3D Hologram Learning Kit Development for Elementary Education

Youbin Kim(✉) and Dong Yeong Lee

Hanyang University, Seoul, Republic of Korea
{gumi0508,dannylee}@hanyang.ac.kr

Abstract. This paper aims to explain the design for immersive learning resources that include 3D holographic learning content intended to complement basic textbooks. Also, it shows a development process for a portable learning kit that is accessible and universally available for collaborative learning to increase the interest and understanding of elementary school students.

When it comes to designing 3D hologram learning content, we have worked with scientific content based on the national curriculum for fifth and sixth grade levels in elementary school. We used an IAP process (A Design Process based on Iterative Agile Prototyping) for developing a tangible learning kit, which consists of a reflective mirror, a tablet holder, and a height adjustment stand, providing 3D holographic images via a tablet and an app controller.

We have assessed the learning kit in order to define problems and improvements for future development. As a primary test, the 3D learning content was evaluated with student users from the perspectives of immersion, and social interaction. For the secondary test, we conducted a usability analysis from teacher's observation and interviews focusing on tangible interaction, and convenience. As a third test, the kit was evaluated by experts in field of EdTech (Education and Technology) to reveal its weaknesses and strengths in aspects of marketability with feedback and possible improvements. Through this exploratory study, we have identified the strengths and weaknesses of this 3D hologram learning kit and defined further improvements as a universal teaching resource in the future classroom.

Keywords: 3D hologram · Learning kit · Elementary education · EdTech

1 Introduction

In the era of the fourth Industrial Revolution, educational learning systems and methods have changed rapidly, incorporating advanced technologies such as AR/VR, holograms, big data and AI. Traditional education has mostly been carried out by means of didactic instruction, which is a one-way approach to information and cognition. Nowadays, however, educators favor experience-oriented teaching methods and tools that offer learners interactive experiences as well as psychological satisfaction about the fulfillment of essential learning. Going forward, education will expand especially into virtual spaces providing a significantly new kind of learning through interactive device design that includes various interactive contents, something that users have not yet experienced.

This work was supported by the research fund of Hanyang University.

P. Zaphiris and A. Ioannou (Eds.): HCII 2020, LNCS 12206, pp. 464–479, 2020.
https://doi.org/10.1007/978-3-030-50506-6_32

In 2012, the Republic of Korea's Ministry of Education established 41 smart education research schools to provide learning environments for virtual experiences. Also, these schools have developed appropriate curriculums and courses for virtual education via high-tech equipment (KERIS 2012). However, educational tools using AR/VR technology have problems: there is a lack of sufficient content because it is costly and time consuming to develop software. At the same time, it is inconvenient to have educators and students wear headsets while trying to participate in the educational experience.

On the other hand, holographic technology is more valuable because it can directly show virtual objects without any mediating devices. This technology is useful as a tool for collaboration through mutual communication. New forms of virtual learning with various interactive contents, including EdTech products based on holographic technology, will provide new tools for more collaborative learning experiences rather than unidirectional approaches to information and cognition. However, the existing hologram equipment is large, cumbersome, and difficult to install, and the equipment must maintain a Wi-Fi network with a minimum guaranteed constant speed of 20 megabits per second (Ghuloum 2010, p. 698). At the same time, the cost burden and space limitations make it impractical for easy use in the classroom.

Therefore, this paper aims to create resources for designing a 3D hologram learning kit that provides immersive learning experiences meant to complement basic textbooks. In addition, the ultimate goal is to develop a portable learning kit that is accessible and universally available for collaborative learning. The learning kit will display learning content that leads to effective learning, increasing the interest and understanding of elementary school students. Additionally, this learning kit must be evaluated for suitability and feasibility in various aspects that will be assessed to reveal weaknesses and strengths in order to justify any improvements. Thus, this paper aims to achieve the following objectives.

Research Objectives

– To reveal the importance of 3D holograms in the teaching and learning environment.
– To create 3D hologram learning content as science learning resources for elementary education.
– To develop a portable kit for interactive and collaborative team teaching.
– To evaluate the suitability of the content and learning kit from the user's point of view.
– To analyse the market feasibility of the 3D hologram learning kit.

To implement research based on the objectives above, this study is divided into 4 stages: learning content design, learning kit development, primary/secondary test of user experience, and experts' feedback that answers pertinent questions.

Research Questions

– What is the appropriate learning content of elementary science courses?
– Which design is best suited to form a kit shown as a 3D hologram?
– Does the 3D hologram content lead to efficient learning for elementary students?
– What difficulties will elementary instructors face while using this kit?

– What are the 3D hologram kits' strengths and weaknesses compared with traditional methods or competing products?

2 Theoretical Research

2.1 The Importance of 3D Hologram Technology in Learning Environment

A hologram is a three-dimensional projection of laser light. The word, hologram, comes from the Greek terms, "holos" for "whole view"; and "gram" meaning "written". Dennis Gabor, a Hungarian physicist, he researched about electron microscopes, discovered the basic technology of holography in 1947 (Gabor 1948). In 1962 scientists in both the United States and the Soviet Union created 3D holographic technology (3DHT). However, 3DHT has advanced notably since the 1980s owing to low-cost solid-state lasers that have become easily accessible for consumers. The way 3DHT operates is by creating the illusion of three-dimensional imagery. A light source is projected onto the surface of an object and scattered. A second light illuminates the object to create interference between both sources. Essentially, the two light sources interact with each other and cause diffraction, which appears as a 3D image (Ghuloum 2010). The importance of 3DHT on the learning environment has increased due to the instructional advantages of technological services via ICT integration that has successively made novel forms of education. This learning process is interactive beyond merely playing a video in a 3D hologram. Here, hundreds of teaching resources appear as if real materials actually exist in the classroom. Moreover, 3DHT enhances the educational process by bringing in famous characters that speak about themselves as well as explain points of interest, just like an assistant teacher would. As a virtual teacher, the character leads the learners' interest and increases their immersion in the class. According to Sandra Andrews at Arizona State University College of Education, "The virtual world gives a greater sense of presence than discussion boards. The students get a better feel for the teacher, and it is more fun" (Harrison 2009). Hence, the studies have shown that the learning results by virtual materials aid better retention of information and understanding of a given topic.

2.2 Examples of Previous 3D Hologram Technology for H-Learning

Currently, sophisticated technological tools for H-learning have been proposed as different ways of expressing educational content in 3D holograms. The first type is when a virtual teacher, unrestricted by time and space, teaches students. The process goes a step further when the holographic teacher appears to be in the classroom, seeing and speaking to the pupils as if they were all in the same room. For example, this system was demonstrated by Duffie White in Edexcel, the largest supplier of Internet connections to the UK education market, at the BETT2000 Educational Technology Show in London (BBC News 2000). Math teacher Catharine Darnton was digitally teleported into the exhibition center at Olympia from Graveney School in South London. The distance was a few miles; however, since the system used internet protocols, the audience and the teacher could have been anywhere and shared their experience. The second type interacts with philosophers or historical masterminds from the past. This is utilized in museum education. At the TEDx Copenhagen, the founder of the Carlsberg dynasty appeared in front of 300 invited guests over 170 years after his passing. The audience at the world famous Glyptothek museum was stunned to see the founder of the iconic international beer brewery, JC Jacobsen in real time as a hologram.

The third type is when the learner wears a holo-lens and chooses specific resources according to the courses. Here, learners experience embedded 3D images within reality relating to the educational contents. Pearson and Microsoft released HoloPatient and HoloHuman, which provide nursing schools with a series of digitally created healthcare scenarios. Students wearing HoloLens see holograms of professional actors pretending to be ill and learn how to diagnose and treat them (Microsoft 2018). The final type is 3D Studio by Hypervsn, which is an online service with the integrated 3D content marketplace that provides a new way of creating and customizing 3D content for one's own work. Avoiding expensive creative agencies, users are able to take 2D images and convert them into 3D visuals. This program includes a feature that adds stunning animation in a variety of languages, fonts, colors, and textures. The platform allows educators to design custom curricula for their own specific needs. Action recognition systems without additional headsets also demonstrate interactive features which lead to engagement focused on studying and other key interactive offerings (Figs. 1 and 2).

Fig. 1. A holo-lens in use (Source: Microsoft)

Fig. 2. 3D studio for 3D content creation (Source: Hypervsn)

3 Development of the 3D Hologram Learning Kit

3.1 Designing the 3D Hologram Learning Content

When it comes to designing 3D hologram learning content, we have utilized scientifically accurate educational sources based on the national curriculum for fifth and sixth grade elementary school levels established by the South Korean Ministry of Education. The revised national science education standards for 2018 stipulate that educators at these grade levels must foster scientific thinking, research skills, problem solving, communication skills, participation, and learning skills as core capacities (Korean Ministry of Education p. 211 2018). The standards for overall learning aim to develop scientific understanding and inquiry ability as well as to stimulate students' interest and curiosity about natural phenomena and objects. The national curriculum for content design adopted the following achievement criteria (Table 1):

Table 1. Setting up the earth science curriculum for content design

Core concept	Core content	Content element	Achievement standards	Specific learning objectives
Composition and motion of the solar system	The solar system is made up of various objects, including the sun, planets, and satellites	Planets in solar system	Understand the types and features of the planets in the solar system	1) Students will observe shapes and distinguish sizes of Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune 2) Learners will distinguish the planets' sizes and know distances between them
		The sun	Know the shapes and features of the sun and about solar energy	1) Students will observe the appearance and surface of the sun, and learn about its characteristics and processes 2) Students will understand the importance of the sun for life on earth

In order to build effective learning experiences, we have adapted the mobile application system to control curriculum-based learning. We have designed stereoscopic images based on this core content for science education in application guidance and services. The content interfaces are clear and user-centered, helping students and teachers obtain information and complete critical tasks easily. The users' experience has been designed by clearly organizing the overall menu composition in order to deliver the main content. In addition, the flow plan and pagination of content has been organized using wireframes. We have also used an iterative prototype of IAP process for developing the app and a tangible learning kit, which is an ICT convergence design process developed by Kim and Lee (2019). It is a way to come up with new ideas while repeatedly drawing on paper, demonstrating that creators can become users who evaluate and improve their apps continuously. The following table depicts the order of interfaces and functions in the easy-to-show 3D holograms (Table 2).

3.2 Designing the 3D Hologram Physical Learning Kit

For the development of a physical learning kit designed for both students and teachers, we have used an IAP process for ICT convergence product design. This is a participatory design process model for innovation as well as an extension of the methodology for developing the learning content. Four design researchers fashioned kit prototypes iteratively using the various given paper resources and found them to work according to the following three principals.

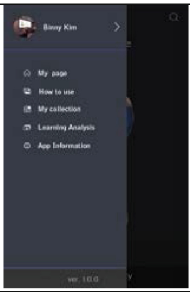
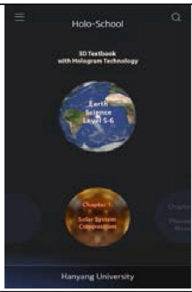
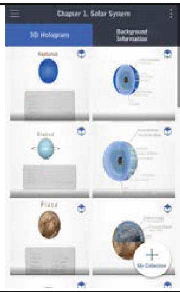
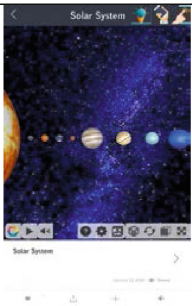
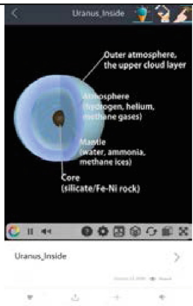
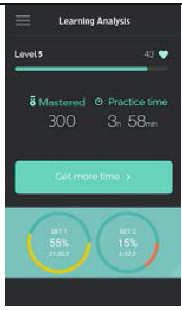
Durability. This is the ability of a physical product to remain functional without requiring excessive maintenance or repair when faced with the challenges of normal operation over its design lifetime (Tim 1994, p 25). We focused on the aspects of the kit's structure stability as well as on sustainable tactile design materials.

Ergonomics. This refers to the understanding of interactions between humans and other elements of a system in order to optimize the performance and effectiveness of the working system, including accessibility, usability, and safety (Wickens C. D. et al. 1998, p. 295). We intended an easy-to-assemble kit that rested on the table at the user's sitting height.

Portability for Collaboration. Portability in product design means the quality of being small and light enough to be easily transported. We aimed for a smaller kit that is also easier to carry than the existing heavy hologram devices. Such portability enhances the potential for teamwork and idea exchange as well as how users can implement cooperation within the academic environment.

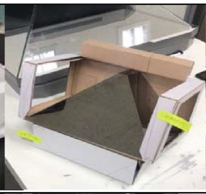
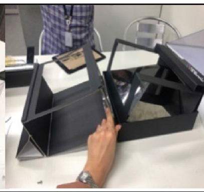
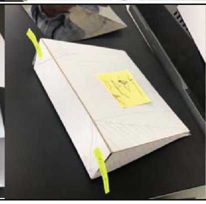
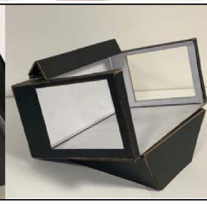
In the field prototyping of the IAP process, we discovered potential users' needs and problems by deconstructing the existing hologram devices. We repeatedly attempted to research key questions regarding a product that is more robust and intensive. The "decision prototyping" exploratory phase generated data to clarify the product's ergonomics, usability, and convenience. We defined problems in virtual situations by marking them with post-its. In the stage of "idea prototyping", we applied an iterative agile process. These activities led to the evaluation of prototypes via quick and lightweight feedback. At this stage, we drew wild ideas on existing prototypes as well as created new functions reflecting novel ideas. Rapid feedback about new ideas gave us insights into innovative solutions. At the same time, we continued to experiment with structural forms so that the triangular reflectors could function well technologically at the same time as the learning content was displayed accurately on the tablet screens.

Table 2. Flow and functions according to app pages

Page name	Left bar	Main screen	Content list
Images			
Functions	1) My profile 2) My collection 3) Introduction 4) Learning analysis 5) App information	1) Searching content 2) Selecting a subject 3) Selecting content of a chapter	1) Listing holographic content by curriculum 2) Information section on educational goals and background content
Flows	1) Users register their own profiles as soon as they enter main page. 2) Users check how to utilize app service through introduction in menu bar. 3) Users choose the subjects and sub-topics they want to teach or to learn.		
Page name	3D hologram content 1	3D hologram content 2	Learning Analysis
Images			
Functions	1) Transferring holographic image to tablet 2) Adjusting volume of background music 3) Adjusting image size 4) Adjusting image angle 5) Stopping planet rotation	1) Press 'Like' to select 2) Sharing images with others 3) Saving images in "My Collection" 4) Listening to the information	1) Number of images students "like" 2) Number of images viewed in total learning time 3) Previously viewed image 4) Percentage completed
Flows	1) User sets up contents, rotation, sound, etc. 2) User sends desired contents to the tablet by pressing a specific button. 3) User moves the contents and adjusts size and angle by sliding fingers and using pinch-zoom. 4) User checks amount of the time spent and content learned according to subjects.		

Various prototypes have been made to rise to the technical challenge of presenting holographic resources from different physical angles so that many users can communicate with each other from different positions, postures, and locations in order to stimulate team collaboration. The 3D simulated images that appear on cell phones and tablets use a transparent acrylic pyramid. Projected stereoscopic motion that contains 3D holographic content enhances the viewer's perception and motivates participation (Table 3).

Table 3. Development procedure of 3D hologram learning kit

Process	Field prototyping	Decision prototyping	Idea prototyping	Actualization
Images				
				
Procedure	1) Deconstructing existing hologram devices. 2) Discovering problems through user interviews and tablet testing. 3) Prototyping possible ideas reiteratively with easy-to-access materials.	1) Defining problems in virtual situations using holograms. 2) Marking size and structure problems on physical prototypes. 3) Clarifying common problems and refining structure shape.	1) Generating wild ideas regarding shapes and materials. 2) Simulating the different ideas. 3) Selecting the final texture and form. 4) Demonstrating functionality through feedback.	1) Branding and character design for marketability. 2) Designing all-in-one portable packages for easy portability and collaboration. 3) Examining the manufacturing process to consider mass production and economic feasibility.

The package—the whole kit—consists of a reflective mirror, a tablet holder, and a height adjustment stand. The various data in the 3D app link to the tablet's screen through a Wi-Fi connection. This allows educators and students to view and project high quality holographic images in a universal learning environment. In addition, the controlling function of the app enables students to rotate and zoom in on or out of 3D holographic images for interactive learning and new experiences. The interconnected operating system for the final output via Wi-Fi can be represented by the following Fig. 3:

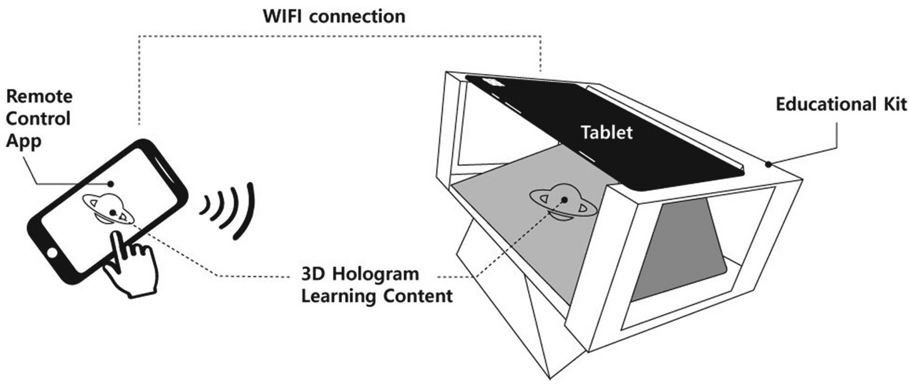


Fig. 3. The 3D hologram learning kit's cross connecting system (Drawing by Youbin Kim)

4 Evaluation

4.1 Methodology

The methodology of evaluation adapted for this study is comprised of three tests, analyzing qualitative and quantitative data as a method of mixed research. We specifically focused on one formative evaluation case utilizing of Kantosalo's (2015, p. 280) criteria for interaction design evaluation methods. As with all human studies, ethical issues arose in relation to child participants; thus we used the consent forms of Waller et al. (2009, p. 27) to obtain agreement with the children's parents.

For the primary test, we conducted a comparative evaluation of 2D textbooks and 3D learning content. The evaluation focused on how and to what extent the 3D content affects a student's understanding and interactive participation. We recruited fifth and sixth grade students and divided them into two teams, each of which had five students. Educators facilitated a real educational situation, and the student teams became involved with the content and tools while researchers observed. We assessed the level of high/middle/low from the perspectives of perceptual coupling, configurability, legibility, high concentration, letter perception, and continuous interaction. Also, in aspects of social interaction we evaluated the encouragement of participation, collaboration, physical focus, social awareness, and effective communication.

The secondary test evaluates usability of the learning kit as a teaching tool for elementary school teachers. A sample of five primary school teachers individually implemented the 3D hologram in a teaching environment with the help of a kit guide. A researcher checked the teachers' behavior and noted the details on an observation sheet to determine important factors in relation to tangible interaction and convenience. The checklists were quantified through a one to five on the Likert scale where "one" indicates a level of strong disagreement while "five" indicated strong agreement. Afterward, the teachers completed an experience survey according to the interview protocol.

As a final assessment, the kit was evaluated at the Consumer Electronics Show (CES 2020) to reveal its weaknesses and strengths from the perspective of market suitability. Forty-one experts in the fields of university academia, and EdTech related professionals provided feedback pointing out possible improvements. The questionnaire focused on evaluating the 3D hologram learning kit's for educational institutions by identifying advantages and disadvantages.

Results of Primary Test. First, in order to measure content immersion, Team A received a 2D textbook to learn about the solar system and planets. Team B was given a 3D hologram kit that covered the same material. An instructor explained the same guide to both teams for the same length of time. Both teams had 30 min of study time, and after a ten-minute break, they took an exam about the features and components of the planets Jupiter and Saturn, as well as about the order of the solar system. This was done to understand how well they concentrated on the content.

Team A read for only 10 min and paid no other attention to the material for up to 15 min. On the other hand, Team B focused on the 3D holograms, manipulating the application until time was up. During those 30 min they were immersed in the experience as if playing a game, which demonstrates augmented concentration and continuous interaction through high participation. To identify the aspect of legibility, five students of Team A wrote short answers to the questions, answering on average only three of the five questions; also, the students drew very simple pictures of Jupiter and Saturn. Team B correctly answered all five questions, and their responses were much more expansive and creative. At the same time, their descriptions and expressive drawings were quite detailed. Team A had no problems recognizing the letters in the textbook in terms of letter perception. However, Team B found it difficult to recognize the rotating 3D letters. They asked their teacher three questions during the 40-min learning period. This revealed the connection between letter recognition and learning, and it seems to reveal that the difficulty in perceiving 3D characters lowers the perceptual coupling and interrupts the flow of learning.

In order to evaluate the results of cooperation and interaction between team members, comparative analysis was performed through video recording. During the given time, Team A's communication about the subject was minimal and the students made no attempt to collaborate with one another in order to solve any problems. However, in the case of Team B, one student assumed a leadership role and suggested participation to another student, and together they informed the others about how to adjust the 3D content; inter-student communication continued until the end of the study period. Therefore, this demonstrates how the 3D hologram kit encourages participation and effective communication during learning. Regarding collaboration, Team B showed a higher degree of teamwork in that they cooperatively solved problems, using the discussion time to share their opinions about the questions. However, since the students took so much time communicating and cooperating rather than answering the end-of-period questions, the value of the physical focus score is low (Tables 4 and 5).

Results of Secondary Test. For the secondary test, a sample of five primary school teachers implemented the 3D hologram kit with the help of a kit guide while we conducted observation, checking the usability checklist. Statistically, the results show high scores for direct haptic manipulation, lower thresholds of physical interface, and accurate movements in the aspect of tangible interaction. Also, the in-depth interviews revealed that almost all the teachers were satisfied with adjusting their own apps and

Table 4. Results of comparative test between 2D textbook and 3D hologram learning kit

Criteria	Sub-factors	Team A	Team B
Immersion	High concentration	Low	High
	Legibility	Middle	High
	Letter perception	High	Low
	Continuous interaction	Low	High
	Perceptual coupling	Middle	Middle
Social interaction	Encouragement of participation	Middle	High
	Collaboration	Low	High
	Physical focus	Middle	Middle
	Social awareness	Low	High
	Effective communication	Low	High

explaining the content. The 3D hologram kit was also effective in delivering learning content because of its rapid and accurate operation, as well as its response from its interface operation. However, it received low scores for spatial and continuous interaction because there is little interactive response in conjunction with its surrounding situations and environments (Table 4).

In the aspect of convenience, the kit could be set up by following the simple instructions on the package and worked according to the teachers' needs without any problems. Also, it was possible for multiple users to operate the hologram at the same time because of the multiple input points. The educators had no problems utilizing whatever holographic content they wanted to store in their collections. They also felt that the kit was easy to move and assemble for use, which generated high scores for the sub-factors of convenience.

Results of the Third Test. Forty-one experts at the Consumer Electronics Show (CES 2020) responded to our questionnaire about the advantages and disadvantages regarding the learning kit's marketability. Remarkably, the respondents identified "universal compatibility" and "ease of distribution by effective packaging" as the main strengths with percentages reaching more than 30%. This is because, unlike traditional hologram devices, the kit is able not only to easily utilize any tablet and phone but also to access any global market. Additionally, the experts believed that the learning kit is suitable as a classroom product offering educational instruction with a significant level of over ten percent for both "low initial cost of infrastructure in schools" and "applicability of various teaching resources" because it is effective in both theoretical and practical subject content delivery. Also, two responders mentioned "possible language translation for global retail", which shows that the 3D hologram content and kit are expandable regardless of national or language barriers.

However, the experts overwhelmingly pointed out "difficulty of self-development for new content" as the main disadvantage, with a score that reached more than 40%. At the same time, over 20% of the sample believed that there are technical limitations in the categories of "Wi-Fi access constraint" and "platform limitation" because the kit cannot be used in a non-Wi-Fi area or can only be used by downloading the

Table 5. Outcomes of comparative test between Team A and Team B

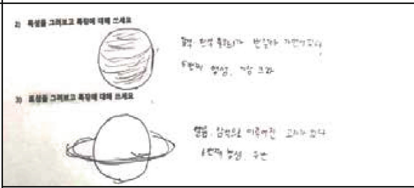
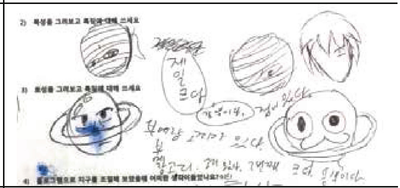
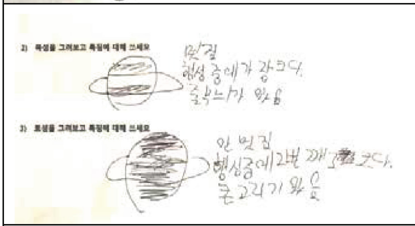
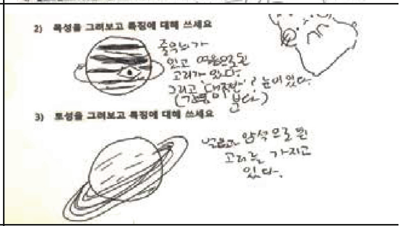
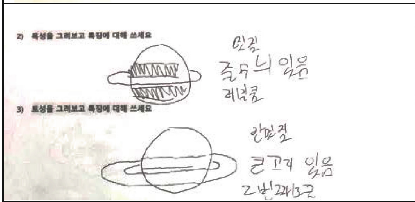
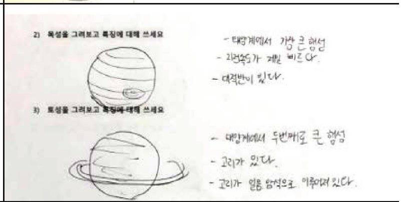
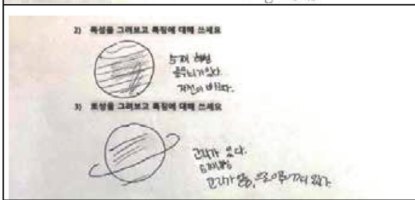
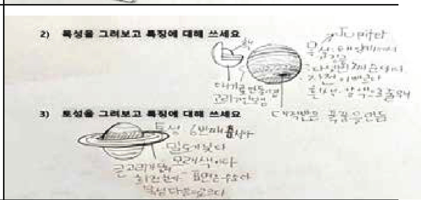
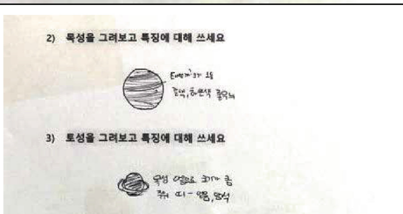
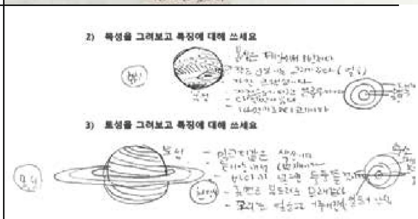
	Team A	Team B
Outcome images		
		
		
		
		
Test images		

Table 6. Results of usability test captured via observations and interviews

Criteria	Sub-factors	A	B	C	D	E	Average	Comments
Tangible interaction	Haptic direct manipulation	5	5	4	5	5	4.8	Users are able to hold and operate movement according to haptic interface
	Accurate movement	4	5	4	4	4	4.2	Depending on the degree of operation, the hologram images respond accurately
	Realtime feedback	2	4	3	3	3	3	Work instructions provide quick feedback in real time
	Lightweight interaction	4	3	3	4	2	3.2	Even with the lightest touch, the kit tends to respond well
	Environmental interaction	2	1	1	2	2	1.6	There is little interactive response in conjunction with surrounding situations and environments
Convenience	Control constraints	3	3	4	4	3	3.4	Holographic movements can be controlled according to users' needs
	Multiple access points	4	3	3	2	4	3.2	Due to multiple input points, multiple users can operate the hologram at the same time
	Configurability	3	2	3	4	3	3.0	The installation is simple and the setting function is conveniently

(*continued*)

Table 6. (*continued*)

Criteria	Sub-factors	A	B	C	D	E	Average	Comments
								configured without an instructional manual
	Lower thresholds of physical interface	4	5	5	5	3	4.4	It is easy to utilize holographic content that educators want to store in their collection
	Portability	5	5	5	5	4	4.8	It is easy to move and easy to assemble for use

application. Additionally, "lack of technical know-how" was also identified as a relatively unimportant barrier in the aspect of personal ability, due to users' possible slowness to adapt to new technical devices or innovative trends (Fig. 4).

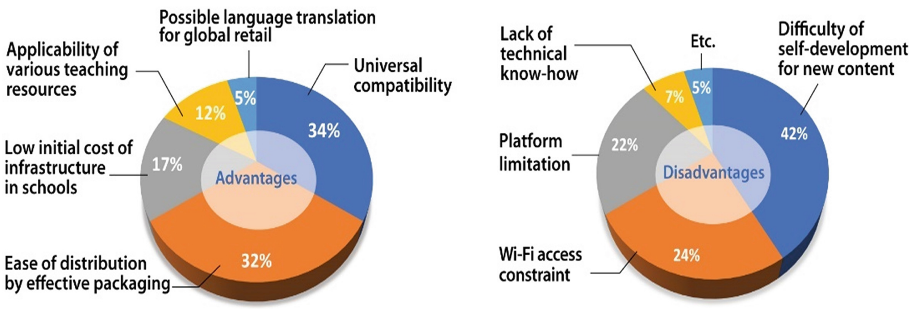


Fig. 4. Advantages and disadvantages of 3D hologram learning kit

5 Discussion and Conclusion

The 3D hologram learning kit is a medium that more effectively enhances interaction between students and teachers for collaborative education compared to traditional 2D textbook learning. Through our intensive research we have designed 3D hologram learning content and created the 3D hologram images based on educational resources in accordance with the national curriculum for fifth and sixth grade elementary school levels. Using iterative prototyping we developed a portable kit, consisting of a reflective mirror, a tablet holder, and a height adjustment stand. After that, we assessed the kit's learning content's user interaction, usability for teachers, and marketability as a school product. Through exploratory tests, we identified the learning kit pros, cons, and needs for improvement. We will also discuss possible improvements for further development in order to enable the learning kit to become a universal teaching resource.

In the first test, we assessed the learning content regarding immersion and social interaction. The results revealed that most of the learning content is well designed in terms of legibility, effective communication, high concentration, encouragement of participation, and collaboration. However, we found some problems with the letter perception, perceptual coupling, and physical focus. Hence, we suggest the following improvements:

- To increase perception of three-dimensional letter, the titles should be limited to five words. Assistive backgrounds will also improve text readability.
- Storytelling through holographic will enhance physical focus and thus attract viewers as well as complement perceptual coupling.

The second test evaluated the physical learning kit from the perspectives of tangible interaction and convenience of educators' usability. Observational research revealed mostly high scores about almost all sub-factors such as haptic direct manipulation, lower thresholds of physical interface, precise movement, and portability. However, there was a lack of environmental interaction regarding the spatial feature. Therefore, in order to consider environmental interaction, the kit's inside design should apply the following elements and take into account reactions to the potential surroundings:

- Depending on the brightness of the environment where the hologram is reflected, it is necessary to adjust the light.
- A design solution for the sound system must be able to manage ambient noise.

The third test surveyed 41 EdTech professionals to identify advantages and disadvantages of the 3D hologram learning kit regarding its marketability. They concluded that the kit has strengths for universal compatibility and ease of distribution. However, the main problem related to the expandability of the learning content is that teachers cannot incorporate any of their own new content. Additionally, the experts pointed out the kit's technical limitations, which limit it to Wi-Fi zones only. Moreover, the content only operates through downloading the application. The following solutions will resolve these problems:

- Through technical developments, customized app functions should make it easy for educators to include their own content.
- In addition to connecting the tablet to a mobile phone via a Wi-Fi connection, Bluetooth access should be added for more than one device.
- Establishing open source systems will allow users to download new content from online web sites without application accounts.

In conclusion, this study conducted several tests for the initial development of new ideas for a 3D hologram learning kit. Moreover, we defined the above problems and suggested enhancements. Continuing improvements will help the kit become a more reliable educational tool for students and educators. At the same time, we defined the kit's various strengths and potentials. Below, we will discuss how the kit has expansive possibilities for the future.

As a new medium, a 3D textbook in forward-looking education, the concept of the learning kit can be applied to a variety of basic subjects beyond science education. Furthermore, STEM based convergence education of national curriculum subjects like technology, mathematics, engineering, and art can also be accessed through similar 3D hologram kits. At the same time, these kits can be used as collaborative educational tools for different institutions; not only elementary education but also higher levels such as middle school, high school, and university will benefit greatly. Furthermore, it is possible to expand this concept beyond educational institutions and include industrial organizations and company education programs by displaying stereoscopic 3D content in the medical, architectural, and engineering fields.

As mentioned previously and as a result of this study, the kit will become useful global teaching material due to its translatability and easily distributed portable packaging. We ultimately intend that the kit lead to great social impact that provides interactive experiences for teachers and students as well as enhances cooperative teamwork and collaboration through enthusiastic participation.

References

BBC News: Meet the hologram teacher (2000). http://news.bbc.co.uk/2/hi/in_depth/education/2000/bett2000/600667.stm

Gabor, D.: A new microscopic principle. Nature **161**, 777–778 (1948)

Ghuloum, H.: 3D hologram technology in learning environment. In: Proceedings of Informing Science & IT Education Conference 2010, pp. 693–704 (2010)

Harrison, D.: Real-Life teaching in a virtual world. Campus Technology (2009). https://campustechnology.com/Articles/2009/02/18/Real-Life-Teaching-in-a-Virtual-World.aspx

Kantosalo, A., Toivanen, J.M., Toivonen, H.: Interaction evaluation for human-computer co-creativity: a case study. In: ICCC, pp. 276–283 (2015)

KERIS: Workshop sourcebook of research school for smart education. Education and Research Information Service (2012)

Kim, Y., Lee, J.: A study on product design process for innovation based on iterative agile prototyping. J. Ind. Des. **13**(2), 61–71 (2019)

Korean Ministry of Education: National Science Curriculum, Korean Ministry of Education No. 2018-74, pp. 211–212 (2018)

Microsoft: Using holograms to train nurses: Pearson and Microsoft launch mixed-reality curriculum (2018). https://news.microsoft.com/en-gb/2018/01/22/using-holograms-train-nurses-pearson-microsoft-launch-mixed-reality-curriculum/

Tim, C.: The durability of consumer durables. Bus. Strategy Environ. **3**(1), 23–30 (1994)

Waller, A., Black, R., O'Mara, D.A., Pain, H., Ritchie, G., Manurung, R.: Evaluating the standup pun generating software with children with cerebral palsy. ACM Trans. Access. Comput. **1**(3), 16–27 (2009)

Wickens, C.D., et al.: An introduction to human factors engineering, p. 295 (1998)