

E-Future Classroom :A study Mixed Reality Learning Environment for Deaf Learners in Thailand

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ABSTRACT

Learning environment could both directly and indirectly affect human learning in terms of abstract and concrete concepts. For education, classroom was regarded as one of significant learning environments which teachers and learners provided activities and instructional models to promote learners' learning and help them achieve curriculum objectives. This research aimed to develop an e-future classroom (electronic future classroom) which consisted of several elements as follows: electronic innovative technology, education instruction, education environment, and evaluation standard. The e-future classroom was different from general classrooms since it was a learning resource combined with AR hologram technology and specially designed for deaf and hard of hearing (DHH) learners. Mixed reality learning environment was created to enhance instructional experience by focusing on visual learning to suite target learners through activities in class, instructional models, and knowledge and skill practices. Interactive learning was also emphasized using a variety of technologies such as image, animation, and virtual reality to improve learning efficiency of DHH learners via total communication instruction which was a main instructional model currently used in many schools for the deaf. This e-future classroom was beneficial to increase learning efficiency, learning achievement, information and communications technology (ICT) skill, and information literacy for the DHH learners.

KEYWORDS

E-future Classroom, Mixed Reality Learning Environment, Deaf and hard of hearing (DHH)

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Introduction

Recently, development of disabled person has been more emphasized, especially providing equal education for all learners including learners with special educational needs and disabilities (SEND) as established by the United National Scientific and Cultural Organization (UNESCO, 1994). In Thailand, the

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development of disabled person has received more attention. For instance, hearing impaired (HI) children were considered the same as normal children and they had capabilities and competencies to develop themselves in all aspects of human virtues to be an important capital of the country (Chaisanit & Suksakulchai, 2011). Moreover, Constitution of the Kingdom of Thailand B.E. 2540 and National Education Act B.E. 2542, Section 10, (Office of National Education Committee, 1999) have explicitly declared that every person has equal right to receive basic education for the duration of not less than 12 years which shall be provided by the state thoroughly, of quality, and without charge. Additionally, National Education Act B.E. 2542, Clause 2 and 3 in Section 10, also pledged “compulsory primary education, with special provisions made for children with physical, mental, intellectual, disabilities, emotional, social, communicative, and learning disabilities, disabled persons, or persons being unable to care for themselves or without caregivers, or underprivileged persons”. The education for disabled persons, as stated in Clause 2, shall be provided since they were born or they have been handicapped without any cost. They also have the right to obtain facilities, media, services, and other educational supports regarding criteria and methods determined in ministerial regulations (Office of the Permanent Secretary, Ministry of Education, Thailand 2007). The disabled need special learning environment and instructional materials to appropriately fulfill their disabilities and requirements. On the other hand, many educational institutions still lack suitable instructional materials for the learning of disabled children. Due to this limitation, a large number of persons with disabilities cannot acquire learning development and are not aware of rapidly changing economy and society (Thai Department of Education, 2003).

Unlike education for general children, special education in Thailand is arranged for children with special needs due to physical, emotional, behavioral, or intellectual disabilities. Special care is required to provide appropriate learning environment and deliver benefits from the education. To prepare the special education for this group of children, Carter (2006) stated educational training should be available for teachers to let them have more knowledge of and experience with learners with disabilities than general education teacher. Furthermore, capabilities of each person should be taken into account when providing the special education. Rosenbaum, Armstrong, and King (1988) noted that attitudes of individuals towards children with disabilities could be influenced by demographic factors (such as age and gender) and types of exposure to these children. Thus, learning environment, curriculum, activities, instructional models, materials, educational technology, and evaluation method should suit the ability of each person. This is concordant with a study of Rosenbaum et al. (1988) who mentioned that educational and emotional change of children should be taken into consideration to arrange suitable learning environment (Memisevic & Hodzic, 2011). Fluency in communication, culture, awareness, and knowledge of the children are also important since they are related to different modes of learners’ communication (Hadadian, Koch, & Merbler, 2012). Therefore, it is very crucial to understand and recognize several variables associated with teaching the learners with disabilities. The teachers’ materials and teaching methods might be adapted to provide educational environment including teachers’ and social factors which could help the DHH students achieve successful outcome (Iam-Khong, Suksakulchai, Poolek, & Plubsawat, 2011).

One of significant factors affecting the students' learning is learning environment which includes characteristics of the teachers and teaching methods (education), the students' family environment (family), characteristics of each student (student), and social influences such as peers and classmates (society) (Samphan & Suksakuchai, 2007). The learning of persons with disabilities is more affected by all of the above factors than normal learners (Iam-Khong et al., 2011). Hence, learning environment refers to circumstance which could negatively and positively affect the learners and their learning efficiency and learning effectiveness. For example, the classroom should be hygienically arranged and equipped with quality facilities to promote learning. A good atmosphere in classroom could have a positive impact on the learners to help them pay attention to lesson, and learn happily and enthusiastically. Thus, these factors should be considered when designing a classroom for the DHH students.

The classroom is a part of environment in the educational institute. It consists of terms, situations, and conditions affecting the learning, various information resources facilitating learning and implication for instruction, and relationship between teachers and learners promoting the children's learning. However, today's classroom for DHH students rarely supports their learning. Therefore, this research applies technology to materials and classroom design for the DHH students to improve their attention and understanding. Visual perception plays an important role for the DHH students or it is known as 'visual learning style'. The students with visual learning style perceive information through seeing or watching the teachers' movements or other materials to promote their understanding and memorization (Habibia, Kuswantob, & Yantic, 2017). This is concordant with a paper of Gentry, Chinn, and Moulton (2004); Techaruangrong, Kaewprapan, and Suksakulchai (2014) which noticed that visual images are necessary for the DHH learners as they could enhance understanding of content. The DHH persons also use gesture (sign language) and lip reading to communicate with each other. It is similar to the work of Bat-Chava and Martin (2002) who stated that the DHH children need to learn in same way but they have to utilize an alternative process to obtain the information. Then, a successful form of teaching and learning for deaf and DHH students is to turn information pathway from auditory to visual to convey the information to the brain of DHH learners. The design of classroom, instructional models, materials, technology, and activities for the DHH learners should mainly focus on visual perception to increase use of their eyes and learning efficiency as much as possible (Arthur, Beecher, & Downes, 2001).

To develop learning styles of the DHH students, Casey (2009) noted that there were three learning styles for the DHH students: (1) activities based on sensory styles linked to hands-on exercises; (2) visual learners (who preferred use of images, pictures, colors, and mind maps to memorize specific information); and (3) kinesthetic activities such as songs, games, and warm-ups. Habibia et al. (2017) mentioned that this type of activities was considered kinesthetic learning style which could be adapted through appearance and motion (Assar & Franzoni, 2009). Hence, the materials and technology design should emphasize benefits to the target learners. According to Fukuda (2009); Wicha, Sharp, Sureephong, Chakpitak, and Atkins (2012), visual aids such as drawings, pictures, and flashcards could be used to effectively support the DHH learners. They should be carefully designed with clarity to allow the students to have essential understanding of tasks they were going to perform. For instance, a video with

capture and sign language interpreter is very beneficial to help the students gain sufficient understanding to complete a task.

In Thailand, it has been found that the instructional materials for the DHH learners are inadequate and obsolete without sufficient technology application. Most of them are provided in old styles. Nevertheless, the information technology has increasingly played a more significant role in the education. Hence, it should be applied to the instruction for DHH learners who have better visual perception than other modes.

The researcher had realized this problem and its impact on the DHH students' learning. Therefore, the e-future classroom had been developed to deliver lessons to this group of students. Both augmented reality technology (AR) and hologram technology were combined to promote mixed reality learning environment and apply AR hologram technology to the education. Teachers and students were able to involve in mixed reality learning environment where they were represented through their avatars and they could interact with them. Avatar representations of teachers and students will be examined as a longer term hypothesis since it establishes a feeling of shared presence, community, and student engagement in class (Callaghan, Gardner, Horan, Scott, Shen, & Wang (2008).

Mixed reality was very helpful as it increased learning efficiency of the DHH children. Working memory was one of vital factors of human learning but there were some limitations. However, MR could be utilized to free up working memory for important matters by restricting intrinsic and extraneous loads to support germane load. Moreover, intrinsic cognitive load and extraneous cognitive load could be decreased by the use of MR. It was also helpful for people suffering from weak working memory and having problems with catching and retaining an inflow of information (Morin, 2013). Working memory could be substituted by MR, when long-term learning was not indeed significant, to help increase concentration while completing a task.

Naturally, mixed reality learning environment was related to immersive circumstance. For example, people's attention during a task could be maintained by applying strategic placement of mixed reality content. Another interesting benefit of mixed reality, based on several research studies, was that human memory could be improved by drawing and moving (Klemm, 2016). Performance of working memory would be better if motor excitability was higher. This would have a positive effect on fluid IQ as well. Involvement of participants could be increased applying the interface of mixed reality due to its truly natural and intuitive way of walking, moving, gesturing, glancing. Mixed reality hologram could be customized and contextualized to suit learning and it could be put in the real world environment of the participants. Furthermore, some people who had difficulty with spatial reasoning could utilize immersive 3D environment in mixed reality to improve their skill (Cheng, 2016).

Regarding many advantages of mixed reality environment, this technology was selected to develop learning efficiency, intelligence quotient (IQ), and memory of the DHH learners. Besides, augmented reality was chosen to apply in the e-future classroom since it was helpful to additional real time information based on the real world while there were both virtual objects and real world objects in the real space at the same time (Azuma et al., 2001) which could help the DHH learners have better understanding of the lessons. The focus of DHH learner's learning laid on total communication which was a principle of

teaching in current schools for the deaf. Nowadays, it could be seen that the instructional models were influenced by multimedia and technology which promoted autonomous learning using teaching method based on analysis and development of language acquisition of the deaf children, especially reading skill. Barnett and Seefeldt (1989) mentioned that repetition in reading helped improve the information useful to readers and it could assist the children with disabilities to better understand what they read (Kamps, Barbetta, Leonard, & Delquadri, 1994). The development of learning and reading should be related with the principles of teaching necessary for teaching general skills, particularly principles of practice, to prepare the instruction and create learning experience. Stages of teaching should be well designed to show the students the real pictures and help them remember and understand the lessons more effectively.

Materials and Method

Context of the study

The DHH children were considered the same as normal children and they had capabilities and competencies to develop themselves in all aspects of human virtues to be an important capital of the country (Chaisanit & Suksakulchai, 2011). Generally, the DHH persons had limited access to the education and the information due to their disabilities. The DHH children under 7 years old might have listening difficulties because of hearing loss at frequencies of 500, 1000 or 2000 Hz or up to 40 decibels or more. They could have delayed speech and auditory processing problems or they could not hear speech sound at all. Also, they could not communicate with others using spoken language as well as they should. Some learners with severe hearing loss might not be able to attend the class or learn like other normal people and then they might lose certain vital elements of human communication which were language and culture (Samphan & Suksakuchai, 2012).

Thai Sign Language (TSL) was used in the schools for deaf in Thailand since it was accepted to communicate among the deaf communities in Thailand (Varee, 2004; Techaraungrong, Suksakulchai, Kaewprapan, & Murphy, 2017). This language had its own structure and grammar and it was completely different from Thai language. Several important components were hand actions, facial expressions, and head movements (Branson, Miller, & Sri-on, 2005). Therefore, the understanding of communication arose from visual perception only, not auditory perception. The clarity of movements was very crucial to communicate with the deaf. TSL was not only the first language and the spoken language of the deaf in Thailand but also the national language of Thai deaf (Thai Department of Education, 2003). Woodward (1996) noted on the current use of TSL that the sign languages used among the Thai deaf in each local community was 83% similar. According to linguistic principle, if the two languages were 83% - 100% similar, they were the same language. It was also found that 52% of TSL was influenced by American Sign Language (ASL) (Reilly & Reilly, 2005). TSL was always improved for more accurate and correct communication. There was a collaboration between Ratchasuda College and National Association of The Deaf in Thailand to conduct researches, provide dictionaries, and define new vocabularies to be sufficiently used in the society such as vocabularies for computer and science industries. Even though TSL was officially announced as

the sign language of Thailand in 1999, there were continuous improvements to create new vocabularies and hand movements to communicate with the deaf people.

Participants

The participants in this study were divided into 2 groups including DHH learners and classroom teachers. For the first group, the DHH learners between the ages of 10 to 12 years were selected using specified sampling. They were students with hearing impairment but without any other disabilities. They were studying in Prathomsuksa 4 to 6 at the schools for the deaf outside neighboring area (Kanchanaburi School for the Deaf). The total samples consisted 13 students including 7 females and 6 males. All of them used TSL for their communication.

The second sample group consisted of 4 science teachers in Prathomsuksa 4 to 6 from 2 schools for the deaf were selected. One of them taught in a school for the deaf in Bangkok metropolitan region whereas another one worked in an upcountry school for deaf. Both of them had expertise and experience in teaching the DHH students.

Process

The data, theories, and relevant studies were explored to develop a research framework including several processes as follows.

Table 1. Summary of e-future classroom design and development process

| Phase/ Objective | Purpose | Activity | Duration |
|---------------------|---|---|----------|
| 1 | Obtain teacher input into the design classroom | Obtain teacher input into the design | 3 week |
| 2 | Design e-future classroom model | Design e-future classroom model Identify design considerations <ul style="list-style-type: none"> - Electronic innovative technology - Education instruction - Education environment - Evaluation standard | 6 week |
| 3 | Design teaching methodology in e-future classroom | <ul style="list-style-type: none"> - Problem based learning: PBL - Project based learning: PJBL - Collaborative learning - Peer instruction | 3 week |
| 4 | Design activity / tests in e-future classroom | <ul style="list-style-type: none"> - Do investigation activity - Do construction activity - Do presentation activity | 4 week |
| 5 | Design evaluation standard | <ul style="list-style-type: none"> - Analyze learning achievement between Pre- & post-test of science)structure, | 3 week |

| | | | |
|---|---|--|-----------------------|
| | | reproduction, and growth of plant, and natural resources) - Observe team work skill - Observe information and communications technology (ICT) skill - Observe information literacy | |
| 6 | Identify participating reactions of participants to the e- future classroom | Oral interview | 25 min. per person |

Step 1. Obtain teacher input to design the classroom

According to previous studies on the instruction of DHH learners in Thailand, most of these students had problems with reading and writing in Thai (Thirajit, 1994). They also required more time to study different subjects than general students. A study of Meadow (1981) found that learning achievement of DHH learners was very low. What they presented in the tests was less than their actual potential. This was because most of the tests were associated with language while the DHH learners had limited language ability. It was considered as an obstacle to complete the tests since those who would get a good score should have a satisfactory knowledge of language. For this reason, the learning achievement of DHH learners was poorer than general learners due to the use of current teaching and evaluation approaches which were appropriate for normal learners. Certain methods were not suitable for the DHH learners (Arrayavinyoo, 1983). Apart from the above problems caused by limited perception of the DHH learners, lack of proper teaching materials was an important issue. Thus, the best learning style of these students was visual. In Thailand, there were some studies investigating requirements and problems with the use of teaching materials in schools for the deaf. They found that teaching materials were essential for teachers' performance. Most of teachers sometimes used their own developed materials. The most frequently used materials were images and realia. Another crucial problem was insufficient teaching materials and inability to apply technology to increase learning efficiency. It could be said that environment was very important for learning. Therefore, suitable learning environment and curriculum should be provided for the DHH learners to promote their development and integration of learning. Various types of learning management should be prepared such as transfer of skills, concrete learning, learning through visual aids and sign language, command-following, and waiting for assistance (Friend, Bursuck, 2002).

The above studies were applied in this paper to design the e-future classroom starting from defining learning problem and perception of the DHH learners. According to an interview with experts and teachers working with the DHH children, it found that the learning problem of DHH children stemmed from inadequate and obsolete materials such as paper, flash card, and video. The modern technology was not implemented for the instruction and there were no interesting activities for the learners. The current learning environment was adjusted to suit the changing circumstance meanwhile the traditional instruction was not adapted to the advanced technology and science affecting the overall

education. Thus, learning paradigm shift should be promoted by changing the traditional instruction or giving a lecture to a new instruction to provide alternatives or materials suitable for learners and changing society. The teaching strategy adjustment using a variety of technologies was important and necessary to support different learning situations. O'Driscoll (2009) stated that one of the most common problems with the DHH students' learning was the implementation of technological and educational potentials. Researchers often found it difficult to use computers in the classroom due to inappropriate software or technology (Burns & Polman, 2006) which caused the learning environment to be too complicated for the DHH students' learning. Moreover, the content did not provide concrete knowledge, and then the learners did not understand the complex content. All of the above problems impeded the effective learning of DHH students.

Step 2. Design e-future classroom model

The following steps were used to design the e-future classroom model.

1. Documents and research studies relevant to classroom models were examined to gather fundamental data on a classroom with proper teaching method.

2. Learning models in terms of definition, element, model analysis, model synthesis, model development, and model evaluation were inspected to determine factors linked to classroom models for children with special needs in Thailand including problem based learning (PBL), project based learning (PJBL), collaborative learning, and peer instruction.

3. Fundamental data on educational technology, access to technology, and ability to use technology to further assess e-future classroom model were analyzed.

4. The data were synthesized to develop e-future classroom model and elements in the classroom based on general factors of normal classes. Then the elements such as context, input, procedure, and product were classified based on each model. After that, characteristics of factors of each element were analyzed. The model analysis of normal classroom was conducted in Thailand only to offer guidelines towards classroom management to be consistent with environment and technology since it aimed to develop the suitable and effective classroom model with the same standard as normal classroom.

5. After the analysis and the synthesis steps, the generated e-future classroom model was evaluated by experts in educational technology and children with special needs. Then the model was adjusted and improved regarding their suggestions to suit the DHH learners in Thailand.

The designed e-future classroom model consisted of input, process, output, control, and feedback as presented in the below figure.

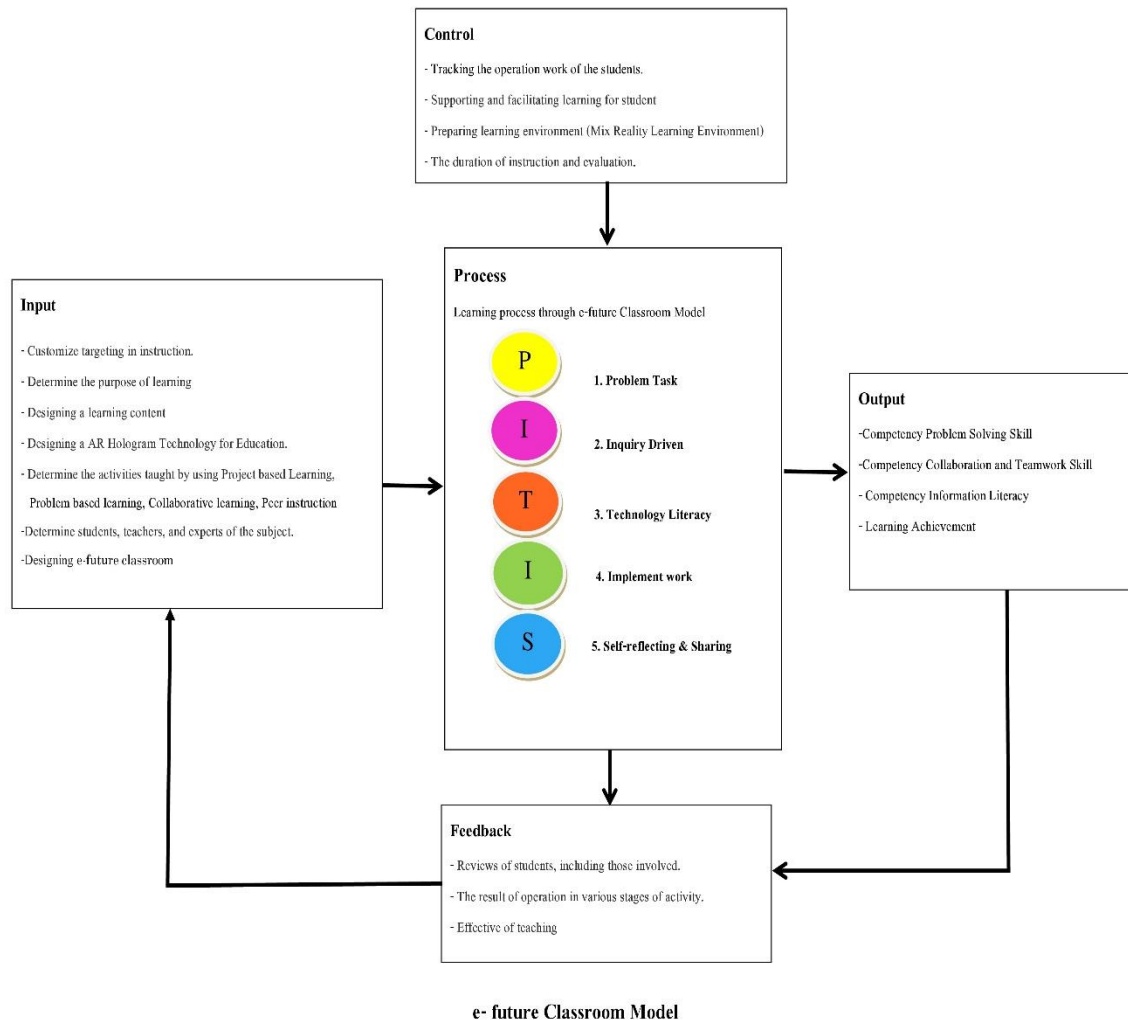


Figure 1. e-future classroom Model for deaf and hard of hearing

The e-future classroom was designed to be a special and unique learning resource for the DHH students. The learning environment was suitably prepared to be the mixed reality-learning environment to enhance instructional experience and develop the learners' skill to utilize the technology to enrich their learning skill and research skill by themselves. This model could serve learning needs of each student and highly encourage collaborative learning between the students and the teachers by focusing on visual learning and virtual information through activities, instruction models, and skill practice to suit the target learners. Moreover, learning interaction was emphasized by combining various technologies such as image and animation for effective learning system in normal

class. For the e-future classroom, it would affect different learning styles; for example, problem based learning (PBL), project based learning (PJBL), Collaborative learning and peer instruction. The role of technology in classroom was clearly determined to meet the users' ability to use a variety of digital media. Additionally, difference of skill and knowledge on the use of technology between the teachers and the students could affect the efficiency of instruction. Thus, it was very essential that the e-future classroom could be utilized as a source of skill practice to upgrade proficiency of technological media at the same time. This would help build relaxing learning environment by using interactive classroom technology. It was important to create the learning interaction by providing the e-future classroom along with the peer instruction which the learners could study specified content together. Additional materials were also prepared for the e-future classroom to support diverse learning styles. The learners who heard or understand the content better than others could help those who did not understand.

One of significant attributes of the e-future classroom was the collaborative learning. As Yau et. al (2003) stated that the collaborative learning stemmed from the use of classroom could provide many benefits; for example, knowledge sharing which was related to phenomenon between the teachers and the learners to create knowledge and enhance experience; ability sharing which encouraged the learners to fully apply their knowledge, skills, and abilities to reinforce collaborative problem-solving skill and the teachers had an important role to arrange learning situations for the learners to integrate their knowledge; support for learners' heterogeneity which stimulated an exchange of learning experience among learner groups and served different needs of individual learners. According to the problems of current learning environment for DHH learners, the e-future classroom was developed to solve these issues.

The e-future classroom consisted of several elements as follows: (1) electronic innovative technology, (2) education instruction, (3) education environment (mixed-reality learning environment), and (4) evaluation standard.

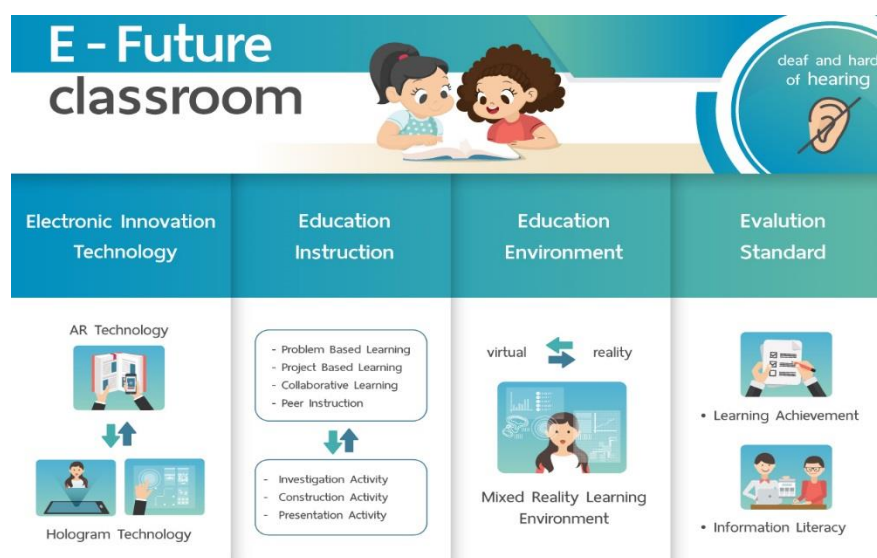


Figure 2. The elements of e-future classroom for deaf and hard of hearing

Electronic innovative technology

The use of electronic innovative technology between the teachers and the learners in the e-future classroom would obviously determine the users' role and meet the users' skill to utilize various types of digital media and technologies. Sometimes, the difference of skill and knowledge on the use of technology between the teachers and the students could affect the efficiency of instruction. For this reason, it was necessary to make use of the e-future classroom as a source of skill practice to upgrade proficiency of technological media at the same time. Edutainment could be created by using interactive classroom technology. The learning interaction was considered as an important dimension needed to occur by presenting the content via the augmented reality technology (AR). This technology combined a real world with a virtual world to create a floating 2-or-3-dimensional image on a screen (Zhou, Duh, & Billinghamurst, 2008). Unlike virtual reality (VR), the environment of AR was real and extended by the information and the images from the system which seamlessly bridged the gap between the real and the virtual worlds. On the contrary, a computer generated virtual environment was expected from VR (Chang, Morreale, & Medicherta, 2010). In addition, the hologram technology was implemented to support the learning. It was a 3-dimensional image created from data recording using laser. Interference pattern of the laser was recorded to represent the 3-dimensional image which was different from general images normally shown in flat and 2 dimensions without depth. The hologram technology made an image look more beautiful due to holography process (Ghuloum, 2010) which dispersed the light from an object to create a new one at the same position when compared to a recording. Changes in position and direction of visual system were accurate as the object was still present. Therefore, the recorded image was illustrated in 3 dimensions (Chavis, 2009; Ghuloum, 2010). The AR hologram technology was also applied to the e-future classroom and the education to provide the mixed reality learning environment which could help the DHH learners better understand the lessons.

The classroom for DHH students was equipped with two types of technology – augmented reality technology and hologram technology to create the mixed reality environment. They were installed at different points in the classroom to allow the students to access information to complete activities. For the application of AR technology, books, brochures, and posters were prepared at various places in the classroom. The students could use an application to look through a marker and learn through AR technology. The information was provided along with the sign language for better understanding. For the hologram technology, a square room was built using PVC pipes. It was covered by a black cloth to prevent the light. In this dark room, images were projected through a projector and displayed on a film hologram. The students could access the information via the hologram technology. The images shown on the film hologram were virtual which could attract the students' attention and increase their learning efficiency.

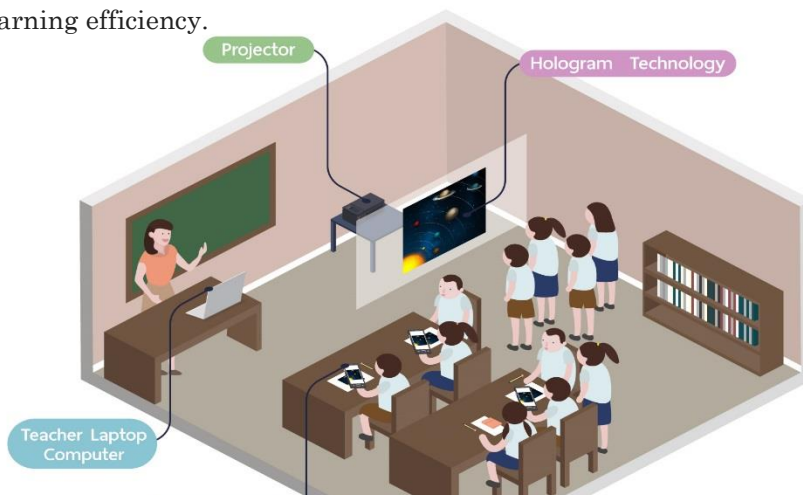


Figure 3. The design of innovative technology use for the e-future classroom

Education instruction

Recently, the learning management had changed from traditional method or lecture to new method. It was improved to serve the students' requirements and changing social context. Kuhlthau, Maniotes, and Caspari (2015) stated that there were emerging learning theories and the most interesting one was constructivist learning theory which was the most concordant with the 21st century learning. The concept of this theory was that learning would occur when learners created their own knowledge from existing one or new one. Based on such concept, the teaching approaches were adapted to suit the 21st century learning since the teachers were not the only one who managed everything in the class. The students must have a chance to implement and create the knowledge based on their understanding. Hence, this type of classroom offered active learning. Additionally, there were several types of learnings regarding this theory; for instance, collaborative learning, independent investigation method, problem based learning, and project based learning.

To the problem-based learning, it focused on the learners by encouraging them to create their own knowledge, think, apply their knowledge, and solve problems. Apart from the knowledge, the students would acquire skills of critical thinking, problem solving, participation in problem solving, and others (Hung, Jonassen, & Liu, 2015). According to the studies on problem-based learning, this type of learning could improve learning achievement, ability to solve problems, and ability to reason. Also, it promoted group learning and motivation which helped the students control their own path to find out answers by themselves.

Another type of learning model was known as the project-based learning. It led the students to solve challenging problems and complete tasks by themselves. Various projects for many subjects were prepared regarding different levels (Thomas, Mergendoller, & Michaelson, 1999). The projects occurred from challenging questions which could not be answered from memory (Bell, 2010). The projects had different roles to stimulate the students to make a decision, search for information, and solve problems. Jarrett (1997) mentioned that searching was a collection of many activities that could serve our nature of curiosity. This method would encourage the students to question, plan, observe, and explain what they discovered. It might be continued through their learning since it turned the traditional instruction relying on the teachers into open learning which could enhance the students' interest. In addition, Thomas (2000) noted that an important limitation of research on PBL implementation was too much emphasis on project-based science conducted by teachers with poor experience with PBL. It could be noticed from this research that a context for PBL administration might be beneficial but it was not easy to plan and implement PBL in the classroom which would affect management or assessment.

Speaking of the collaborative learning, it took place when the students worked together to build the knowledge. It was a pedagogy centering on building shared meaning and expand the knowledge (Metthrew, 1996). Moreover, Buffy (1993) described that knowledge and truth were everywhere. They had been waiting for being discovered by human effort using collaborative learning as a

social method. The collaborative learning was independent and did not depend on any content, subject, or group process. There was no group work assigned by the teachers because they were members in this community with the same responsibilities as the students. Several studies presented that the knowledge could not be transferred from the teachers to the students. The students needed to build their own knowledge through meaningful learning process and activities. Therefore, many types of learning had been developed to support the students. The collaborative learning was based on social constructivism which emphasized that the students had to acquire their own knowledge through teamwork.

According to the design of education instruction for the e-future classroom, various learning models were applied including problem-based learning (PBL), project-based learning (PJBL), and collaborative learning. Also, peer-assisted learning was implemented to help each other learn the content provided. The focus of learning of DHH students relied on total communication. Amattayakul, Tammasaeng, and Punong-ong (1995) noticed that teaching language to DHH students in schools for the deaf required principles of teaching that mainly concentrated on language learning of DHH students, especially reading and writing skills in Thai. Besides, principles of general skills teaching were necessary and related to practice. They could be applied to prepare the instruction (create experience) and reading and writing practice in Thai. Teaching stages and skill practice were designed based on difficulties of language learning – receiving experience, remembering experience, understanding, and being literate. These were included in integrated language acquisition approach which highlighted development of learning as competency. Adequate ability or knowledge were required to complete the task. Competency would lead to ability to achieve anything. This concept was consistent with a study of Medeshova, Amanturlina, and Sumyanova (2016) which found that conscious action stemmed from ability and ideas of personality-oriented. Learning would happen through activities based on the theory coping with continuous development of thinking process. The obtained knowledge would provide a basis of academic ability and then competency of the students.

Education environment

It was similar to the mixed reality learning environment as it combined the virtual environment with the real environment (RE). This combination was called ‘merge virtual in reality environments (MVRE)’ which referred to a higher proportion of the real environment integrated with several objects from the virtual world. The mixed reality learning environment was developed to present the lessons via the augmented reality technology. Quint, Sebastian and Gorecky (2015) noted that the mixed reality concepts seemed to be merged with a new learning environment which could help solve future problems. In other words, these complicated and invisible relations experience were understandable for present and future environments by using the mixed reality based learning environment. Therefore, the augmented reality technologies could be utilized to represent the digital world by combining with different elements in the real world. The hologram technology was also implemented to design the mixed reality learning environment. Cho (2008) stated that the educational process could be improved by taking well known character to life again from the past and describe

something as an assistant teacher. The integration of AR hologram technology could enhance the efficiency of the mixed reality learning environment.



Figure 4. The mixed reality learning environment in the e-future classroom

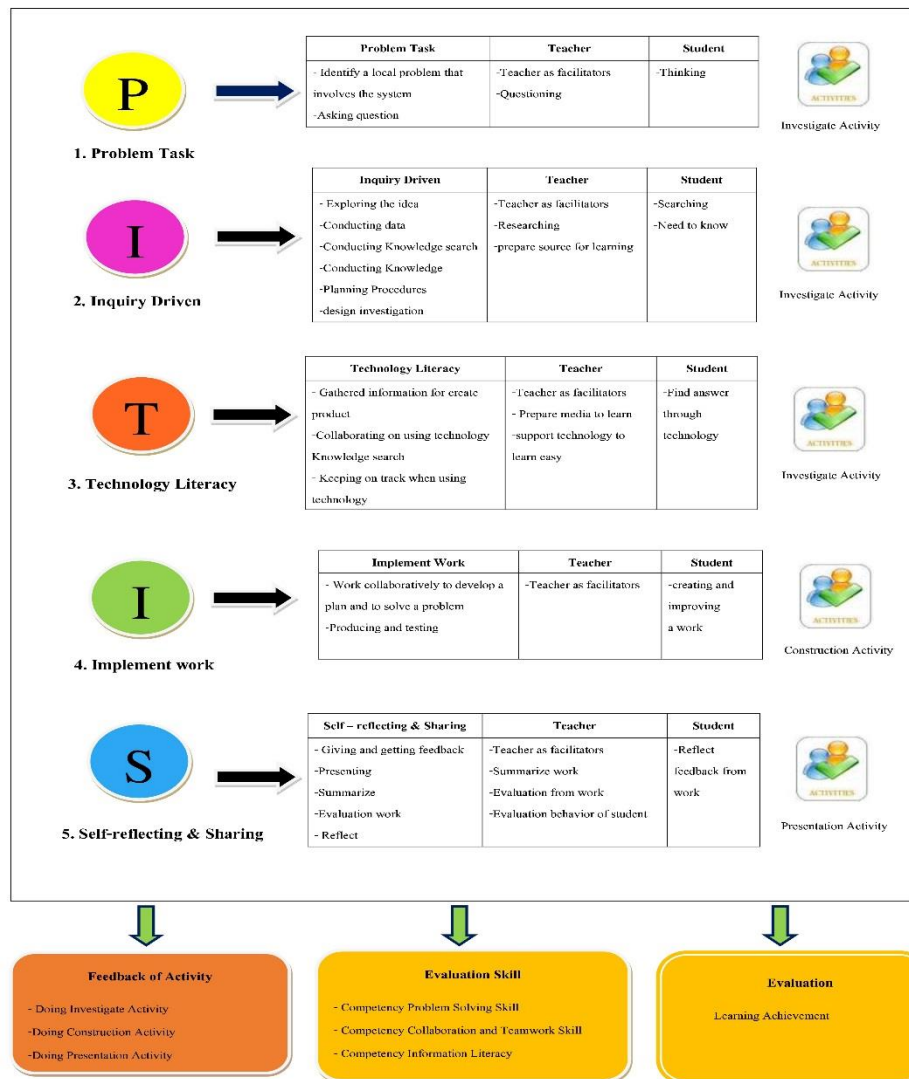
Evaluation standard

The learning evaluation could be conducted through activities, various instructional models, and skills stemmed from the learning integrated with technologies. The objectives of evaluation could be established regarding the teachers' requirement. The instructional models and the activities should be appropriately arranged to meet several objectives and aspects of evaluation such as learning achievement and skills including problem-solving, decision-making and learning, information and communications technology (ICT), and information literacy.

Step 3. Design teaching methodology in e-future classroom

A study of Chandee (2011) was taken into consideration when designing the instructional models and the learning styles to serve the requirements of DHH learners. According to the study, it found that there were certain elements affecting the learning of DHH learners; for instance, education, teaching method, consultation, learning environment, and evaluation. This was concordant with Branson et al. (2005) who mentioned that the learning environment for DHH learners including curriculum, teaching method, materials, evaluation, and educational support should be carefully provided to meet the learners' way of life. It would be beneficial to help them learn and develop their potential like normal learners. The teaching method for DHH learners was designed to encourage them to solve problems, search for information by themselves, and collaboratively learn through the instructional technology. This would allow the learners to practice teamwork skill and information and communications technology (ICT) and information literacy which could be applied to problem based learning (PBL), project based learning (PJBL), collaborative learning and peer instruction. The role of teachers in this context was a facilitator who accommodate and guide the learners to have a thorough understanding of the lessons.

To design teaching methodology for the e-future classroom, both media and project work were combined together. The teachers would use equipment and teaching methods to communicate and transfer the knowledge to the students to meet learning objectives. Project work would offer opportunities to the students to seek experience and meaningful learning and demonstrate their potential. Furthermore, the students would be encouraged to learn by doing in real situations. Thus, the assignments should be based on the students' needs which was the most important goal. The students were allowed to select the work they would like to tackle regarding their own motivation. Structured projects including topics, activities, methods, and presentation were prepared by the teachers. The purpose of this teaching approach aimed to promote learning by searching. The students would deeply learn the contents regarding their own interest and they would be supported by their peer to improve their skills, particularly time management, project work management, teamwork, coordination, thinking, knowledge acquisition, and creative problem solving. The stages of applying this teaching method using media and project work were as follows figure 5.



Learning process of e-future classroom model

Figure 5. Learning process of e-future classroom

1. Introduction (Problem Task) – The teachers should create a good atmosphere and unity among team members. Group dynamic activity might be helpful to get the students ready to join in teamwork and get the class interested to complete the task. Many techniques such as brainstorming, slide or nature might be utilized to attract the students to participate into the work and pay attention to the content. The media used in this stage should present common knowledge or content related to previous class, not in-depth media. It might demonstrate certain problems to let the students think. The media should be simple and illustrated within a short time (e.g. images and flash cards).

2. Teaching Stage (Inquiry Driven and Technology Literacy) – Detailed content was provided to meet the learning objectives. Thus, the teachers should carefully select the media and teaching method. Integrated media might be an interesting alternative but it should be properly ordered to match activities. The media applied in this stage should offer detailed, clear, and accurate knowledge to the students.

3. Practice Stage (Inquiry Driven and Technology Literacy) – It aimed to provide the students with direct experience to let them apply theoretical knowledge or principles they had learnt to solve problems. The media utilized in this stage should stimulate the students to think and make use of the media as much as possible. The students selected the topic by negotiating and synthesizing information to find out the topic of project work. Then they created a general outline of the project work by planning, defining scope, and preparing materials. After that, they did basic research around the topic to follow the plan as assigned to each team member.

4. Wrapping Up Stage (Self-reflecting & Sharing) – This was the last stage which aimed to review the content for accurate understanding regarding the learning objectives. It should take only a short time like the introduction. The media applied in this stage should cover all important contents by summarizing and reporting the project work to the class. Thoughts and feelings would be presented to the class through reporting or presentation process. Also, processing feedback should be given to the students to let them improve their future project work. The teachers were facilitators who provided support and helped the students learn effectively

Step 4. Design activities/tests in e-future classroom

The activities and the evaluation of the e-future classroom were appropriately designed to suit the learning of DHH students. Active learning and learning ability were taken into consideration to design activities and tests. The students would enthusiastically complete the task by themselves using their senses to access the information. Then autonomous learning would truly occur through the technology application in the e-future classroom. The teachers in this context were responsible for arranging learning environment, reinforcement materials, suggestions, and summary. The stages of designing activities for the DHH students were as follows.

1. Documents related to Science Subject were examined to design activities for the DHH students. The activities were provided for several topics including structure, reproduction, growth of plant, and natural resources. These activities would help the students achieve learning objectives in each unit.

2. The activities were carefully designed to help the DHH students better understand structure, reproduction, growth of plant, and natural resources. The content was divided into 3 units; 1) structure and reproduction; 2) growth of plant; 3) natural resources.

3. The tests were designed to evaluate the understanding of the DHH students on structure, reproduction, growth of plant, and natural resources. The students were tested during and after participating in the activities.

4. Behavioral observation form was created to observe the students' behavior during participating in the activities in aspects of information literacy,

problem-solving, decision-making and learning, information and communications technology (ICT), and teamwork skill.

5. Some activities were supplemented for better understanding on structure, reproduction, growth of plant, and natural resources. These activities were separated into 5 parts as follows. 1st Activity – It aimed to provide an introduction, break the ice to build a good relationship between the teachers and the students, and state learning objectives. Matching and self-introduction activities were run in this part. The technology was applied to create a self-presentation. 2nd Activity – The students learned structure and reproduction topics. Investigate activity was utilized to let the students examine plant structure and reproduction. Then they had to answer questions by searching the information through AR technology installed at different points in the classroom. This method could attract the students' attention and guide them to learn step by step since they worked in pair to help find out the right answers. 3rd Activity – The students learned growth of plant. Investigate activity was utilized to let the students explore plants around the classroom and observe the growth of similar plants of each group. After that, they had to present the selected plant. They needed to search for the information through AR technology installed at different points in the classroom following the sequence provided. Each group grew bean sprouts, observed daily changes, and presented results to classmates. 4th Activity – The students learned natural resources. Investigate activity and construction activity were utilized to let the students study natural resources. The students learned this topic through the hologram technology and applied the knowledge to create their own work. Different parts of the plant were combined to tell stories about natural resources; for instance, pollution reduction and solutions. Each group consisted of 4 members and they needed to present their stories via images and information. 5th Activity – The students were required to present their work. It was used in summarizing stage. After each group completed their work, they had to explain background of their work, the knowledge gained, problems or obstacles, solutions, and opinions towards activities and working with other members in a team.

The activities and the evaluation for the e-future classroom were specially designed to suit the learning ability of DHH learners. Thus, active learning activities were prepared to stimulate the learners to enthusiastically perform the activities by themselves. For example, they had to explore, search, do a project, interview, solve problems, and present their work. Various senses were required to do investigation activity, construction activity, and presentation activity along with the use of technology in the e-future classroom. The teachers were responsible for building the learning environment, arrange reinforcing materials, providing consultation, and summarizing the content together.

Step 5. Identify participating reactions of participants to the e-future classroom

Interview questions

The interview questions used to evaluate the learners' reactions to learning via the e-future classroom were shown below.

1. How did you feel about the e-future classroom?
2. How did you feel about the activities in e-future classroom?

3. Did you understand the content when learning in the e-future classroom? (structure, reproduction, and growth of plant, and natural resources)
4. Is this innovative technology easy or difficult to use?
5. How did you feel about the mixed reality learning environment?

The interview questions used to evaluate the teachers' reactions to learning via the e-future classroom were presented as follows.

1. How important was the learning in e-future classroom?
2. Did the learning in e-future classroom help the learners have a better understanding?
3. How did the mixed reality learning environment support the learning?
4. What was the difference between the learning in e-future classroom and traditional classroom?
5. How was the learners' behavior when learning in e-future classroom?
6. Were the designed instructional models suitable to the learning in e-future classroom and the target learners?
7. According to the observation of learners' behavior when learning in e-future classroom, how did it help build the information and communications technology (ICT) and information literacy?

Identify participating reactions of participants to the e-future classroom

Observation behaviors

The students' behavior was observed during participating in the activities under the controlled environment. The activities were designed to gather the students' reaction to various situations. The behavioral observation form was divided into 5 aspects below.

1. Behavior related to access to information literacy – It consisted of keywords and language used to search for the information needed, ability to effectively search for the information, interpretation and understanding on the information, categorization, evaluation of reliability and relevance of the information, communication and use of the information regarding specified objectives.
2. Behavior related to problem-solving, decision-making, and learning.
3. Behavior related to information and communications technology (ICT) – It included proper and correct use of tools.
4. Behavior related to team work – It was associated with expressing opinions, enthusiasm in work, responsibility, systematic work procedure, suitable time allocation, and being a good leader and a good follower.

Data analysis and Result

Analysis of the pre- and post-tests

Table 2. Pre-test and Post-test Results

| |
|---------------------------|
| Wilcoxon Signed Rank Test |
|---------------------------|

| Test | N | Mean | SD | Z | P |
|------------|----|---------|---------|-------|-------|
| Post-tests | 13 | 24.8462 | 4.31753 | 3.184 | 0.01* |
| Post-tests | 13 | 15.2308 | 2.71274 | | |

*P<0.01 ** A level of statistical significance was .01

Z = Tested Value of the difference between Rank Pre-test and Post-test

According to the above table, the students' knowledge gained after learning in the e-future classroom was different to the earlier period with a .01 level of statistical significance. This showed that the students' knowledge obtained from the e-future classroom was higher than before learning. According to the in-depth interview and the observation of the learners' behavior, it demonstrated that the learners felt that the e-future classroom was interesting. They were motivated and excited to learn in the e-future classroom because of the modern technology which was easy to access and not too difficult to use. It helped the learners to have a better understanding of the content when compared to the traditional classroom since certain elements which the learners were not able to see and imagine could be presented using this instructional models. Moreover, the e-future classroom was fun and encouraged collaboration and practice of the learners. The learners also liked the mixed reality learning environment due to the realistic and virtual images which could enhance their understanding of structure, reproduction, and growth of plant, and natural resources.

Analysis of the interviews with teachers and specialists

According to the in-depth interview and the observation of the learners' behavior, it found that

1. The learning in e-future classroom was important for the DHH learners because they largely needed to use their eyes for learning. The technology was suitably blended to design the instructional models and the activities to motivate the learners in the e-future classroom.

2. The learning in e-future classroom could promote the learners' understanding of the content, especially some complicated parts they could not really see.

3. The mixed reality learning environment could provide a positive effect on the learning due to its higher proportion of the real environment integrated with several objects from the virtual world. Additionally, the learning efficiency and effectiveness were better since the mixed reality learning environment could build a good atmosphere in class. Then, the learners could study happily and enthusiastically with higher motivation.

4. The learning in e-future classroom was very different from the traditional classroom. This was because the implementation of innovative technology to create the mixed reality learning environment. Several skills of learners were developed through the e-future classroom; for example, teamwork skill, information and communication technology (ICT) and information literacy which could be applied to some aspects of evaluation.

5. Regarding the learners' behavior in e-future classroom, it was obviously seen that the learners were much more interested in studying. They had fun

learning by doing to use the technology combined with the e-future classroom which could more easily explain the complex content. The interaction between learners and technology was good as well.

6. The designed instructional models and the activities were appropriate to the e-future classroom and the target learners. The instructional models employed in this class consisted of problem based learning (PBL), project based learning (PJBL), and collaborative learning. The activities stimulated the learners to solve problems and develop many skills better. Also, these activities could be effectively adapted to various contents and teachers' objectives in the future.

7. According to the behavioral observation of individual learner, it found that the learners were able to effectively utilize the technology. They could learn and access the technology quickly. It could be said that simple technology for children's learning could improve the information and communications technology (ICT) and information literacy of the learners in a short time.

Analysis of the observation with teachers and specialists

Regarding non-participant observation in the classroom, the results were demonstrated as follows.

1. Behavior related to access to information literacy was observed based on keywords and language used to search for the information needed, ability to look for the information by themselves, ability to effectively search for the information, suitable time allocation to find correct information, ability to interpret and understand the information, understanding on the lesson, categorization, evaluation of reliability and relevance of the information, communication and use of the information regarding specified objectives. The first evaluation found that the average percentage score of the students was 15.38% while the score gathered from the final evaluation was 100% which increased by 84.62%.

2. Behavior related to problem-solving, decision-making, and learning was observed based on understanding on significance of problem-solving process, decision-making process, as well as principles and tools that assisted decision-making, ability to properly and timely respond to changes, and ability to effectively use the information. The first evaluation revealed that the average percentage score of the students was 30.76% whereas the score collected from the final evaluation was 92.30% which increased by 61.54%.

3. Behavior related to information and communications technology (ICT) was observed based on the use of tools or devices, information, and software, and ability to follow instructions. The first evaluation demonstrated that the average percentage score of the students was 23.07% whereas the score collected from the final evaluation was 100% which increased by 76.93%.

4. Behavior related to team work was observed based on participation in expressing opinions, answering questions, interaction, enthusiasm in work to complete the assigned task on time, responsibility, systematic work procedure, work delegation, proper time allocation for work, and punctuality. The first evaluation illustrated that the average percentage score of the students was 15.38% whereas the score collected from the final evaluation was 92.30% which increased by 76.92%.

Discussion

The e-future classroom was a specially developed learning resource. It was different from normal classrooms since it was designed for the deaf and hard of hearing (DHH) learners. The innovative technology such as AR hologram technology was combined to create the mixed reality learning environment to present the complicated content as the virtual image. This could enhance the understanding of DHH learners who mainly used their eyes for learning. The sample observation demonstrated that they were interested in the content taught in the e-future classroom along with the AR hologram. Since the samples could repeat the lesson, they were able to develop their skills, memory, and understanding of the content. The e-future classroom could build fun and entertaining atmosphere and increase the DHH learners' motivation. This was concordant with a study of Galimova and Shvetsova (2016) who stated that the use of modern educational technology could promote learning communication skill of the learners since it was based on human-and-activity-centered approach. It was not only beneficial to access the technology, but also helped develop the process and increase the interest effectively. There were several elements for successful preparation of learning activities; for instance, good type of activities, new technique, and interesting technology, which could support the learners to achieve learning objectives, indicators, and standards of each subject. In conclusion, the e-future classroom was considered as an educational innovation containing models, approaches, and technological media. It could provide satisfactory outcomes when used to solve the problems and develop effective learning skills regarding the requirements of DHH learners.

Disclosure statement

No potential conflict of interest was reported by the authors.

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