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A multi-dimensional perspective on instructional design-based ICT integration: A case study

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Abstract
This study aims to implement an exemplary instructional design-based ICT integration to allow students to acquire both course achievement and knowledge society skills. The research used the case study method. The participants consist of 30 students, who attend the course of Science and Technology at the 7th grade level in a state school, along with a teacher and two mentor researchers. During the application process, the researchers asked to prepare a video from students. Video content was associated with course outcomes. The data was collected through logs of tablet usage, videos of the tablet screen, reflection reports, informal and semi-structured interviews, participant observation, focus group meetings, and achievement tests. The data were analyzed through descriptive statistics, paired sample t-test, Jaccard similarity analysis, and content analysis. The findings showed that students' course achievement had improved significantly. In addition, it revealed that the students analyzed, organized, and evaluated the information both through the applications provided to them on the tablets and by choosing and using the tools and equipment they had in their laboratories and working collaboratively. Moreover, the teacher stated that she had an authentic experience that gave her the opportunity to improve her competencies on how to integrate ICT according to contextual conditions. In conclusion, the implementation is presented by setting goals within the contextual conditions from a micro perspective and to achieve an effective and efficient instructional design-based ICT integration through the design, implementation, analysis, review of the process as well as improvements where necessary.

Keywords ICT integration · Knowledge society skills · K12 · Instructional design · Science and technology

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1 Introduction

ICT integration is a multi-dimensional, dynamic and complex process involving elements on the system (country policies, education system, professional development, teacher training, curriculum, etc.), individual (self-efficacy, skills, motivation, belief, and self-regulation), and technology (data collection, data reporting, and sharing) (Yildirim et al., 2017; Bebell et al., 2004; Ertmer et al., 2012; Roblyer, 2006; Tondeur et al., 2009). One of the main indicators of the success of this process in terms of educational goals is to create suitable conditions for the development of knowledge society skills for the individual and to increase course success (Ertmer et al., 2012; O'Neal et al., 2017; Sansone et al., 2019; Schmid et al., 2014).

In the knowledge society, K12 education is expected to support students to develop appropriate and meaningful skills for life by encouraging collaborative knowledge production (O'Neal et al., 2017; Sansone et al., 2019). Studies indicate that ICT integration can play an important role in providing this support (Moltó Egea, 2014; Sutherland et al., 2014). The studies on ICT integration state that teachers need to know when, how, and why to use ICT to ensure learning (Yıldız & Usluel, 2016; Ertmer et al., 2012; Kjellsdotter, 2020; Sansone et al., 2019; Schmid et al., 2014). In order to meet this requirement, the teachers should be individuals who have technological-pedagogical knowledge in schools with a developed infrastructure, renew themselves, and attach importance to their professional development (Olofsson et al., 2020; Starkey, 2020). However, this requirement describes the ideal conditions rather than the current condition (Olofsson et al., 2020; Starkey, 2020).

The objectives to be achieved in the ICT integration process may vary according to contextual conditions. For example, Wu et al. (2019) identified different problems regarding ICT implementations in rural and urban settlements and suggested that rural schools need to focus on the development of ICT infrastructure and quality digital content whereas urban schools need to focus on the inadequate epistemic beliefs of teachers and design processes. Further, Olofsson et al. (2020) explained contextual conditions based on four different aspects: student profile, support services, e-content, and use of digital tools in school activities. Such contextual conditions yield inconsistent results in theory and practice when defining the competencies required for an ideal ICT integration (Olofsson et al., 2020). Thus, it is possible to argue that there is a need for flexible approaches that address the integration process depending on contextual conditions.

This study argues that conducting studies that take into account the instructional design (ID) on how ICT integration can be applied in different contexts can bring about the effectiveness of the integration process. In fact, although ICT integration and ID models seem to be different from each other, ID and ICT integration are intertwined (Chan et al., 2013; Kale et al., 2020; Qasem & Nathappa, 2016; Wang, 2008). For example, in a study involving a group of teachers using the ID and ICT model separately, researchers found that teachers in both groups used common components (Kale et al., 2020). So, the more ID strategies are used in ICT integration, the more likely it is to use ICT in K12 education and strengthen teaching practices (Aşık et al., 2020; Kali et al., 2015; Tondeur et al., 2018; Wang, 2008).

From this point of view, this study aims to perform an instructional design-based ICT integration to acquire both course achievements and knowledge society skills in the course of science and technology at a K-12 school. In this process, this study has also been tried to ensure that the teacher has an authentic experience that provides the opportunity to develop their competencies on how to integrate ICT according to contextual conditions. In the implementation process, the instructional design-based ICT integration model developed by the researchers (Yildirim et al., 2017) was used. To achieve this, the following research questions are proposed:

In learning-teaching processes carried out on the basis of instructional design-based ICT integration;

1. Is there a significant improvement between students' pretest and posttest scores in their course achievements?
2. How do students' learning experiences relate to the following knowledge society skills?

   a. Access, assemble, reorganize of knowledge
   b. Interpret, analyze & evaluate of knowledge
   c. Collaborate on projects and teamwork
   d. Select appropriate tools & evaluate the impact
   e. Generate knowledge products

3. What are teacher's reflections about ICT integration implementation?

2 Theoretical framework

2.1 Knowledge society skills

In the literature, there are various names and classifications regarding knowledge society skills, such as "21st-century skills (Ananiadou & Claro, 2009; Binkley et al., 2012; Partnership for 21st Century Skills, 2009; van Laar et al., 2017), new literacy skills (Mioduser et al., 2008), knowledge-related skills (Anderson, 2008)" in K12 education. In this study, knowledge-related skills were grounded suggested by Anderson (2008). Although the knowledge-related skills are based on, when the skill definitions suggested by the researchers with various names were examined, the skill sub-dimensions were not independent of each other and could be interrelated to each other. Thus, a matrix was created by the researchers to show the relationships between the skills discussed in these studies. Then, this matrix was visualized using the Social Network Analysis (SNA) techniques (Fig. 1).

Based on the relationships established between skills, "(F1) Basic Skills" took a central place and four separate clusters emerged regarding skills that are similar to each other and related to each other. From this point of view, although there are different classifications and nomenclatures, knowledge society skills are basically classified as 1-"Problem-solving, Creativity and Critical Thinking", 2-"Information Management", 3-"Communication and Collaboration", and 4-"Life Skills". For

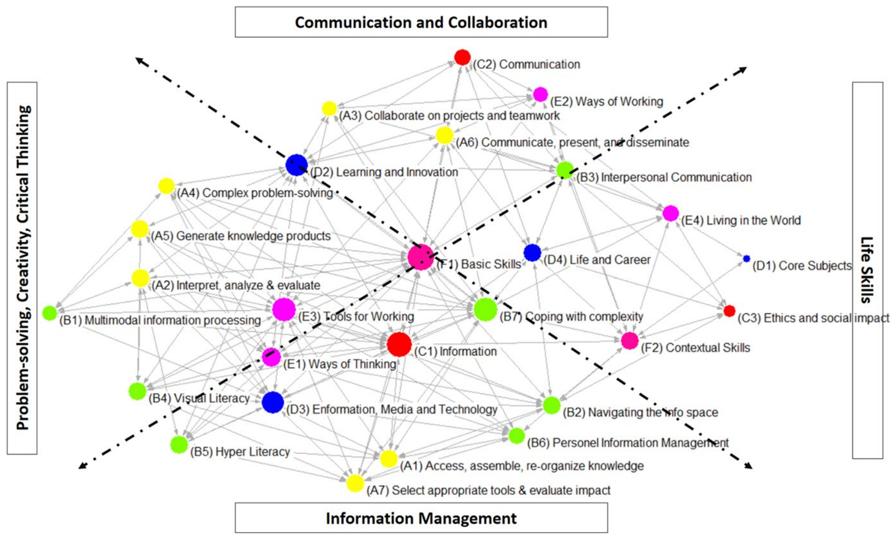


Fig. 1 Visualization of knowledge society skills with SNA. A: Anderson (2008); B: Mioduser et al. (2008); C: Ananiadou & Claro, 2009; D: Partnership for twenty-first Century Skills (2009); E: Binkley et al. (2012); F: Van Laar et al. (2017)

example, "(C2) Communication", "(B3) Interpersonal Communication" and "(A3) Collaborate on Projects and Teamwork", "(A6) Communicate, Present and Disseminate" skills are named differently, but because they are related to each other, communication and collaboration skills collected in the cluster.

Based on the relationships emerging in Fig. 1, this study argues that the ICT integration process on the way to becoming a knowledge society should be organized in a way that will support information management by providing students with cooperative learning opportunities and enable students to develop their problem solving, creativity and critical thinking skills.

2.2 Models of ICT integration and instructional design

On the use of ICT in education, ICT integration models are utilized for the appropriate selection of ICT and its effective and efficient use as well as for the retention and sustainability of the process for the purpose of supporting student learning in teaching and learning processes (Yıldız & Usluel, 2016, 2019; Birch & Irvine, 2009; de Brabander & Glastra, 2021; Kale et al., 2020; Lin et al., 2012; Mishra & Koehler, 2006; Toledo, 2005; Tondeur et al., 2008a, b; Vanderlinde & van Braak, 2010; Wang & Woo, 2007; Wang, 2008), and besides instructional design (ID) models are used for systematic planning of teaching and learning processes (Kale et al., 2020; Kim & Downey, 2016; Shih, 2017). While these models explain the dimension related to ICT integration from many aspects (infrastructure, teacher competency, sustainability, etc.), they have limitations in providing examples on the integration process.

For example, the model of TPACK (Mishra & Koehler, 2006), one of the most referenced models, considers the success of ICT integration as the intersection of the technological, pedagogical, content knowledge of teachers. However, there is no adequate answer to questions such as how TPACK will be reflected on course plans or the use of ICT in courses (Schmid et al., 2021; Usluel et al., 2015). In another study, the groups with five different TPACK perceptions (low T, low C, low P, all low, all high) showed small and insignificant effects on planned technology use and being technology users (Schmid et al., 2021). Hence, it can be argued that while defining the skills required for ICT integration for teachers, efforts are needed to understand how to improve these skills.

What is expected from teachers in the ICT integration process is that they choose the ICT that suits learners' needs, learning goals, and learning approach and improve the culture of teaching and learning with ICT (Ertmer et al., 2012; Schmid et al., 2014). Starkey (2020) stated that the competencies expected from teachers regarding the integration of ICT into teaching practices are three-dimensional: (1) use of technology for teaching, (2) critical use of technology, and (3) teaching to learners using technology (Starkey, 2020). This type of classification assumes that schools have technology that teachers can use in the classroom. However, the contextual conditions of schools such as access to technology, parent and student profiles, and teacher competencies differ. At this point, some researchers draw attention to the positive results of taking instructional design models as the basis for making context-appropriate planning in the ICT integration process and realizing an effective process (Kim & Downey, 2016; Sansone et al., 2019). For example, Kim and Downey (2016) stated that the lesson plans developed under the guidance of the ASSURE instructional design model for an effective technology integration contribute to student learning and support the creation of student-centered, active learning lessons. Therefore, this study argues that basing instructional design models that will contribute to systematic planning in the ICT integration process may contribute to the effectiveness and efficiency of the process.

2.3 Teachers' competencies in ICT integration

In the ICT integration process, teachers are expected to have certain competencies for using technology at a basic and advanced level (Atman Uslu & Usluel, 2019; Battigelli et al., 2010). Briefly, these competencies are related to the use of technology such as designing learning activities, developing course materials, etc. to achieve learning goals. They are also expected to gain experiences that facilitate producing appropriate solutions for changing conditions (e.g. infrastructure, discipline, school) (Banas & York, 2014; Haydn, 2014; Olofsson et al., 2020; Starkey, 2020; Voet & De Wever, 2017). However, teacher competencies are considered as one of the major obstacles (Afshari et al., 2009; Bingimlas, 2009; Bozkuş & Karacabey, 2019; Bukaliya & Mubika, 2011; Pelgrum, 2001; Yazlık, 2019).

Teachers should know how to plan and design the learning process, taking into account contextual conditions such as learning objectives and the number of students regarding the integration process (Yıldız & Usluel, 2016; Ertmer et al., 2012; Sansone et al., 2019; Schmid et al., 2014). Thus, there is a need for teachers should have competencies about when, how, and why to use ICT, and how to support students with ICT and should plan the way that they can use their competencies in designing appropriate learning tasks for their students (Yıldız & Usluel, 2016; Kjellsdotter, 2020; Sansone et al., 2019; Schmid et al., 2014). Also, to successfully integrate ICT in education, it is essential that a teacher needs to gain experience on the type of problems that technology can solve and the ways to overcome the problems in the ICT integration process (Instefjord & Munthe, 2017). In this regard, it is possible to argue that teachers should gain practice-based experiences for the multi-dimensional and dynamic nature of ICT integration (Røkenes & Krumsvik, 2014). Thus, guidelines based on instructional design that offer a gradual experience for planning the use of ICT in the course allow teachers to develop strategies depending on the condition (Kale et al., 2020; Kali et al., 2015; Kim & Downey, 2016; Sansone et al., 2019). Besides, ICT integration based on instructional design can provide a rich, original and practical context for teachers to learn technology and for professional development.

3 Methods

This study is a design case study describing "a real artifact or experience that has been intentionally designed" (Boling, 2010; p.2). Design cases are a critical component of learning and practicing design (Boling, 2010). Design cases may focus on the activities, lessons, courses, or learning environments (Howard & Myers, 2010; Rowland et al., 2011).

3.1 Study group

Case studies enable researchers to examine the data within a specific context in a small geographic area or a very limited number of individuals with purposeful sampling, regardless of the general population (Howard & Myers, 2010; Schoch, 2020; Yin, 2018; Zainal, 2007). This study was conducted with a total of 28 students, 12 girls and 16 boys, who study at the 7th grade level in a state school and attend the course of Science and Technology, along with a teacher and two mentor researchers. The ICT use among the students was analyzed and only 1 student has not used ICT before (id:12) whereas 11 students (id:1,2,6,16,18,20,21,22,23,26,27) have used one of them at least for one year; the remaining 16 students have used at least one of them for two years or longer (Appendix 1).

3.2 Data collection tools

An important aspect of case studies is that data collection is based on as many data sources as possible (Creswell, 2007). The data for the pilot study were collected through group and individual reflection reports, videos of tablet screen recordings, informal interviews with the teacher, and participant observation. The data for the implementation were gathered through the semi-structured interview on the process with the teacher, the focus group meetings on the implementation with the students, log records, videos of tablet screen recordings, and observation (Table 1).

Tablet Log records were obtained via "App Usage Tracker", an open-source and free application, while the videos of tablet screen recordings were obtained through "SCR Screen Recorder", which is an open-source and free application too. The videos of screen recordings present audio records as well.

3.3 Data analysis

Data analysis includes descriptive statistics, Jaccard similarity, and content analysis. Excel was used for descriptive statistics, visualization of quantitative data, and calculation of the Jaccard similarity coefficient. Nvivo was used for content analysis. The content analysis was conducted by the researchers together. In the first stage, the data were transcribed and a total of 16 data sources were formed. These sources include the tablet screen recordings of each team ($n = 7$), the semi-structured interview with the teacher ($n = 1$), the group focus interviews with the students ($n = 7$), and the observation notes of the researchers in the implementation process. Deductive and inductive coding techniques were employed for the coding of the data (Miles & Huberman, 1994). While the data on the learning experiences of the students, the teacher opinions, and observation notes were inductively coded, deductive coding techniques were used to associate these codings with the skills on knowledge (Anderson, 2008).

After the coding of the data, Cohen's Kappa coefficient was calculated for reliability. Firstly, a random sample of 10% of the codings was sent to another researcher, who was a subject area expert (SAE). The researcher was asked to match the relevant codes in the code list with the corresponding coding section in the transcripts. When the researcher could not do any matching, the researcher was asked to make suggestions on codes regarding the coding section. The comparison of the codings made by the researcher (match the relevant codes in the code list) and those made by the researchers of this study yielded an accuracy rate of 81.3%.

The similarity of the learning experiences on the knowledge society skills between the groups was determined through the calculation of the Jaccard distance.

Table 1 Data collection tools

Data Collection Tools	Pilot Study	Implementation
Group reflection reports	+	–
Individual reflection reports	+	–
Informal interviews with the teacher	+	–
Semi-structured interview with the teacher	–	+
Focus group meetings with the students	–	+
Participant observation	+	+
Videos of tablet screen recordings	+	+
Tablet log records	–	+

This distance is calculated as follows after a matrix is created to show the groups where the codings obtained through the analysis of qualitative data are in (Schulz, 2008):

3.4 Instructional design-based ICT integration process

In the implementation process of this study, the instructional design-based ICT integration model developed by the researchers (Yildirim et al., 2017) was selected as the baseline. Thus, an ICT integration was carried out by setting goals within the existing condition from a micro perspective and to achieve ICT integration through the design, implementation, analysis, review of the process as well as improvements where necessary, to allow learners to acquire both the knowledge society skills and course achievements.

3.4.1 Description of the existing condition

For the description of the existing condition, informal interviews were made with the school management, the teacher of the course where the study was conducted, and other teachers. Surveys were administered to obtain information on students and parents.

There are about 30 students in the school classrooms. The school has one computer and two science laboratories. There are 27 computers in the computer laboratory and one computer in the science laboratory. Although these computers have Internet access, it is not possible to access networks such as YouTube and Facebook due to the secure Internet restrictions of the Ministry of Education. The bandwidth is very limited as well. The information technologies (IT) teacher can provide guidance with technology integration work at the school. The IT teacher and other teachers stated in the interviews that cooperation for ICT integration could not be achieved.

A female teacher with 3 years of experience in Science and Technology participated in this study. She has been working for 1 year at the school where the study was conducted. The use of technology of the teacher in the courses until this study has been limited to showing presentations via a projector, asking the students to watch a movie, and analyzing materials on the achievements through the Education and Informatics Network of the Ministry of National Education and a website offering commercial online content. The teacher actively uses a smartphone in her daily life and has active Facebook and Instagram accounts. However, there is low awareness of software or applications for teaching purposes in schools.

In short, the existing condition can be characterized by the need to improve infrastructure facilities for the access of the school to ICT, relatively high awareness of the students on ICT use, and low awareness of the teacher on ICT integration. The existing condition is taken into consideration for the planning of the implementation process; the teacher was supported during the implementation process and the researchers produced solutions to improve the ICT access of the students.

3.4.2 Identifying goals

In this stage, the knowledge-related skills (Anderson, 2008) and the outcomes of the subject of “Refraction of Light” in the course of Science and Technology were determined that they could be included in the ICT integration process. Anderson (2008) considered knowledge society skills as “knowledge-related skills” under 7 headings (see Fig. 1). For the pilot study, the first three skills on knowledge were taken into consideration given the inexperience of both the teacher and the students (Appendix 2).

3.4.3 Designing the implementation

As suggested in the literature (Sansone et al., 2019), the collaborative learning method was employed in this study based on the objectives. To do that, groups of four were formed for the students to study both in-group and out-group. Tablets were considered suitable for acquiring the course achievements that potentially facilitated the implementation process. Even if a tablet for each student was not purchased, it could be made available for common use in a school. For this study, tablets as many as the number of the groups in the study were provided through collaboration with a state university (7 tablets). Four students who did not have any tablet or smartphone at home were assigned to the groups that had students with a higher frequency of tablet use. Other students were randomly assigned to the groups. The Internet access of the tablets was achieved through the personal hotspot on the two smartphones of the researchers in the implementation process. As the evaluation method, formative and summative assessments were employed. In this process, the researchers decided to perform an achievement test for the observation of the students and for their course achievements.

The implementation was performed in two stages. First, a pilot implementation was carried out to identify weaknesses, and then it was revised based on the needs and applied.

3.4.4 Pilot study

The pilot study was performed for 40 min in a classroom course hour (not in a laboratory). Each group was assigned with tasks on the outcomes of the subject matter. The study was conducted with the course teacher accompanied by a mentor. The collaborative groups were supported on the problems experienced in the process and the misunderstandings of the students by the mentor or teacher. The data were collected through the observation notes of the mentor and the informal interviews with the teacher.

The data were analyzed through content analysis by two researchers and the teacher. The resulting themes were “problems experienced” and “the level of achievement of goals” and “necessary improvements.” The problems experienced in the implementation process were reported based on the analysis of the data, and improvements were identified (Appendix 3).

3.4.5 Implementation

The outcomes of the subject of "Refraction of Light and lenses" were addressed in the implementation process. As the students were familiar with the process and the shortcomings in the pilot study were eliminated, the goal was to develop all knowledge society skills (Anderson, 2008) (Table 2).

No changes were made to the teaching method/approach/strategy and the type of technology and evaluation method used by the teacher during the design of the implementation. The Internet access of the groups was provided via the network access of the mobile phone closest to them.

During the implementation, the students were assigned tasks intended to improve all of their knowledge society skills. They were further given homework and asked to watch YouTube videos on the course outcomes. They were then expected to analyze and interpret the information they gained both from the videos and from the courses through collaborative work. In the next step, they were asked to prepare a video via tablet to show that they acquired course achievement. To that end, a video editing app (Com-Phone) was downloaded on the tablets. Through this app, the students could produce a video adding screen effects, voice records, or texts to the photos they took or downloaded on the course outcomes. In the last step, the groups were expected to share their video on the Facebook group and then to discuss them to reveal what they think and to identify whether there was any incorrect or incomplete information in the videos.

3.5 Analysis (findings)

The analysis section presents findings on the learning experiences of the students to acquire the knowledge society skills (Anderson (2008) uses the concept of "knowledge-related skills"), the course achievements they acquired, and the opinions of the teacher, who was also a subject area expert, on the implementation process.

3.5.1 Students' course achievements

After the implementation process, the extent to which the students acquired the course achievement was analyzed based on the comparison of the pretest and posttest scores). Since four students did not take the posttest, the pretest and posttest of 24 students were compared in the analysis. Posttest was normally distributed (Statistic = .969, df = 24, ρ = .649) whereas the scores of the pretest were not normally distributed (Statistic = .889, df = 24, ρ = .012) according to a significance level of 5%. Following that, the square root of the scores of the pretest and posttest was calculated. The results of the repeated Shapiro-Wilk test demonstrated that the scores of both the pretest (Statistic = .925, df = 24, ρ = .075) and

Table 2 Goals of implementation

Course Outcomes	Knowledge-related skills	Tasks
• The student observes the refraction of light by experiment using lenses with thin and thick edges. • The student determines the focal points of thin and thick-edged lenses by experimenting. • The student gives examples of the usage areas of lenses in daily life and technology. • The student designs an imaging tool using mirrors or lenses.	1. Access, assemble, re-organize knowledge 2. Interpret, analyze & evaluate 3. Collaborate on projects and teamwork / 4. Complex problem-solving 5. Generate knowledge products 6. Select appropriate tools & evaluate impact 7. Communicate, present, and disseminate	1. Access the information regarding homework through technology 2. integrating lesson book and experimental and internet searching materials during the lesson 3–4. working collaboratively during the analysis, interpretation, and evaluation period 5. creating a video for what they have learned thereby through the app (video creating) 6. using the photographs taken, drawn, downloaded, and adding voice record, text content through apps while generating knowledge products 7. sharing their products on Facebook and interacting with other groups

Table 3 Paired samples test

	N	Mean	Mean Square	Std. Dev.	Std. Error	t	df	Sig.
Pretest	24	6.24	39.00	1.20	0.24	−3.43	23.00	0.00
Posttest	24	6.93	47.99	1.18	0.24			

the posttest (Statistic = .974, df = 24, ρ = .767) were homogeneously distributed. There was a significant difference between the square root scores of the pretest and the posttest, and this difference was for the scores of the posttest (t = −3.43, df = 23, ρ = .00) (Table 3).

Besides, the pretest and posttest scores were separately compared for each student to determine the impact of the implementation on the success of each student (Fig. 2).

The posttest scores of a group of students decreased after the implementation (n = 4; purple framework: a minimum of 7 scores); the pretest and posttest scores of a group of students did not change much (n = 6; blue framework: a maximum of 3 scores) and the posttest and pretest scores of a group of students increased compared to the pretest scores (n = 14; green framework: a minimum of 7 scores). This being said, following the implementation, more than half of the students (58.33%) improved their course achievements.

3.5.2 Acquisition the knowledge society skills

Findings related to knowledge-related skills are given in Table 4. The overview is that behaviors referencing knowledge-related skills are observed in all groups. The groups selected the tools and equipment in the laboratories suitable for their purposes to create their videos and produced their videos through collaborative work via the applications available in the tablets.

Below are the findings on each of the relevant skills on knowledge respectively.

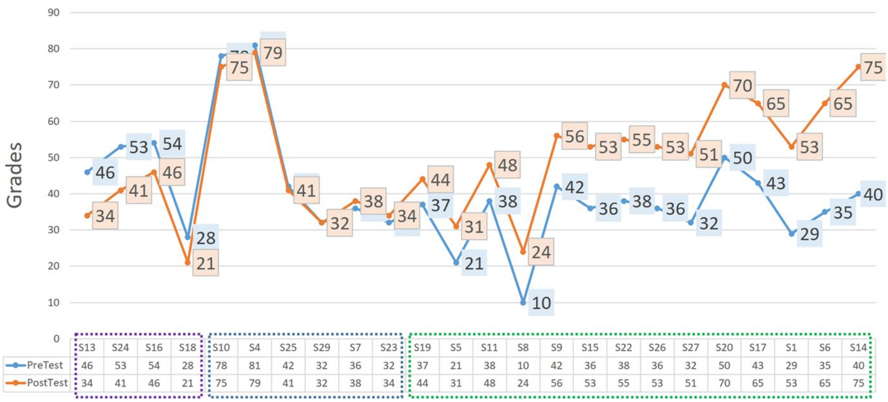


Fig. 2 Students' pretest posttest comparison

Table 4 Knowledge-related skills observed in groups

Knowledge-related skills	G1	G2	G3	G4	G5	G6	G7
Access, assemble, re-organize knowledge	+	+	+	+	+	+	+
Interpret, analyze & evaluate	+	+	+	+	+	+	–
Collaborate on projects and teamwork	+	+	+	+	+	+	+
Select appropriate tools & evaluate impact	+	+	+	+	+	+	+
Generate knowledge products	+	+	+	+	+	+	+
Communicate, present, and disseminate	–	+	–	–	–	+	+

Access, assemble, re-organize knowledge The students reviewed the printed materials available to them and accessed various information sources through online research on their tablets to prepare video content for creating a video (Table 5). Then, they organized the information they obtained.

The content of the videos of the students consists of lectures (audio content, subtitled content, or both audio and subtitled content) and visuals that support these lectures. They benefited from various information sources including coursebooks, the internet, assignment videos, lecture notes, and prior knowledge to prepare the content of the subject lecture. For example, the screen recordings of the groups were analyzed and it was found that one of the groups searched images with the keyword "information on lenses" using the web browser in the tablet. The members of the group chose a visual among the resulting visuals and downloaded their choice. Thus, the students exchanged their ideas through a collaborative process, accessing the type of information they wanted via technology, analyzing the results, and choosing the piece of information that serves their purposes. Therefore, the students had learning experiences on the acquisition of four skills on knowledge: "access", "analyze & evaluate", "collaborate on projects and teamwork" and "select an appropriate tool."

Interpret, analyze & evaluate After the students accessed the information sources, they decided on the sources to use for their videos through analysis and evaluation (Table 6). While creating content for their videos, some groups assessed the quality of the visuals, as well as the photographs, which were taken (G1, G3, G4, G5, G6) whilst some (G5 and G6) assessed the quality of the resulting video. There was no finding on the acquisition of the skills to "interpret, analyze & evaluate" in the experiences of G7. As seen in Table 5, it is notable that the students in this group directly used the information they obtained online without reflecting on them.

Collaborate on projects and teamwork It was observed that the students were highly collaborative within and between groups during the implementation process (Table 7). The students were supported by the teacher to develop the experiment, to complete the missing tasks, to understand the tasks, to use the applications on the tablets. Besides, the students got help from the mentor to understand the tasks and to use the applications on the tablets. G1 and G2 got help only from the teacher

Table 5 Students' learning experiences related to "access, assembly, re-organized knowledge" skills

Theme	Category	Code	G1	G2	G3	G4	G5	G6	G7
Resources used to access information in the video creation process	Information sources used in creating images	taking photos/recording videos of experiment material	+	–	+	+	+	+	–
		download images from the internet	–	+	–	–	–	–	+
	Information sources used to explain the topic (outcomes)	coursebook	+	+	–	+	+	–	–
		internet information resources (video, text)	–	+	+	–	–	–	+
		assignment videos	–	–	–	–	–	+	+
		lecture notes	–	–	+	–	–	–	–
		prior knowledge	–	–	–	–	–	+	–

Table 6 Students' learning experiences related to "interpret, analyze & evaluate" skills

Category	Code	G1	G2	G3	G4	G5	G6	G7
Assessment of the content to be used in the video (product)	visuals	+	–	+	+	+	+	–
	information to be given	–	+	–	–	–	–	–
Assessment of the quality of video (product)	generated video	–	–	–	–	+	+	–
	drawn picture	–	+	–	–	–	–	–
	taken photo	+	–	+	+	+	+	–
	recorded sound	+	–	–	–	–	–	–

whereas G7 was only supported by the mentor and G2, G3, G4, and G5 received assistance from both the teacher and the mentor. For example, G2 and G7 formed an opinion on the product they would produce by examining what other groups did and asking questions to other group members. For example, G3, the first group that came up with the idea of using experimental materials, shared their experimental setup with G5.

In addition, some students displayed behaviors that affected peer collaboration positively and negatively during the collaborative work (Appendix 4).

Select appropriate tools & evaluate the impact While creating the videos, the groups selected the most appropriate tools that they can use for the aimed content for the videos, such as drawing visuals, taking photos, obtaining information for the text for the lecture, creating the text, audio recording, etc. (Table 8). Most of the groups (G1, G3, G4, G5, G6) used the feature of taking photos on the tablet for the visuals (experimental materials) in the videos. The idea of Group 3 and 6 for shooting an experiment video through the laboratory equipment inspired other groups and motivated them. The groups which used the laboratory equipment (G3 and G6) made video and photoshoot on the subject of the refraction of light, which is an outcome of the subject, by holding the flashlight of their phones on the lens and also shot videos similar to the videos that were given as homework before the implementation process.

In addition, the tablet log records of the groups on their use of ICT were thoroughly analyzed (Fig. 3). The behavior of getting help on how to watch the video (product) was specifically observed in G1. G2 spent considerable time while surfing on the Internet and searched for images to choose the visual materials for the product. G5 and G6 spent more time on the social network (Facebook). The behavior of using online information sources effectively was specifically observed in G7.

Generate knowledge products All groups collaboratively combined various content such as audio, visual and text, etc. by selecting the tools and equipment in the laboratories suitable for their purposes and using the applications available in the tablets to produce a video to achieve the course outcome. Only two groups (G5 and G6) paid attention to the quality of their products and these groups were not satisfied with their products and re-designed them. G1, G3, and G5 spent more than the

Table 7 Students' learning experiences related to "collaborate on projects and teamwork" skills

Theme	Category	Code	G1	G2	G3	G4	G5	G6	G7
Taking help during the implementation process	Student's taking help from the teacher	to develop the experiment	–	–	–	–	+	+	–
		to complete missing tasks	+	–	–	–	–	+	–
		to understand the task	+	+	–	+	–	–	–
		to find the location of downloaded images	–	+	–	–	–	–	–
		to record voice	–	+	+	–	+	–	–
		to watch the created video	+	–	–	–	–	–	–
	Student's taking help from the mentor	to understand the task	–	–	+	–	+	+	+
		to download images from the internet	–	–	–	–	–	–	+
		to edit video layers	–	–	–	–	–	–	+
		to record voice	–	–	–	–	+	+	+
		to export video	–	–	–	+	+	+	+
	Intergroup collaboration	to learn from other groups	–	–	–	–	–	+	–
		to inspire from the work of other groups	–	+	–	–	–	–	–
		to share experimental materials	–	–	+	–	–	–	–
		to use experiment of another group	–	–	–	–	+	–	–

Table 8 Students' learning experiences related to "select appropriate tools & evaluate impact" skills

Theme	Category	Code	G1	G2	G3	G4	G5	G6	G7
Selecting and using the appropriate technology for the purpose	Selecting and using the tablet apps	drawing apps	–	+	–	–	–	–	–
		camera for taking pictures	+	–	+	+	+	+	–
		web browsers for download images from the Internet	–	–	–	–	–	–	+
		web browsers for information to be used in lecture	–	+	–	–	–	–	–
		voice recording apps	–	+	+	+	+	+	+
		text writing apps	+	+	–	+	+	+	–
		social network apps	–	–	–	–	+	+	–
	Selecting and using the laboratory equipment	experimental materials for video making	–	–	+	–	–	+	–
		experimental materials for photographing	+	–	+	+	+	+	–

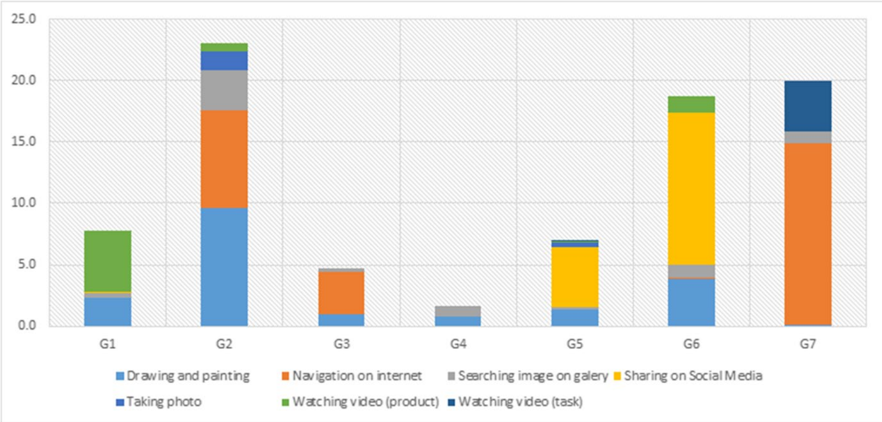


Fig. 3 Time (minute) spent in other mobile applications by groups

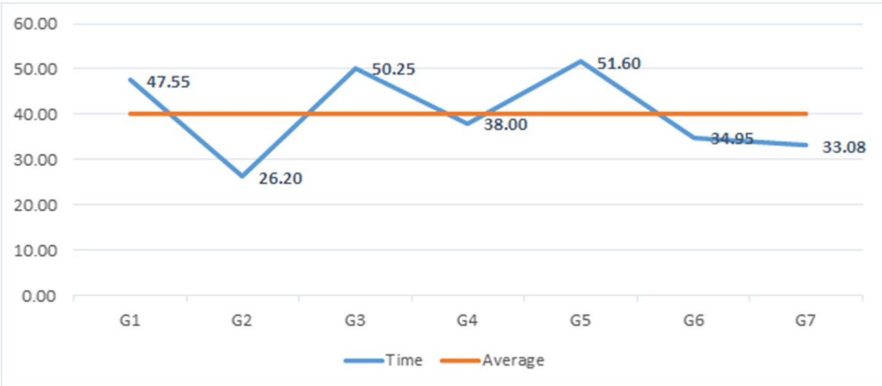


Fig. 4 Time (minute) spent in Com-Phone by groups

average time whereas G2, G4, G6, and G7 spent less than the average time to create the videos (Fig. 4).

Video contents (text and/or sound recording), sample video frames, and video durations of the products created by the groups were given in Appendix 5. The videos of all groups except G7 featured voice recordings and texts. G1, G3, and G6 created an experiment setup and successfully demonstrated the working principle of the lenses. Other groups preferred to provide information on lenses, rather than creating an experiment setup.

Table 9 Students' learning experiences related to "communicate, present, and disseminate" skills

Category	Code	G1	G2	G3	G4	G5	G6	G7
Sharing on social network	preferring facebook	–	–	–	–	–	+	+
	preferring instagram	–	+	–	–	–	+	–
Not sharing on social network	unwillingness to share	–	–	–	+	+	–	–
	not have an account	–	+	–	–	–	–	–

Table 10 Jaccard similarity coefficient between groups

Groups	G1	G2	G3	G4	G5	G6	G7
G1	0.00	0.86	0.72	0.62	0.69	0.75	0.91
G2	0.86	0.00	0.77	0.80	0.80	0.82	0.77
G3	0.72	0.77	0.00	0.68	0.56	0.69	0.74
G4	0.62	0.80	0.68	0.00	0.48	0.59	0.82
G5	0.69	0.80	0.56	0.48	0.00	0.43	0.70
G6	0.75	0.82	0.69	0.59	0.43	0.00	0.65
G7	0.91	0.77	0.74	0.82	0.70	0.65	0.00

Communicate, present, and disseminate Some groups preferred to share their videos on the course outcomes on social networks; others did not want to share their videos or simply did not share as they did not have an account (Table 9).

Comparing the learning experiences of the groups for similarity The sub-dimensions of the knowledge society skills were thoroughly examined; the experiences in the implementation process were complex and each group featured different dynamics. The Jaccard similarity index was calculated to see which behaviors were shared by the groups (Table 10). As the similarity coefficient gets closer to 0 and the color gets closer to green, the learning experiences of the groups become more similar to each other; as the similarity coefficient gets closer to 1 and the color gets closer to red, the learning experiences of the groups become more different than each other. Accordingly, considering the similarity coefficients of G2 and G7 in relation to other groups (G2: 0.77-0.86; G7: 0.65-0.91), their learning experiences differed from other groups. On the other hand, the most similar groups were G5 and G6 (0.43) as well as G4 and G5 (0.48). Thus, it seems that some groups partly showed similar behaviors (G4-G5, G5-G6) whilst others (For example, G2 or G7) had behavior profiles specific to themselves. A reason for this may be that the knowledge society skills are complex and the practices for the acquisition of these skills are caused differently.

3.5.3 Teacher's reflections

Considering the interview with the teacher and the observations of the researchers, the following themes were identified about the implementation process: "the opportunities on the learning and teaching process", "Concerns", "the role of technology" and "suggestions." The course teacher stated in the interviews that the implementation had positive effects on the acquisition of the course achievements. However, the teacher had some concerns regarding the implementation. These concerns are the lack of any support from the mentor in courses normally performed and the lack of technological knowledge (Appendix 6).

Prior to the implementation, the teacher expressed that she had concerns about technical deficiencies and that the students may not acquire the course achievements. Following the implementation process, the teacher reported that she observed that the students acquired the expected achievements. Yet, the teacher stated that her/his concerns on the acquisition of the course achievements by the students were still present and that these concerns could be only eliminated by testing the students. It seems that the implementation had positive effects on the beliefs of the teacher. The possibility that the habitus of the teacher was an obstacle against her/his changing her/his beliefs on the learning processes needs to be taken into consideration as well.

Additionally, the teacher stated that it is a prerequisite to designing the classroom arrangement suitable for collaborative work, to equip teachers with technical competencies, and to improve the infrastructure and classroom arrangement to ensure that such practices can be performed.

4 Results and discussion

This study presented an example implementation of the ICT integration based on contextual conditions with a focus on instructional design. In this way, with a multi-dimensional perspective, this study adds to the literature that argues that ICT integration and ID are intertwined (Chan et al., 2013; Kale et al., 2020; Qasem & Nathappa, 2016; Wang, 2008). After the implementation process, this study discussed the improvement of the knowledge society skills and the course achievements of students, the reflections of the teacher (the subject area expert) and two mentor researchers; following that, it offered insights into the effectiveness of this ICT integration implementation from a multi-dimensional perspective.

This study clearly shows that ICT integration and instructional design are intertwined and that more successful results can be achieved by addressing them together. The steps of analysis, review, and improvement in the instructional design-based ICT integration process for teachers to enrich their experiences. These steps serve as gradual tasks for teachers to achieve learning goals by using ICT as a tool. This study also allowed the teacher, who is also a subject area expert, to gain experience on how to design and perform learning-teaching activities considering the contextual conditions and her/his competencies. Indeed, gaining such experiences is of great importance, as expressed in the literature as well (Yildiz & Usluel, 2016; Atman Uslu & Usluel, 2019; Sansone et al., 2019). Therefore, this study offers significant insights into the ways teachers can perform an ICT integration in their courses based on the contextual conditions and their competencies, encouraging them to overcome obstacles and providing them with an exemplary implementation. In fact, the major obstacles of teachers on ICT integration have been identified as teacher competencies, knowledge society skills, beliefs, and lack of infrastructure in the literature (Afshari et al., 2009; Bingimlas, 2009; Bozkuş & Karacabey, 2019; Bukaliya & Mubika, 2011; Ertmer et al., 2012; Ertmer & Ottenbreit-Leftwich, 2013; Pelgrum, 2001; Yazlık, 2019).

In this study, some students' course achievement was significantly improved after the implementation process. Yet, a part of the students (31,77%) failed to improve themselves regarding the course achievements following the implementation, which deserves further discussion. The potential reasons for this need to be examined in a wide range from individual student characteristics to the dynamics of the group.

This study found that the groups completed the tasks given in various ways and had learning experiences, allowing them to acquire the knowledge society skills. The learning experiences of some groups were similar whereas other groups exhibited unique behaviors. A variety of information sources presented to the students contributed to the richness of the resulting products. Moreover, another reason for the richness of the resulting products may be that the knowledge society skills are complex and the practices for the acquisition of these skills caused different experiences due to the nature of these practices. As another reason, similarities or differences in the prior knowledge, skills, and interests of the students may be shown. On the other hand, while creating content for their videos, some groups assessed the quality of the visuals as well as the photographs taken whilst some assessed the quality of the resulting video. In this way, the tasks given allowed the students to have experiences of "Access, assemble, re-organize knowledge" and "Interpret, analyze & evaluate." Nevertheless, the solution of complex problems in terms of the knowledge society skills is only possible by experiencing task stages with different difficulties (Anderson, 2008). In the current study, due to the lack of experience among the students on such implementations, the tasks featured a low level of difficulty, which potentially contributed to the completion of the tasks given to the students and to the success of the implementation process.

Remarkably, the students collaboratively worked both within the group and between the groups during the implementation process. The groups came up with solutions to the problems encountered during the implementation process by getting support from their peers in other groups, the teacher, and the mentors. So, the extent to which students can receive such support opens up an important question for the sustainability of such implementations. Given that the learners were greatly supported over a short period of time during the implementation process, achieving the objectives of the ICT integration may be more challenging when the teacher is left alone to perform the integration. If the goal is to achieve ICT integration depending on the context (under the current conditions), a strategic road map is necessary about how the teacher is supported in the first steps and in the later steps of the process or about how the teacher can progress without any support. Such a strategic road map may be sketched in more detail with the improvements to be made after the cyclic steps of the process of an ICT integration based on instructional design.

All groups of students produced a video with the content they collaboratively developed through various ICT tools to achieve the tasks given for the course. It has been reported in the literature that making learners productive enables them to acquire knowledge-related skills in the knowledge society, allows them to gain deeper learning experiences and to become competent in their subject area (Adams Becker et al., 2016; Anderson, 2008; Sarıca & Usluel, 2020). In this sense, the increased availability of technology provides more opportunities to make learners productive (Adams Becker et al., 2016; Luckin et al., 2009).

It is also striking that the videos created by the groups had two different foci. Some groups only presented information on lenses in their videos, some concentrated on showing the working principle of lenses through their experimental setup. For that reason, it is possible to argue that the resulting product of the groups which created an experimental setup meets the expectations of the course achievement. Here, it is worth mentioning that the groups did not have the same experiences with ICT access and ICT use and their prior knowledge was different too before the implementation process, which appears to be a decisive factor in the quality of the resulting product. Such uncertainty may be eliminated by a future experimental study.

The reflections of the subject area teacher in this study indicated that the implementation process positively changed the opinions of the teacher (e.g. the acquisition of course achievements), but the teacher still had concerns. Blume (2020) argued that traditional skepticism toward innovation among teachers is usually reinforced by the demographic and sociological characteristics of the teacher population and the nature of their education in the country (Blume, 2020). The habits of teachers affect the reception of messages on technology integration and most teachers do not receive education in classrooms where technology is significantly used (like in the current study). Therefore, it takes time for them to abandon the learning approaches they adopted for a long time or to adapt to new approaches (Belland, 2009). To eliminate the negative beliefs of teachers on ICT integration, teachers need to see more practices and be supported by designing and performing such practices (Belland, 2009; Chai, 2010; Tondeur et al., 2012; Tsai & Chai, 2012). In this regard, while designing an implementation for ICT integration, which also includes the Instructional Design steps, this study offered a "how-to" experience to the teacher on the meaningful use of technology, which facilitates learning. It also offered the teacher to practice overcoming the obstacles against ICT integration. However, teachers should experience how to solve the problems in the process for a successful ICT integration (Instefjord & Munthe, 2017). They are expected to have advanced innovation and creativity skills to solve such problems (Royalty et al., 2019). Re-organizing teacher training with design-based approaches may lead to a change in the habitus of teachers and prevent their negative beliefs (Novak & Mulvey, 2021). Furthermore, ICT integration based on ID can allow teachers to develop strategies by considering different conditions (Kale et al., 2020; Kali et al., 2015; Kim & Downey, 2016; Sansone et al., 2019). Therefore, this study offered an opportunity for the teacher to experience an ICT integration based on ID with the contextual conditions and competencies and revealed that this opportunity positively affected the opinions of the teacher.

At this point, it can be argued that the need for a paradigm shift is considered in line with the expectations of the new century from education to perform similar implementations. Future studies need to review curricula as the first element (which courses, which outcomes and which knowledge society skills), secondly lesson duration, and the design of physical classrooms as the third element. Indeed, the school where the implementation process was carried out had a limited number of factors that offer authentic experiences both for students and for practitioners and facilitate the implementation process. For example, fixed lessons of 40 min duration and existing laboratory designs did not provide a flexible learning/teaching environment for such implementations. So, we may say that arrangements that will provide more flexibility to the teacher in terms of course time or physical classrooms in line with the determined curriculum will be important for an effective ICT integration.

5 Conclusion

This study performed implementation of ICT integration with a focus on instructional design steps. The students had learning experiences that supported them in the acquisition of both the knowledge society skills and course achievement. The teacher, who was a subject area expert, has lived experience designing and applying learning-teaching activities according to the existing conditions and competencies. Thus, this study demonstrated that it is possible to acquire the knowledge society skills required by the information age and achieve educational goals with minimum needs for ICT integration through instructional design knowledge. Therefore, this study suggested that teacher training programs or in-service training adopt ICT integration processes with instructional design knowledge based on a multi-dimensional approach.

6 Limitations and future research

The limitations of this study can be discussed under several items. Firstly, this study makes no claim of generalizability. It was conducted with an inexperienced teacher and in a school with poor technological facilities located in a neighborhood where middle-class families reside. For that reason, the context where this study was performed may affect the results. Olofsson et al. (2020) stated that there is a need for increasing the practices specific to conditions in contexts different in terms of student profile, support services, e-content, the use of digital tools in school activities. Secondly, as the teacher was inexperienced, two mentor researchers supported this implementation process in this study. Thus, the availability of two mentor researchers does not reflect the normal conditions in a school.

This study will potentially offer various insights for future studies. First of all, the students behaved contrary to expectations regarding the dissemination of information. The underlying reasons for this are that the students had concerns about the quality of the resulting product and did not share it on social media and wanted others to see it. More detailed studies may focus on the concerns of the students about sharing their products.

Although the students had a significant improvement in course achievement, experimental studies with control groups are needed to compare such implementation with the courses designed by the teachers through the methods they are familiar with. From the perspective of the improvement of the knowledge society skills, this study can be considered as a start for high-level skills. It is necessary to elaborate on the results of more practices that integrate course achievements with twenty-first-century skills and offer authentic experiences, like in the current study. From this standpoint, there should be more sample implementation on how to perform such practices more effectively and productively.

The habits of teachers from the past, their beliefs, competencies on ICT skills and knowledge appear to be obstacles for the process involving ICT integration (e.g. Belland, 2009; Bozkuş & Karacabey, 2019; Ertmer & Ottenbreit-Leftwich, 2013). Although the teacher in this study had some concerns after the implementation process, this process positively affected the teacher. Regarding this, future studies may examine the impacts of in-service training (intended to use the instructional design-based ICT integration model (Yildirim et al., 2017) developed) of teachers of different subject areas on teacher beliefs and course plans.

It is reported in the literature that ID and ICT integration models have specific features, but they are in intense interaction with each other in the achievement of goals (e.g. Kale et al., 2020; Qasem & Nathappa, 2016). Considering the ICT integration process with ID may offer authentic experiences on the creation of contextual information that ICT integration has difficulty explaining (e.g. Mishra, 2019; Schmid et al., 2021) and on the improvement of skills. Thus, more studies similar to this one are needed to combine ICT integration models with instructional design knowledge.

Appendix 1

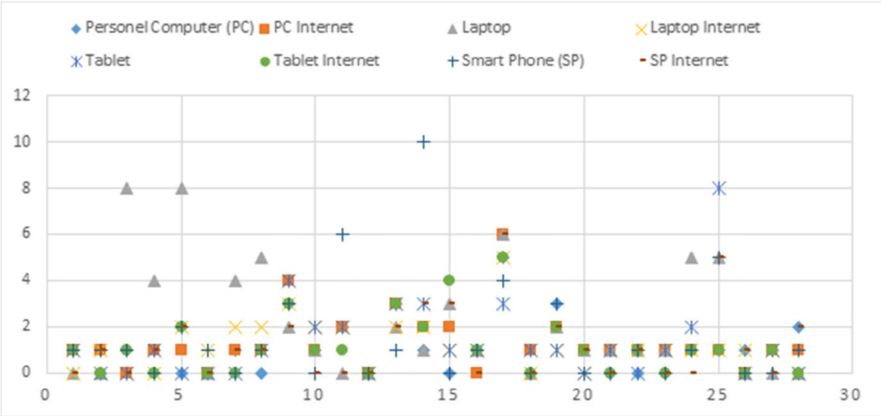


Fig. 5 Students' experience of using ICT

Appendix 2

Table 11 Goals of Pilot Study

Course outcomes	Knowledge-related skills	Tasks
• The student gives examples of situations where light is both refracted and reflected • The student draws simple beam diagrams to explain the refraction phenomenon in various environments • The student gives examples of events that can be explained by the refraction of light • The student discovers that light can be refracted into colors in the prism	1. Access, assemble, re-organize knowledge 2. Collaborate on projects and teamwork 3. Interpret, analyze & evaluate	1. By connecting your tablets to the internet, download the 7th Grade Science and Technology coursebook to your tablet from "http://eba.gov.tr" 1. Watch the video of the experiment on the refraction of light 1. By using Google, search for other sources about refraction and compare the information in these sources with the information in the sources provided above 2. Complete the assigned tasks by sharing tasks within the group 3. After discussing the information reached by refraction in the group, report how refraction happened

Appendix 3

Table 12 Behaviors that affected peer collaboration positively and negatively

Category	Code	G1	G2	G3	G4	G5	G6	G7
Positive behaviour	Get peer approval	+	–	–	–	–	–	–
	The subject what will be written	+	–	–	–	–	–	–
	Change of person performing the task	+	–	–	–	–	–	–
	Deciding on voice recording content	+	–	–	–	–	–	–
	Choosing group leader	+	+	+	–	–	–	–
	Deciding who will make the voice recording	+	–	+	–	+	–	+
	Distribution of tasks	+	–	–	+	+	+	+
	Preparation tasks	–	+	+	+	+	+	+
	Exploring of apps	+	+	+	–	+	+	+
	Making guidance	–	+	+	+	+	+	+
Negative behaviour	Not being the previous lesson	–	–	+	–	–		–
	Failure to prepare the appropriate content to the task	–	–	–	+	–	+	–
	Engaging with other things not related to tasks	+	–	–	+	–		–
	Uncooperative	–	+	–	–	–	+	+
	The complexity of the task status	–	–	+	–	+	+	+
	Peer conflict	–	+	+	–	+	+	+

Appendix 4

Table 13 Themes in the pilot implementation

Themes	Description
Problems	Only one group accessed videos. The reason for this is that two mobile phones could not provide the required bandwidth for the application.
The level of course achievement	When the teacher asked the group which watched the video content to describe the experiments in the video, she determined that the students could not acquire the course achievements. As the students were accustomed to a course where the teacher is the narrator, they may have considered the implementation insignificant. Also, the technical problems may distract the students. A course of 40 min might not offer enough flexibility for such practices. In general, the student who completed the tasks in the group was the one who was most experienced about using tablets in the group. Other group members followed this student. It is important to give further guidance to the groups about the tasks.
Improvements	Three mobile phones will be used to improve internet access. The seating arrangement in the classroom will be re-organized for effective use of the Internet. The teacher will explain to the students that she will not give any lecture on the subject, and it has been decided that the implementation process will last for two-course hours (80 min). It has been agreed that greater mentor support (with 2 mentors) will be given so that in-group activities can be monitored and guided for the implementation process. It has been planned that the setting for the implementation will be the science laboratory to allow group members to use the materials in the laboratory and to improve their in-group interaction and collaborative work.

Appendix 5

Table 14 Videos (Products) prepared by groups

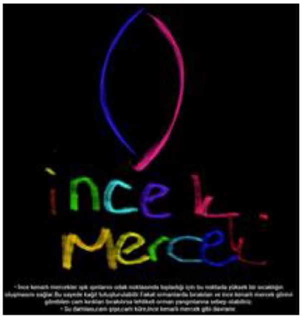
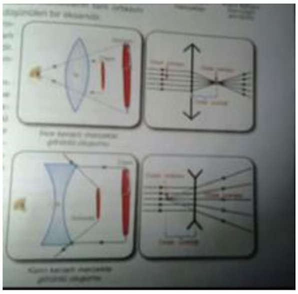
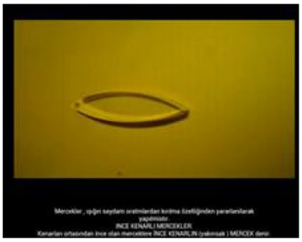
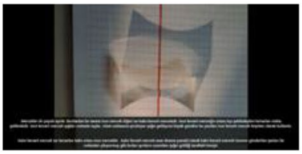
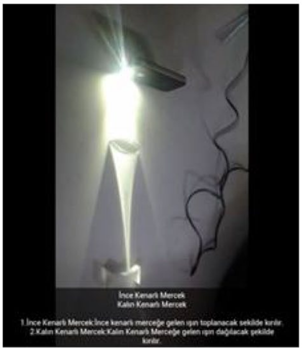
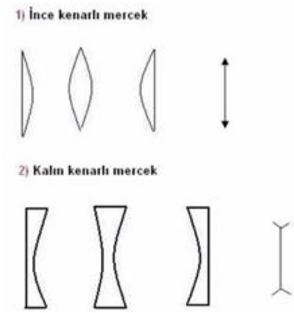
Group	Duration (second)	Sound record	Text	Video Frame 1	Video Frame 2
G1	54	+	+		
G2	41	+	+		
G3	44	+	+		

Table 14 (continued)

G4	39	+	+		
G5	79	+	+		There is no different frame.
G6	56	+	+		
G7	55	+	-		

Appendix 6

Table 15 Teacher's reflections

Themes	Codes
Opportunities	*"It was very good in general. The students enjoyed it. They said they understood better. I attended some of the interviews… I told them that I will not repeat this subject and will start a new subject and asked them if they wanted me to repeat it. They did not see it necessary and wanted me to repeat it."* *"Everyone was engaged. One of the students, who was always sleepy during my lectures, used the lenses and talked for the audio recording. They were active. I do not know if she learned the subject or not, but she was engaged. She did not take notes before that."*
Concerns	*"Three of us barely managed the implementation. I am doubtful that if I was alone, it would not be that comfortable. Because I am technically incompetent in some areas. You two helped me in these areas."*
Concerns & the role of technology	*"It is good for the applicability of technology in the course, but… We have hardware problems, so we are reluctant… You need to make many preparations as there is no Internet available at the school. As such problems would appear, we did not put it into practice due to my concerns. Otherwise, such practices are good… But I had concerns before the lesson as I was going to lecture. Would the students understand the course? I did not write on the board and did not let them take notes on their books. I did not write the name of any lenses on the board or draw the ray. I did not do anything about the path we would follow. But, the students said that they understood the subject; what's more, they gave examples of where these lenses are used in the videos. I hope I can observe in the written exam that they really understood the subject. I still have some concerns. I can only overcome them after the exam."*
Suggestions	*"If this is to be done individually, there should be tables for group work… Round tables may be organized for each group. An area may be established for them to use the documents, lenses, etc… We could not connect the light source everywhere we wanted. We had to fix it somewhere, and the students came over there to do it. But, an arrangement can be set up for them to work on their own tables."* *"The teacher needs to be technically knowledgeable in this area. I was technically incompetent in other subject areas, which is a major weakness. And, if the infrastructure and classroom in the school are made suitable for this practice, such practices can be continuously performed. In my opinion, this is an activity that needs to be continuously performed."*

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