, tracking system, registration of the virtual objects, and calibration to the environment (Azuma et al. 2001).

While various sensory interfaces such as auditory, haptic, and movement senses can be used, the interface most commonly in AR is visual displays such as head-mounted display, handheld display, or webcam-based displays. HMDs, which present a personal view of the AR environment, can be either optical or video displays. Optical displays are half-silvered mirrors with optical combiners to allow the augmented object to be seen in the real view of the user. Video displays on the other hand present a closed-view video that uses layering (chroma-keying) to augment the displayed video. These HMDs have their own advantages and disadvantages in terms of quality, immersion, and flexibility (Azuma 1997).

The commonest AR display devices are now handheld devices including mobile phones. The current high penetration of portable and mobile devices in the society particularly the younger audience makes ubiquitous learning and mobile learning with AR highly accessible to this crowd. Displays for AR are increasingly more powerful, compact, and portable making their availability more streamlined than before for wider user adoption (Lee 2012).

AR tracking can be designed as vision-based or sensor-based. Vision-based tracking can be further classified to a priori and ad hoc. An a priori system has prior knowledge of the object being tracked, and the most common example of this as well as all types of tracking is marker-based tracking. Sensor-based tracking, on the other hand, utilises the GPS, magnetic compass, depth camera, inertia, infrared, or a combination of these technologies (Palmarini et al. 2018).

Use of AR Applications

AR is applied in a diverse range of fields and industries. The gaming market is one where it has found great success in. Some popular mobile applications include Pokémon Go; Temple Treasure Hunt; Zombie Go; Zombies, Run!; and Geocaching. These games have been instrumental in popularizing AR technology to the masses as well as introducing a large-scale social collaboration in AR.

In tourism, it can be used as a cultural heritage tour guide to display the view of the site prior to becoming ruins (Lee 2012). Museums can enhance the experience with viewing dinosaur fossils with augmented dinosaurs (Lee 2012). Art galleries use AR to display lost artwork.

The aviation industrial maintenance has used AR to reduce training time and error rates. An aviation maintenance inspector requires 2000 hours to become trained (Palmarini et al. 2018). The complexity of aircraft systems allows AR to be the preferred training method compared to traditional teaching. By reducing eye and head movements, allowing the user to skip the paper manual and concentrate the task at hand, AR reduces time and error rate in complex maintenance operations, thus improving profitability.

In sports, applications such as PoolLiveAid use AR to guide players in pool game with visual aids. It estimates the direction of where the ball will go and displays this in real time as the player can interactively adjust their aim to the visual cues.

AR is applied in the healthcare in a diverse range of fields including rehabilitation, physical medicine, psychology, psychotherapy, and mental health. AR's interactivity becomes an advantage when being used as a patient education tool. Weghorst as cited by Azuma et al. (2001) describes AR to rehabilitate people with Parkinson's disease suffering from an akinesia. In the treatment of phobias, AR is used for subjects to transfer acquired skills in therapy to the real world (Riva et al. 2016).

AR in Education

By bridging the gap between the virtual and physical world, AR has revolutionized our conventional teaching methods. There are now many emerging applications of AR for use in digital classrooms. As an example of its use, Google Sky Map is a planetarium application to teach astronomy when viewing the night sky.

Of the various subjects and fields, AR is most commonly applied in the field of sciences at 40.6% (Bacca et al. 2014). Though the target group of most research on AR application is mostly students of bachelor's or equivalent level, various AR games have been successfully designed for school-going students.

Some examples of AR games for early years of learning include an AR system for K-12 students to learn means of transportation (Lee 2012), a virtual space in AR for learners to collaboratively construct geometric shapes for K-12 students to learning geometry (Lee 2012). In physics, AR objects with various kinematic properties were created for learning through their estimated visualized results in real time (Lee 2012).

An exciting application of AR is the concept of "magic books" where the information presented through books are integrated with AR. These are similar to the 3D pop-up book, but, instead of physical viewing and interaction, 3D models are rendered virtually in an AR display.

Numerous literatures on anatomy learning in AR have been published for target groups ranging from children to medical students. These applications typically superimpose organs onto the user's body or a friend's body. Similar to virtual museums with lost artwork, a repository of anatomy learning objects in the laboratory is designed as an AR museum for medical students to explore.

In the higher education sector, AR can be used to simulate field work and even work-based learning (WIL). For example, in the medical field, clinical experience is highly regarded for medical and health professionals to form core competencies with the consideration of patient safety. A pilot work by the authors developed presentation of clinical signs in AR to facilitate physical examination (Sen et al. 2017). Preliminary data has shown potential in authentic learning of clinical skills without posing risks to patients. In spite of numerous published articles, AR's role as a supplementary method of delivery in education remains as a huge potential that needs to be explored further.

Potential Benefits of AR

For a generation of learners more technologically fluent than ever, AR holds great potential in enriching their learning. AR applications offer a very efficient method to deliver small bite-sized learning content for students. Such small chunks of content through AR can be used to explain a topic and augmenting information on a pre-existing learning topic (Bacca et al. 2014).

In educational research, AR has been the subject of study by educators for its impact on learner. Commonly studied measures to evaluate AR in education are learning gains, motivation, engagement, and collaboration. In general, most studies indicate improvement in learning outcomes. AR has been found to have positive effects on conceptual thinking, interaction with others, and cognitive load. Objectively, this was evidenced by a study that found improvement of performance (by 53.5%), motivation (by 28.1%), and engagement (by 15.6%) with use of AR (Bacca et al. 2014).

In another study, students learning about solar systems through AR were found to achieve greater scores compared to conventional learning methods. Similarly, students learning about parts of the aircraft turbine engine through AR showed improvement in short- and long-term retention of information. This was consistent with another study that used AR to teach word pictograms using more detailed information in comparison to desktop conditions. Compared to pre-existing level of achievement, learning gains in AR learning modality were higher in low to average achieving students and thus had a more impact than on high achievers (Radu 2014).

Game-based learning increased the learner's engagement and significantly found greatest positive impact in less academically successful students (Lee 2012). Another study found that game-based learning promoted student collaboration in solving tasks in K-12 mathematics, language, and scientific literacy (Dunleavy et al. 2009).

Educational Theories in Relation to AR

Various theoretical underpinnings have been put forward to explain the impact of AR in education. One of them is the conceptual blending theory that describes how, in AR, the combination of virtual objects with real objects within a real space gives new meaning to the learner. In AR, the dynamic physical qualities of the visual presentation may become the focus of the learner's attention because of the learner's control over the content. Teaching children astronomy in different mediums found that children use different ways to conceptualize content. In AR, children learned to identify planets based on movements, while in PC presentation, children focused on details and visual look of the planets (Radu 2014).

Constructivism is a learning paradigm that encompasses an active, contextualized process of constructing rather than acquiring knowledge, based on personal experiences and the environment. Constructivism accounts for the learner playing an active role in connecting theory and application by interacting with the AR content that creates both an engaging personal experience as well as interactive environment. Being actively involved through AR can provide experiences in a novel way toward authentic (real-life) scientific inquiry (Zhu et al. 2014). Some examples are the "Alien Contact" AR project where students could act "like a real scientist" when solving situational puzzles and medical education AR applications where transfer of knowledge to real-life situations was achieved by learning the orientation of superimposed human organs even if mistakes were made (Dunleavy et al. 2009; Radu 2014; Sen et al. 2018). The students found the experience with the AR environment to be a personalized and explorative experience for themselves (Zhu et al. 2014).

Reduced cognitive load may be an explanation of improved task performance. In repair and maintenance on military tanks, workers performed faster with fewer head movements (Radu 2014). Puzzles with AR instructions had faster completion time with fewer steps (Radu 2014). In healthcare training, AR decreased the amount of practice toward proficiency and reduced failure rates in real life (Zhu et al. 2014). In relation to Mayer's multimedia learning theory, this could be explained by the spatial and temporal contiguity effect. AR can present the information within the same plane in the real environment, while temporally, AR presents information closely with a physical phenomenon to allow an association to form (Radu 2014). This real-time interactivity has been found to provide a focused guide for users to learn more effectively (Riva et al. 2016).

Enhancing the learning experience with whole-body interaction using AR relates to the concept of "embodied cognition." "Embodied cognition" links the conceptual understanding of the abstract concept with physical activity such as gesturing or hand movements (Radu 2014). Inputs to the AR experience enhance skill proficiency in a range of motor skills, hand coordination, hand-eye coordination, fine motor, and gross motor (Radu and Macintyre 2012). The enhancement of the learning experience with tactile, audio, and visual cues is a form of multisensory integration.

In experiential learning theory, the shared experience from coordinating a mixed reality space with learners becomes meaningful to the student. When students perform such a shared activity such as navigating a map together in AR, students experienced more effective collaboration with greater retention and motivation in the learner (Radu 2014), a typical example of the experiential learning theory.

Affective reactions, such as enjoyment and pleasure, toward the immersive technology support the “flow theory” (Suh and Prophet 2018). AR environments can create strong engagement between the narrative and real world. This may explain how unmotivated students transform to become highly engaged. Students can become willing to play the game repeatedly out of pleasure as they enjoy the challenge of graduated difficulty in these AR games (Dunleavy et al. 2009). This is driven by their internal goals as well as the balance between challenge and their goals (Radu 2014). Furthermore, some of the AR GPS-based games can allow students to express creativity and environment exploration. Higher enthusiasm in learners in turn produces higher satisfaction ratings.

Challenges in Using AR for Education

While the AR tools in creating an immersive educational experience are advancing rapidly with the betterment of technologies, there are still limitations of current AR technology. The development of AR content in AR involves both high cost and considerable time. Although open libraries (e.g., open CV, open GL, MATLAB) and software development kits (SDK) are freely available to facilitate its programming design, most of them are based upon mid-to-low-level programming languages (e.g., C++, C#, Java, HTML, CSS, etc.). These programming aids are not yet user-friendly for the public at large and still require highly skilled people to utilize them in creating AR systems.

AR applications for education are designed to enhance specific learning tasks and thus to customize to the educators needs; many of these well-designed AR applications still need to be created from scratch rather than through ready-made templates. Thus, the process still requires visual designers, 3D artist, and games/AR designers rather than it being in the purview of sole educator. Visual designers are also involved in designing presentation of the information within the AR applications. Some, though not all AR objects are 3D models superimposed on the real environment, and this 3D modelling requires skills in design software applications such as Catia, Blender, and 3Ds Max; therefore, a 3D artist may be sought making the AR applications of good quality but expensive to produce. Creating AR-based games will also require collaboration with game designers (Palmarini et al. 2018). Due to its intricate development phase, direct access to author content is not yet accessible to educators (Bacca et al. 2014).

Creation of accurate realism of content is limited by current image capture technology. Video blending limits the user’s view to the capability of the cameras but may lack realism altogether (Azuma 1997). Human eye can adapt to six orders of magnitude of light, but brightness determines the eye pupil size which in turn also determines the depth of focus. Current display technologies like using the pinhole model show that all objects are in focus regardless of distance (Azuma 1997). Furthermore, displays may also adapt poorly to the real environment causing errors in depth perception (Azuma et al. 2001). In comparison, if the environment is too bright or dark, the virtual object is immediately identified as virtual. Accommodation-vergence conflicts in the eye, low resolution, and inaccurate lighting cause the virtual object to appear further away. Over time, users adapt to this displacement and exhibit large overshoot in real-life performance (Azuma et al. 2001). Further development in graphics is needed to simulate better match depth and real distances as in a human eye (Azuma 1997).

Other anticipated issues with AR are mostly related to technological failures. Time learning could be lost due to either GPS failure, software instability, or incorrect setup of the system. GPS failure could be as high as 30% which could be also complicated by environmental factors such as weather extremes that may prevent GPS-based outdoor-based AR activities (Dunleavy et al. 2009).

To avoid the challenges of GPS-based AR, majority of educational AR projects opt for marker-based AR for ease, stability, and less complex tracking. Furthermore, open libraries offer more readily available marker-based AR with more technical support (Bacca et al. 2014).

However, marker-based tracking suffers greatly from registration issues. The tracking algorithms depend heavily on the marker's position, orientation, and visibility which are frequently affected by weather and wear (Palmarini et al. 2018). Frequently, common tracking algorithms track poorly causing frustration to users (Bacca et al. 2014). It is challenging for input devises with low frame rates like webcams to depict quick gestures, thus resulting in interrupted interactions in AR (Radu and Macintyre 2012).

Registration error occurs when the system is unable to accurately track the desired object seamlessly. This triggers motion sickness to the user due to conflicts in the human senses. For example, a visual error occurs when the user perceives the virtual hand at the wrong distance over the real hand (Azuma 1997). Temporal latency also contributes to registration error. The interactive nature of the AR medium dictates that the system must respond to the user's unpredictable actions. Registration latency causes static and dynamic errors where objects remain still or move inappropriately (Azuma 1997). The augmented information is delayed resulting in reduction of task performance (Azuma et al. 2001).

Apart from the software issues as described above, there could be challenges in usage of the hardware. Hardware displaying AR can be the source of physical discomfort to the users. An example of this is the "tunnel vision" due to the limited field of view of some displays that may even aggravate motion sickness (Radu 2014). Such a limited field of view also interferes with team interaction and collaboration (Bacca et al. 2014). Prolonged exposure to display screens causes fatigue and eye strain to the user, also known as computer vision syndrome (Azuma et al. 2001). Repetitive strain injuries resulting from bending or sustaining postures for long periods of time also occur (Radu and Macintyre 2012).

Limitations in the hardware can also pose challenges in AR design. A study found that younger children would typically hold the device with both hands because the device is too heavy for one hand. This interrupts their live interaction in the session as they had to place it down before moving the markers. Some types of displays also limit the physical space for exploration, counteracting benefits of gross motor training (Radu and Macintyre 2012).

Though AR applications appear to aid visualization, the use of AR systems and hardware can counterproductively increase cognitive load (mental activity exerted on the working memory). These systems are quite complex to set up, and configuration of the head-mounted display to the platform itself can be complicated and time-consuming (Radu 2014). An education session utilizing more than a single type of device to access the content also contributes to high cognitive load (Suh and Prophet 2018). Some students may become overwhelmed by the amount of AR content for use within a short time span (Dunleavy et al. 2009). High requirements of support and management from technical staff raise the question of how feasible AR curricula are on a large scale. Teachers, working independently in classroom situations, find it challenging to support and troubleshoot the technicalities of the AR activity without support from technical staff (Dunleavy et al. 2009). Despite these difficulties, students remain highly motivated to learn how to use the new technology (Radu 2014).

Distracted attention occurs when students ignore important parts of the learning task (Suh and Prophet 2018). Similar to how in assembly task training, workers tend to ignore previous errors and proceed to complete the task with poor recall of the errors made (Suh and Prophet 2018), in AR game-based learning, students may become focused on "winning the game" and ignore the steps in solving the problem, thus resorting to guessing or copying another person's answers to "win." This is also described as attention tunneling (Radu 2014).

Features of novel technology, such as AR can distract the students. An infrared function of an education session caused them to fail to complete the learning task (Bacca et al. 2014; Dunleavy et al. 2009). Distraction is also aggravated by teacher domination in the session (Suh and Prophet 2018). Limited number of displays also makes participation difficult, and students no longer pay attention to the session. In this way, the benefits of AR technology are no longer at play because students are ignoring the real environment.

Distracted attention outside the classroom can be dangerous. Studies featuring GPS-based tracking found students too engrossed with the game space and lose awareness of the real environment (Suh and Prophet 2018). They were guided back to safety when wandering into traffic area (Dunleavy et al. 2009).

Studies found negative cognitive reactions to immersive technology and presumably, toward AR as well. Demographically, immersive technology is less well-received with the female gender and older age groups (Suh and Prophet 2018). Personal attributes like high sensation-seeking tendency and poor personal innovativeness also contribute to poor response to mixed reality technology (Suh and Prophet 2018).

In comparing AR with VR, AR has fewer graphic requirements because of fewer virtual objects to render. In addition, realism can be compromised in goals of AR; thus, high-quality graphics are not necessary. Lower-resolution and monochrome images can be used (Azuma 1997). For example, to outline a workflow, simple lines can be used to demonstrate the desired design.

In terms of tracking, AR requires a higher registration and representation fidelity (Suh and Prophet 2018). These errors are very easily detected in an AR environment. VR is more forgiving. This is because in VR, "visual capture" causes the user to eventually adapt to the systematic errors from prolonged exposure. While in AR, "visual capture" would not be beneficial in the goals of most AR applications as accuracy is key for translation of skills to the real world (Azuma 1997).

Future of AR in Education

It has been predicted that global research, education, and training by 2030 and beyond will witness a prime focus on the AR/VR industry and its applications. With the advent of social media having drastically changed how people interact with each other, its platforms are a potential avenue for incorporation of learning with mixed reality (D'Angelo 2017). As technological advancement will overcome some technical difficulties highlighted earlier, AR will become not only more ingrained as part of everyday life and social platforms but will be more ubiquitous and more accessible to all (Suh and Prophet 2018).

With the markerless AR technology growing, development of new algorithms to identify forms can resolve major issues associated with markers (Bacca et al. 2014) which will make use of AR universal and not limited by connectivity. Trends show that new computer-aided design models can potentially overcome registration and tracking issues. By extracting features of the virtual object and comparing with the image of the real object, the real object is identified through the image being captured by the camera. This technology attempts to overcome lighting issues, one of the greatest challenges in AR technology (Palmarini et al. 2018).

Further research on AR in the field of education is on the cards. Research is focusing on novel technologies with computer vision and motion sensing capabilities that allow users to interact with the digital environment with greater immersion than before. For example, an interactive performance system for dance learning measures visual and sonic aspects of gestures by a system called action graph. This system enables mapping of gestures with desired augmented generation of functionalities, thus enhancing dance training interactively (Iqbal and Sidhu 2017).

Types of studies on AR are also expected to change. There is yet large-scale educator-led AR-based curricula in place. Larger study sample sizes will be possible once developer tools and AR hardware become more accessible. Further studies are still needed to identify curricular-specific and technology-specific characteristics that contribute to learning (Dunleavy et al. 2009).

Evaluation methods on impact of AR applications are presently mainly qualitative in nature and need to be diversified to include more quantitative measures on user experience (Suh and Prophet 2018). As AR is becoming more ubiquitous and no longer remains a novel educational tool, studies that compare AR with non-AR delivery of education cross-sectionally need to extend their focus to longitudinal studies to identify long-term effects on learning once its novelty has worn off (Palmarini et al. 2018). Such research will help reveal the genuine positive learning impact of AR technology apart from its novelty effect.

There is a need for more studies of impact of AR application on diverse groups of students. Target groups of educational AR are mainly of students at tertiary level of education and of scientific backgrounds (Bacca et al. 2014). AR applications' ability to support learning should not be limited to those already in an educational institution. Further studies can provide more information on its applicability to other possible target groups in other fields such as vocational studies, art, language, psychology, and therapy (Suh and Prophet 2018). Another identified potential target group is the use of AR for special needs students (Bacca et al. 2014). Multimodal applications can be used as therapy for sensorial and physical impairment. VR has been found to be effective in aiding autistic people to cope in social situations (Riva et al. 2016). In mixed reality settings, AR can potentially create inclusive educational settings for people with special needs (Bacca et al. 2014).

Types of content suited for AR are being explored extensively to match the appropriateness of the content to the design of the AR. As an example, topics that rely heavily on abstract thinking may be difficult to be designed and taught via AR, while visual-based content may be more suited for AR delivery. Further studies are ongoing to measure the learning benefits of these identified types of content objectively. As raised by several studies, AR will likely be complement to education delivery not a substitute (Azuma 1997; Rodriguez-Pardo et al. 2015).

As discussed earlier, low-achieving students found greater learning gains with AR compared to high achievers. To be inclusive and benefit both ends of the student cohorts, further customization is needed to create content appropriate for a range of pre-existing level of achievement. The creation of tools for educators to author content and personalize to the learner's needs is another facet that has yet to be addressed. Only a few (2 out of 32 studies) identified in a literature search found some personalization process (Bacca et al. 2014). Ideally, future research will identify the differences in learning gains when tailored to the audience's needs.

Social acceptance is an important factor to be studied to determine whether wider use of AR would be feasible (Azuma et al. 2001). For example, what society thinks of AR will affect how likely a user would wear a head-mounted device in a public area. As current applications are still in the prototype phase, data on market penetration remains to be fully gathered (Zhu et al. 2014). However, its acceptance will improve vastly as AR is gradually being integrated to everyday life and is being seen both as an educational tool as well as a platform for social interaction.

The application of AR in education has opened up new vistas in learning paradigm such that the current and future designs of AR in education may need guidance from learning theories. AR applications have opened up new possibilities than what the present traditional learning strategies can afford. Design guidelines for human-computer interactions exist and can be the building blocks for future AR design guidelines. These guidelines will also need to be field-specific (Zhu et al. 2014). Due to AR's nature of being highly hardware dependent, its applicability is being given due to the consideration to the learners' age group which may dictate the type of hardware used in its particular learning needs, especially, as previously discussed, where younger age group user struggle with handheld devices (Radu and Macintyre 2012). Identifying the limits of AR applicability is crucial for educators to select appropriate content to teach in AR. With considerations of current gap of research in AR, guidelines for effective designs of AR-based educational experiences can be proposed (Radu 2014; Bacca et al. 2014).

Conclusion

AR has been gaining ground since its first use almost 50 years ago. With its expanse of potential benefits, AR integration in education has been evolving and increasingly widespread especially now that mobile platforms are so easily accessible. As an effective supplement of education delivery, AR has been found to increase visualization, interactivity, and knowledge content. Many beneficial AR factors on education have been identified though more detailed studies are needed to examine their long-term relationship to learning. In order for AR to reach its full potential in the field of education, further studies as well as technological advancements are necessary. It has been raised consistently that guidelines are needed to aid in the design of AR-based learning environments. Learning theories have been identified and require further application in the development of these guidelines.

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Augmented Reality in Education, Scope of Use and Potential

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Synonyms

Augmented reality; Education; Emerging technology; Information and communication technology; Innovation

Augmented Reality: Definition and Features

Augmented Reality: General Idea

Augmented reality is a technology that has gained popularity in recent years; it is often referred to in the subject literature as an emerging technology that has great potential for educational activities. This technology is based on the idea of applying an additional layer of digital information to images of real objects and locations in real time, thus complementing and extending them with new, additional elements that are valuable to the user (Azuma et al. 2001). The additional layer of information can contain text, images, videos, or other multimedia or interactive components that expand the view of the physical world with digital elements. The main features that distinguish augmented reality from other technologies include seamless blending of virtual and real elements into one environment, giving users the ability to interact with this environment in real time, and providing accurate 3D placement of virtual and real objects (Azuma et al. 2001). The aim is to provide the user with a visually attractive and cognitively rich information transmission of a hybrid nature that combines physical and digital environments (Barfield 2015). Augmented reality is already widely used commercially in business and entertainment, but it is also finding applications in the services of cultural institutions and more often in educational activities and their promotion.

Augmented Reality: Technical and Practical Conditions of Use

On the practical side, the use of augmented reality requires the use of a mobile device, usually a smartphone, tablet, or special goggles. The application of the digital layer to the physical environment of the user can take place in two main ways: based on geolocation options the mobile device sends information about the user's location to the application, and this information is compared to a database of digital objects assigned to this location (this is the principle of many augmented reality games or the popular Layar search engine), or with the use of special markers (so-called beacons) that can be located in space and contain encoded information read by the mobile device's cameras, as is often used in custom applications created for a given company or institution (Geiger et al. 2014; Sato 2017). Digital information can be displayed in a "head-up" model that displays information directly in the user's line of sight, on transparent surfaces such as special glasses, or in the case of applications for pilots or drivers, on a vehicle's windscreen. This type of presentation has many benefits because it allows information to be received naturally, without the user having to look away and at the mobile device; this is especially important in applications designed for people who must simultaneously follow the physical environment and the hybrid environment of augmented reality. Digital information can also be displayed in a "head-down" model which displays information on a traditional mobile device such as smartphone or tablet; this is a popular solution due to the widespread availability of mobile devices and their ease of use (Smith et al. 2017).

In the context of the practical aspects of the application, attention should be paid to three things that can significantly influence the quality of the message provided through augmented reality. The first factor is the technical parameters of the mobile device on which the application is viewed. Smoothly combining the physical and digital realms requires the device to have sufficient memory capacity and a fast network connection. The functionality and user-friendliness of the application itself are also very important: the service must be intuitive, easy, and pleasant for the user so the information can be delivered effectively (Tsai et al. 2016). The third factor is the information and media literacy of the user: receiving information in hybrid environments such as augmented reality requires competence in the field of multimedia processing and the ability to understand cognitively rich messages, which may not be easy for everyone.

Augmented Reality Versus Virtual Reality: Similarities and Differences

The concept of augmented reality is often discussed in the subject literature alongside the topic of virtual reality, which may raise questions about the similarities and differences between these technologies. As explained earlier, augmented reality is based on combining digital and physical environments; specifically, on the image of the real world, a digitally generated information layer is placed which enriches the general message with new and relevant elements. As a result, the user can see physical and digital objects and information at the same time. Virtual reality, on the other hand, is based on the idea of immersing the user in an artificial digitally generated world and cutting off external stimuli from the real world. The goal is to give the user the impression of being in a 3D world that may or may not resemble the real world (Kipper and Rampolla 2012). Virtual and augmented reality are therefore two different concepts that should not be confused, but they are often discussed together in the subject literature because of the popular concept of the so-called virtuality continuum that was described in the 1990s by P. Milgram and F. Kishino. These authors presented a scale in which at one end there is the real world, at the other end there is virtual reality, and between there is what is referred to as mixed reality, which includes augmented reality. Virtual and augmented reality are thus found together on the scale of the virtuality continuum; hence they are often discussed together. However, they differ from each other essentially: virtual reality is a completely artificial digital environment, whereas on the virtuality continuum scale, augmented reality is close to the world of physical objects (Milgram and Kishino 1994).

Augmented Reality in Education: Current Scope of Use

Augmented Reality in Early Education

Augmented reality, due to its multimedial and visually attractive character, is used at early stages of education to increase children's motivation and attract interest in learning. Augmented reality is practically used, among others, to teach children simple motor skills: for example, pointing, moving, or catching objects; coordination, memorization, recognition of colors and geometrical shapes, simple language skills, information, and media literacy skills; as well as basic competences in various educational subjects such as mathematics, biology, or languages (Salvador-Herranz et al. 2013; Solano et al. 2017). According to G. Salvador-Herranz et al., using AR in the education of preschool children led to "students showing greater attention in class, accompanied by a notable interest in the subject being taught" (2013, p. 37). Augmented reality can also be used as an educational tool to help build ethical competences and awareness, such as responsibility in the field of pro-ecological behavior (Bodén et al. 2013), road safety rules (Lugmayr et al. 2018), as well as soft skills related to collaboration and working in teams.

To summarize, augmented reality can be used at the entry level of education to teach core physical, intellectual, and emotional competences and more specific knowledge in different educational subjects, as well as to build social competences, attitudes, and behaviors. The interactive and multimedial nature of the message and its visual attractiveness can help motivate children to learn and help them build early, positive experiences related to education.

Augmented Reality in Middle-Stage Education

At the middle stage of education, augmented reality is widely used in teaching various subjects, especially those that are stereotypically seen by students as difficult or tedious, such as mathematics, physics, chemistry, geography, or history (Cai et al. 2014; Estapa and Nadolny 2015). It increases their motivation to learn, improves memorizing processes, and increases the level of understanding of the given subject. Similarly, as in the case of primary education, at middle school, and high school levels, a beneficial effect of using augmented reality on educational processes can be observed. Evidence for this can be found in the results of research carried out by S. Cai, X. Wang, and F. K. Chiang, who showed that using augmented reality in teaching chemistry has a positive influence on chemistry education among middle school students, especially low-achieving ones (2014). Similar results can be found in a paper by A. Estapa and L. Nadolny, according to whom the use of augmented reality in mathematics education clearly increases students' level of motivation to learn this subject (2015). It is worth noting that research is always conducted on a specific group of students and often shows that the influence of augmented reality differs between different groups (for instance, more able students vs. less able students) and different subjects, but generally it seems the use of augmented reality has a positive effect on students' learning experience and their motivation to study, which may translate into greater achievements in understanding and remembering a subject's content.

Augmented Reality in Higher Education

Augmented reality is widely used in many fields of higher education, in particular science, biology, chemistry, and medicine. It is a valuable tool for visualizing information that allows students to deal in an accessible way with complex models, projects, and layouts. This is particularly useful to students of physics, chemistry, architecture, or engineering as it allows them to visualize phenomena and/or design complicated systems (Akçayır et al. 2016); it is also useful in the fields of biology and medical sciences for memorizing large amounts of knowledge, for instance, to study human or animal anatomy (Moro et al. 2017). Some research showed a positive effect of the use of augmented reality on students' cognitive processes in the field of medicine. Research conducted by S. Küçük, S. Kapakin, and Y. Göktaş showed, for instance, that using an augmented reality application when studying anatomy reduces the cognitive load yet yields higher learning achievements (2016). This thesis can also be confirmed by research conducted by C. Moro et al. that showed the great effectiveness of virtual and augmented reality as tools for learning anatomy in the field of medicine; they provide an engaging, interactive environment for studying and increase students' motivation and enjoyment (2017). Analogous results have also been shown, among others, in research conducted with students of physics. M. Akçayır et al. showed that using an augmented reality app can significantly help students to develop their laboratory skills, as well as to build positive attitudes toward physics laboratory classes (2016).

As in the case of learning at entry and middle levels, students can also use augmented reality to learn personal and social skills such as the ability to study effectively. According to research by J. Martín-Gutiérrez et al., augmented reality facilitates collaborative work among students and creates an environment for autonomous learning (2015). Augmented reality is used not only by students of science and medicine but also by students of humanities and social sciences, such as history, communication, linguistics, or art. Research conducted by J. A. Delello, R. R. McWhorter, and K. M. Camp on a group of students of marketing, human resource development, and education showed that for all three disciplines, augmented reality is a useful tool for learning that creates a positive experience for students and encourages them to learn (2015). The use of new information and communication technologies such as augmented reality may positively affect the motivation to learn, as well as support students' creativity, the ability to understand cause-and-effect processes, as well as develop empathy and other moral values.

Augmented Reality in Adult Education

Nowadays, education lasts a lifetime, and many adult people who are professionally active want or need to continually improve their education. Augmented reality can also be applied to work-related adult education, for instance, during training or courses. Analogously, as in the stages of education discussed previously, in adult education augmented reality can be used both to build specific professional skills characteristic of different professions, as well as to build general personal and social competences, such as group work skills, work planning, and time management, and to increase motivation to work. Augmented reality is used, among others, in applications supporting the repair of vehicles by mechanics or in applications for professional drivers, pilots, engineers, architects, and designers. There are not many papers exploring this topic; however, based on the promising results of studies from the higher education sector, it can be assumed that augmented reality may also be useful in processes of lifelong learning and self-improvement of adult learners.

Augmented Reality in Special Education

A very important aspect of the usefulness of augmented reality is its use in the education of people with various types of disabilities, most often emotional, intellectual, cognitive, and sometimes also physical (Richard et al. 2007). There is a lot of research related particularly to the usefulness of augmented reality in the education of people (especially children) with Asperger syndrome and autism at various stages (Escobedo et al. 2014; Nazaruddin and Efendi 2018; Syahputra et al. 2018). Research has shown that augmented reality can help people with autism spectrum disorder (ASD) to better focus on tasks, which is crucial for knowledge acquisition processes in various disciplines. Augmented reality can also be helpful in the process of developing social skills, such as understanding situational contexts or recognizing body language and emotions (Escobedo et al. 2014; Syahputra et al. 2018). Research conducted by C. Chen, I. Lee, and L. Lin clearly showed, for instance, that "through repeated ARSFM training, adolescents with ASD can more accurately recognize and more appropriately respond to the emotional facial expressions they see in everyday social situations. This augmented experience can increase the ability of people with ASD to understand others' emotions and improve the assessments of emotional expression and social skills of adolescents with ASD" (2015, p. 402). Augmented reality can also help in recognizing objects (Nazaruddin and Efendi 2018), which can be useful in learning many subjects that require the manipulation of shapes and their location in space, including mathematics and physics. All in all, augmented reality can be used in the education of people with special needs as a tool to help them focus attention, better understand models and spatial relations of objects, and increase general social skills, as well as motivation to learn.

Main Areas of Augmented Reality Use in Education: Summary

Summing up, it can be concluded that augmented reality is used at various degrees of the education of children, teens, adults, and those with disabilities, to support the development of various groups of competences in science, medicine, humanities, and social sciences. The subject literature analysis shows that augmented reality may help in the development of spatial imagination, visualization and understanding of models, decision-making skills, critical thinking, and understanding of processes (including social and historical). Augmented reality also helps in the formation of language skills (particularly foreign language learning), the ability to discuss and work in groups, as well as in the development of general imagination and creativity (Wójcik 2016). Importantly, using augmented reality in the process of learning often increases students' enjoyment, satisfaction, and motivation in the subject being taught. As J. Bacca et al. conclude, augmented reality is particularly effective as a tool for "better learning performance, learning motivation, student engagement and positive attitudes" (2014, p. 146). Of course, not all research results clearly show a high-quality difference in teaching with the aid of augmented reality. Bearing in mind that many factors contribute to the final effect of education, in the process of assessing the influence of augmented reality on education, it is important to take into consideration the target group, the subject being taught, the teacher's competence, and the quality of the application itself. However, it seems that the majority of studies show the great utility of augmented reality for teaching and learning.

Augmented Reality in Education: Benefits and Risks

There is no doubt that the use of augmented reality in education has many advantages. First of all, it is an innovative technology that can be used to transfer knowledge in a new, attractive way that increases motivation to learn and helps build positive learning experiences. The engaging and visually appealing multimedial character of the message arouses interest and willingness to learn in both children and adults. As has been shown, augmented reality may increase the effectiveness of education in many fields and at different levels of education, including the education of people who are struggling with intellectual, emotional, or cognitive problems. However, as with any innovation, there are certain dangers that must be remembered. Some authors conducting research in pedagogical sciences and psychology point out that cognitively rich environments such as augmented reality can overwhelm the user and cause feelings of confusion, stress, impatience, or information overload (Wu et al. 2013; Bower et al. 2014). According to Wu et al., “There are also challenges related to learners and their learning processes. In an AR learning environment, students could be cognitively overloaded by the large amount of information they encounter, the multiple technological devices they are required to use, and the complex tasks they have to accomplish” (2013, p. 47). As Bower et al. conclude, “(. . .) utilization of technology is by no means a guarantee of success. On the contrary, poor use of emerging technology can result in inferior learning outcomes” (2014, p. 12). The use of augmented reality in itself does not bring educational benefits but only serves as a tool for achieving didactic goals and must be used correctly in order to tap potential and minimize risk. One often-mentioned risk factor is the need for users of augmented reality to have specific competencies that enable effective use of this technology. The use of applications based on augmented reality requires, for instance, a specific level of technical knowledge that enables smooth operation of mobile devices and apps. A systematic review of the subject literature conducted by M. Akçayır and G. Akçayır showed, for instance, that some of the biggest challenges that may discourage students when using augmented reality in the classroom are related to technical problems and the usability of applications (2017). For the effective implementation of augmented reality, it is therefore necessary to have good quality electronic equipment, well-designed applications, and the competences for their proper use on the part of students and teachers. In addition to technical competences, it is also very important to take into consideration students’ level of competences in the field of information and media literacy. The ability to selectively receive information shared in cognitively rich environments is necessary to fully benefit from the potential of augmented reality. These competences should ideally be represented among students, teachers, and parents but at least among teachers so they can assist students. This is especially important when working with the intellectually, emotionally, or cognitively disabled, as was pointed out, among others, by M. A. Nazaruddin and M. Efendi in the context of using augmented reality applications to teach people with autism (2018).

The use of new information and communication tools in educational processes is often also hindered by practical problems related to the need to purchase appropriate equipment and applications, which can be expensive when providing for large groups of students. Using augmented reality applications also requires constant updating of equipment and teachers’ knowledge in the form of training, all of which can be very expensive. The downside of using augmented reality in education is therefore the need to incur regular financial expenses which may be beyond the financial capacity of many schools.

Summing up, it can be concluded that using augmented reality as an educational tool has both pros and cons. The risks and negative aspects of using this technology can mostly be neutralized by rational planning of the role of new technologies in the educational process and costs related to their use, as well as by equipping students and teachers with the competences necessary for the effective and responsible use of augmented reality.

Augmented Reality in Education: Potential for the Future

The positive effect of using augmented reality on the teaching of competences has been proven in many areas, but many have not yet been examined, and, as emphasized by Wu et al., in comparison with research on the use of other tools in education, for example, the Internet or multimedia, research on the effectiveness of the application of augmented reality is still in the early stages (Wu et al. 2013). Augmented reality is, however, mentioned in many publications by both scientists and practitioners in various fields as a so-called emerging technology that will develop and become more and more popular in the future (Bacca et al. 2014; Ponce et al. 2014; Ozdamli and Hursen 2017). According to F. Ozdamli and C. Hursen, "Augmented Reality is a developing technology which has the potential to influence the teaching–learning process" (2017, p. 122). A similar opinion is presented in a paper by C. S. C. Dalim et al., according to whom "Integrating AR in education may lead to a brighter future for the educational sector. AR has the potential to engage students in a better learning experience that could create a more comprehensive teaching and learning process" (2017, p. 586). Based on these predictions, it seems that incorporating augmented reality into educational processes is a wise decision; however, much depends on the level of acceptance of this technology by students, parents, and teachers. Research carried out so far in this area is rather promising. A study conducted by A. Balog and C. Pribeanu showed that the perceived usefulness and enjoyment of using augmented reality tools in education are factors which greatly affect the level of acceptance of this technology among students (2010). C. S. C. Dalim et al. identified six factors that influence the acceptance of augmented reality: the balance between the technical and pedagogical aspects of an augmented reality application; the reliability of an augmented reality app; a student's ability to use augmented reality independently without help from teacher or parent; the ability to include others in the process; students' individual features and background; and the platform used to deliver augmented reality (2017). Knowing the factors that influence the adoption of new technologies can facilitate their widespread introduction and encourage the belief that augmented reality may have great potential for educational activities in the future.

Conclusions

Augmented reality is already widely used in various stages of education, in different age groups, and to shape various competences. The cited studies show the possibilities of the effective application of augmented reality in the education of children, adolescents, and adults in many areas: history, geography, biology, medicine, mathematics, physics and chemistry, languages, motor and spatial skills, object recognition and coordination, and social competences such as working in groups or autonomous learning. Importantly, many studies indicate that the use of augmented reality not only increases the efficiency of learning specific knowledge or competences but also increases students' satisfaction and motivation to learn, all of which helps to create a positive educational experience.

In summary, it can be said that augmented reality is applicable everywhere that it is important to visualize complex processes, procedures, or objects or to increase students' level of motivation and enjoyment when learning subjects often considered difficult or tedious. Augmented reality's full range of applications in education is not yet known, but it seems that this technology has great potential. However, as with any innovation, it is important to maintain a reasonable approach and implement new solutions gradually to avoid possible negative effects that often accompany the use of technology in education, such as cognitive stress or information overload.

Cross-References

▶ Assisting People with Physical Disabilities through Technology
▶ ICT-Based Inclusive Education
▶ Implementation of ICT in Secondary Schools
▶ Literacy and Technology
▶ Mobile Computing and Mobile Learning
▶ Mobile Learning
▶ Students' Computer Literacy and the Use of Tablets in Upper Secondary Schools
▶ Tablet Use in Higher Education
▶ Technology Enhanced Learning

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► Technology-Enhanced Learning in Programming Courses, Role of

Autonomous Learning

► Digital Literacy, Creativity, and Autonomous Learning