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Design Based System Research of an Online Platform Prototype to Foster Higher-Order Questioning

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Abstract. The process of questioning is more important than that of answering, and the way how learners ask questions is a major factor that determines the depth of their answers. To develop a higher level of thinking, learners need to expand their thinking by practicing to ask higher-order questions, rather than lower-order ones. Because higher-order questions tend to promote critical thinking skills and encourage learners to use their creativity and logical reasoning. To this end, the study aims to identify strategies for higher-order questions and design a prototype to develop an online questioning platform to guide and train higher-order questioning skills. This platform is designed to support scaffolding, with a purpose of fostering learners' higher-order questioning skills. A Design-Based Research (DBR) method was adopted that consists of a formative cyclical procedure including analysis, design development, and execution evaluation. To further identify the higher-order questioning strategies from the teachers and experts, an application named Kakao Oven was implemented to develop an online questioning platform prototype that includes these newly deduced functions. The result of DBR and the prototypes identified higher-order questioning activities, functions, and scaffolding strategies applicable for future online questioning platforms.

Keywords: Higher order questioning, online question platform, scaffolding, prototyping.

1. Introduction

Higher-order questions are advanced cognitive demands on students beyond simply recalling or reading given information from texts. Hence, higher-order questions could lead students to higher cognitive thinking above literal questions. In particular, because higher-order questions appeared to promote learners' critical thinking skills (Appelbaum, 2000), this type of question is more often required in the fast-changing modern society. From this perspective, 'questioning' is proposed as an essential survival skill for self-directed learners who are flexible, creative, and endlessly adapting to changes in the evolving workplaces (Berger, 2014). However, according to the report of Right Question Institute using data from the 2009 U.S. 'National Report Card', not only does questioning fall off a cliff, even as children's use of reading and writing skill steadily climbs through the school years, children simultaneously become less engaged in questioning activities in schools (Berger, 2014). The goal of schooling has been defined as enabling learners to have more right answers than the others, and students become penalized for their incorrect answers.

Mobile technologies have been widely implemented to provide high quality learning opportunities to young learners even in places where educational resources are scarce, such as poor and remote communities. In order to activate students' question activities in classrooms, since 2002, question platform researches applying inquiry-based learning pedagogy to technology such as Question-Posing and Peer Assessment (QPPA), Piazza, and Peerwise, Stanford Mobile Inquiry-based Learning Environment (SMILE) have been researched (Yu, Liu, & Chan, 2005). As research on online questioning platform is becoming more active, researchers were interested in the depth and level of questions that occurred on the platforms. The students appeared to have difficulty to create good questions and many questions were on the lowest level according to Bloom's taxonomy (Bloom, 1956). Also, the level of questions in the usual platforms were low and most of them are mainly multiple-choice question function, which is for simply peer assessment or finding right answer (Kim & An, 2016).

Also, researchers working on the question platforms found that the functions helping students move progressively toward understanding and learning of the higher order question in online platform are not well embodied in the question platforms (Kim & An, 2016). Such scaffolding strategies in computer-based learning environments have been researched, and numerous tools have been developed to support teachers' role to support students' critical thinking (Weinstein & Preiss, 2017). However, the researches on enhancing learners' critical thinking ability using online question platforms have been insufficient (Bradley, Thom, Hayes, & Hay, 2008). Scaffolding students to generate high quality questions requires clear and persistent guidance, modeling, sample questions, evaluation rubrics, and ample practice opportunities (Kim & An, 2016).

Hence, the current study found needs for a question platform that scaffolds learners' higher-order questioning skills. This study aims to design a prototype of an online questioning platform that provides a scaffolding to foster learners' higher-order questioning skills. The research questions are as follows: What are the limitation of current online questioning platforms? What are the core functions of an online questioning platform and what functions can be embodied in a prototype? How can these core functions for higher-order questioning strategies be implemented on an online platform to scaffold and to attain higher-order questioning skills?

2. The Concept and analysis of theory for higher-order question platform

Higher-order questions

Higher-order questions (HOQs) are those that students would not be able to answer by recalling memories or directly reading texts (Khan & Inamullah, 2011). Rather, they require students' advanced cognitive demands and encourage them to critically think beyond literal questions. On the other hand, lower-order questions (LOQs) are those which require students to remember, reiterate, or find information that is within texts. Various definitions of HOQs proposed some common characteristics. The American psychologist Benjamin Bloom (1956) defined HOQ as the ability to break down material into its component parts so that the relationships between parts can be analyzed and the underlying organizational principles are recognized. The question that is used to create new information, the question that expects students to turn a question around and look for opposite ideas, the question that helps thinking that compares the unrelated.

Revised Bloom's taxonomy (1956) suggested that the cognitive process dimension represents a continuum of increasing cognitive complexity—from remember to create. They defined higher order question as a cognitive process which requires higher levels of inferences, analysis, evaluation and creation. In the revised taxonomy, they called a higher order question (Levels III to VI) the question that triggers creative thinking and action and the question that promotes exploratory behaviour by placing creativity at the highest level of the taxonomy. Also it would develop students' critical thinking and expand to problem-solving skills

Critical thinking

Critical thinking refers to reflective and reasonable thinking that focuses on deciding what to believe or do (Ennis, 1985). Its examples include Socratic questioning and havruta learning, which have been studied for decades and are well recognized as good questioning methods. It is an unchanging reality that questioning is an important factor that can promote learners' critical thinking skills (Yu et al., 2005). Socratic questioning, known as a form of active learning pedagogy, allows the learner to develop higher order thinking skills such as analysis, synthesis, evaluation, and

problem solving (Neena, 2009). Critical thinking is also widely recognized as one of the essential skills and as one of the 4Cs for the 21st century skills; the other three are creativity, communication, and collaboration (Rotherham & Willingham, 2010). Bloom's Taxonomy of Learning Objectives arranges a wide array of skills which can be used to teach critical thinking Anderson, Krathwohl, Airasian, Cruikshank, Mayer, Pintrich, Raths, & Wittrock, 2001). The taxonomy provides a six-leveled classification system aimed at standardizing learning goals and engaging students in high order thinking processes that progresses from a lower to a higher level. This classification infers that questions from Levels I and II are LOQs since they rely on simple recall or memorization of information. On the other hand, questions from Levels III, IV, V, and VI are considered HOQs since they include elements of critical thinking. Thus, in this study, questions from Levels III, IV, V, and VI are regarded as HOQs.

Online questioning platforms

Researchers examining a diverse way of scaffolding have emerged in scaffolding student learning on questioning platforms. For example, by helping students rate each other's questions, Kim & An (2016) made a star rating function as a way of scaffolding and suggested a prompter feature (one that enables organizers to assign a list of key phrases or words to be incorporated in questions) as a scaffolding tool for helping students create questions that trigger divergent thinking. Ferreira (2017) developed a game named Puzzle Model that is based on the Bloom's taxonomy and encompasses question starters designed as puzzle pieces from which students need to form the beginning of questions and complete them with their own words. Yu, Liu & Chan (2005) used 10 question stems (e.g. what, why, how questions) and sample questions that are useful to students when they create questions themselves. Having decided which item to assess (from the list of questions in the peer assessment window) and reviewed the information related to the item, assessors can give their feedback using an online assessment form. Kim & Hannafin (2011) used peer assessment feedback to enhance learning by critically evaluating others' works.

Eight web-platforms that are web-based learning systems to facilitate questioning skills were analyzed. The researchers had used platforms in practice, analyzed relevant literatures about each platform, then had the findings reviewed by experts. The result of analysis is as shown in Table 1. Although online questioning platforms with scaffolding have been developed to enhance learners' critical thinking ability, the research of modeling, evaluating, and embodied functions about higher order questioning have not been fully investigated. Therefore, the purpose of this article is to design a prototype of an online questioning platform that support scaffolding (tools) for learners to practice creating HOQs.

- SMILE (Stanford Mobile Inquiry-based Learning Environment) is a learning management system developed to promote critical thinking and higher-order learning skills. It has activities involving generation, evaluation, presentation, and reflection of student-generated questions (https://smile.stanford.edu).
- PeerWise, an online platform, is designed to help students perform better in examinations that they can create multiple choice questions, and answer questions created by their peers (https://peerwise.cs.auckland.ac.nz).
- Quora, a Q&A platform, allows gaining and sharing knowledge. It's a platform to ask questions and connect with people who contribute unique insights and quality answers (https://www.quora.com).
- Piazza is an online platform, to ask, answer, and explore under the guidance of their instructors. It emphasizes on seeking help from peers, collaborative thinking, and the formation of a community having similar information needs (https://piazza.com).
- Socrative, Interactive Q&A platform, allow students to cognitively process questions asked by the teacher to increase participation. Socrative is developed to increase the degree of collaboration learning gained by the students during the learning process and enhances student overall performance (https://www.socrative.com).
- Kahoot, Q&A Platform, aims to promote students' sensory curiosity through surface-level gamification features (e.g. suspenseful music and color displays), and their cognitive curiosity also creates a fun and competitive environment that promotes learning (https://kahoot.it).
- Slido, a Q&A and polling platform, using live polls or quizzes to check, aims to help students to remove fear of asking questions in front of the class. It allows quick polling and summarizes results for classes, meetings and events (https://www.sli.do).
- Brainly, is a student-teacher community-based social learning Q&A platform. Students can ask and get help to solve homework problems, and are encouraged to engage in the community to ask and answer questions from others (https://brainly.in).

These are a few online questioning platforms, and they offer limited functions and levels of questioning skills. Some researches exist and relevant tools were developed to help enhance learners' critical thinking and questioning skills. However, modeling, evaluating, and embodied HOQs functions have not been fully investigated. The purpose of this article is to identify HOQs strategies to entail in a prototype of an online platform to scaffold critical thinking and HOQs skills.

Scaffolding

Zone of Proximal Development (ZPD) has been described as a zone where one is helped to learn with someone before one can perform individually (Vygotsky, 1962). Vygotsky suggested scaffolding in his theory that children learn more effectively when they have others to support them. Scaffolding is an assisted learning process in a ZPD learning environment to reach the next level of understanding.

It draws upon the assistance of teachers, peers, or other adults. Social constructivism insists that the teacher's role is that of a facilitator and guide, and not of a director or dictator. Besides, students are encouraged by their teachers or colleagues to organize their learning in a cooperative and active manner through interactions.

In traditional classroom settings, scaffolding used to take shape as an instructor alone interacting with either a small group or an individual. In modern teaching-learning settings that use the Web, scaffolding takes a different form, and its meaning has changed. Software tools have become a way of supporting learners (Kim & An, 2016).

The strength of software scaffolding in this instance lies in its ability to support multiple students and promote self-reliant learning that engages with a variety of representations of the problem and reinforces task procedures at a higher level of thinking (Kim & Hannfin, 2011).

Table 1. Analysis of questioning platforms and scaffolding types

Function / Platform	Group Discussion	Peer rating	Question level rubric	Question level sample	Thinking step by step	Finding Trigger point	Checklist	Project connection
SMILE	0	0	0	0	0	·	·	·
PeerWise	·	0	·	·	·	·	·	·
Quora	·	0	·	·	·	·	·	·
Piazza	·	0	·	·	·	·	·	·
Socrative	·	·	·	·	·	·	·	·
Kahoot	·	·	·	·	·	·	·	·
Slido	·	·	·	·	·	·	·	·
Brainly	·	0	·	·	·	·	·	·
Prototype Result (4th stage)	(6)		(1)		(3)	(4)	(5)	(2)
Scaffolding Type	Collaboration & Discussion [20] Peer feedback [9]		Examples offering [6]		Engagement in ongoing assessment [6] Question prompts [5]	Question prompts [5]	Conceptual scaffold	Maintenance of learning goals [6]

Several researches, with students of different ages, have indicated the positive effects of software scaffolding on students' learning. For example, student groups in the experimental condition, who received regulatory online support tools such as hints, goal hierarchies and refusing facilities, enhanced learning better than those in the control condition, who were given a non-supported version. Similarly, a study in

which 9th graders participated in an e-learning math class environment showed that those who received a scaffolding tool based on a 'self-metacognitive question' and enhancing regulation and metacognition to solve transfer problems and mathematical explication, performed better on problem-solving procedural and transfer tasks of mathematical explanations when compared to the students in the control group.

Research examining the diverse way of scaffolding have emerged in scaffolding student learning on questioning platforms. For example, there was a star rating function by helping students rate each other's questions . There was a game named Puzzle Model that is based on the Bloom's taxonomy and encompasses question starters designed as puzzle pieces from which students need to form the beginning of questions and complete them with their own words (Ferreira, 2017). There was a prompter feature (one that enables organizers to assign a list of key phrases or words to be incorporated in questions) as a scaffolding tool for helping students create questions that trigger divergent thinking (Kim & An, 2016). There were 10 question stem features (e.g. what, why, how questions) and sample questions that are useful to students when they create questions themselves. Also, there was a functions to a peer assessment feedback to enhance learning by critically evaluating others' works (Yu et al., 2005).

3. Methods

Design-based Research

Design-based Research (DBR) is a general research design framework which provides a guidance for developing a platform in accordance with the aspects of the designed contexts (Collins, Joseph, & Bielaczyc, 2004). The DBR has been applied to designing and building a prototype of an online learning system. For example, DBR has been applied to develop educational games with PowerPoint (Siko & Barbour, 2016). DBR has been also employed to develop a gamification-based online business education platform where the authors had designed 17 game elements, and investigated in what manners do these elements motivated student learning (Chapman & Rich, 2015).

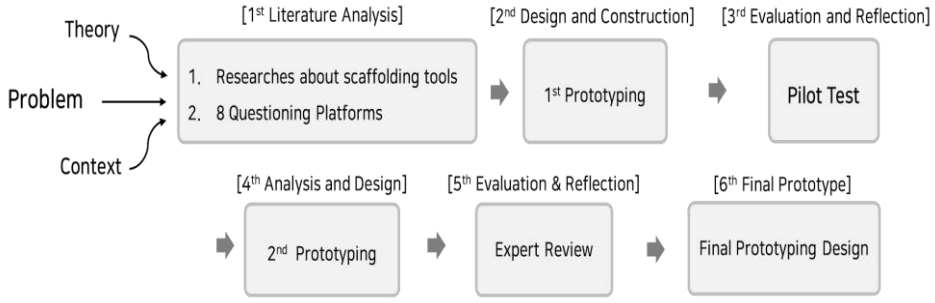

Fig. 1: The iterative process of DBR (Siko & Barbour, 2016)

The DBR consists of three core steps in an iterative process including analysis and exploration, design and construction, and evaluation and reflection (McKenney & Reeves, 2013). This study used Siko and Barbour's process (2016) as shown in Figure 1.

Prototyping Tools and Design

SMILE (Stanford Mobile Inquiry-based Learning Environment) was utilized in two pilot studies as a tool of questioning activity platform. It used for collecting the opinions about the core functions that online questioning platform should entail for helping to learn higher-order questioning skills in two pilot studies. SMILE is a worldwide used mobile educational platform designed by Stanford University to promote higher-order learning via a mobile inquiry-based model of peer collaboration. The SMILE server software is designed to create a highly interactive learning environment that promotes critical thinking opportunities (e.g., creation of inquiries, presentation of questions, analysis of peer-generated questions, evaluation of individual participants and overall inquiry exchange process, etc.). The SMILE also engages participants in inquiry-based learning sessions and generates transparent real-time analytics (Kim & Hannafin, 2011).

Kakao Oven(https://ovenapp.io) was used for building the final HOQs online platform prototype. Kakao Oven is an online based application and PC version UX/UI prototyping tool. It is easy to design a Web and application using Kakao oven, so it can be used for explaining how a Web or application is going to be designed and worked.

Participants for Two Pilot Studies

Two pilot studies, using SMILE, were conducted from September to December, 2018. The participants were sufficiently informed about the study's purpose, and were allowed to choose either anonymous user name or their real name in the platform. first pilot study was conducted with a student group to collect feedback from learners' perspectives regarding a series of technology-implemented questioning activities in which they participated. The student group consisted of thirty Sophomores and Juniors, and equal number of male-to-female students participated.

A second pilot study was conducted with a teacher group of fifteen science teachers from a junior high school. Teachers showing interests in how questioning can be used in science textbooks were recruited, and pilot studies were conducted with teachers who are knowledgeable in online learning environments. That is because those with a high level of understanding about online questioning platforms would be able to provide accurate and adequate feedback regarding their experience. After the pilot studies, teachers provided feedback on instructor' perspectives regarding a series of teaching with technology-implemented questioning activities.

4. Results

Stage One: Literature Analysis

The eight of the popular questioning platforms that have been used in the educational field were analyzed in this study. Each of the eight questioning platforms was compared to identify what kinds of scaffolding functions they have. The scaffolding functions can be identified as having group discussion, peer rating, question level rubric, question level sample, thinking step by step, finding trigger point, checklist, and project connection as shown in Table I. The scaffolding types that support literature review of scaffolding functions are summarized in Table I as well.

Stage Two: Design and Construction (1st Prototype)

The two pilot studies used SMILE to identify the key features for scaffolding in the questioning platform. The pilot studies have four activities including (1) creating level five questions, (2) rating the quality of other questions, (3) discussing the reason for the rating, and (4) creating 'what if' questions. The detailed finding by performing the four activities were addressed in the Stage Three. Overall, it is suggested that the questioning platform should have the scaffolding functions with more targeted for generating higher-order questions.

Stage Three: Evaluation and Reflection

The stage three is an evaluation and reflection section in DBR. A structured interview was conducted with three main topics: (1) what aspects of functions in SMILE should be improved to facilitate the high order questioning and (2) what functions or materials do they need to be added to guarantee the learners' optimal use and improve HOQs? The finding from the structured interviews were reflected in the stage four.

Stage Four: Analysis and Design

In this Stage, the findings of literature analysis and the pilot studies were organized into the following six functions: (1) show star metric, (2) add a "what-if" section, (3) include questioning steps, (4) add thinking triggering, (5) show HOQ checklist, and (6) add peer feedback. These six functions were embodied to the final HOQ platform using the Kakao Oven UX/UI prototyping tool. The detailed explanation about the function consists of the following:

(1) A function of "Show Question Level Rubric"

This function is designed for helping learners who have difficulty creating a question based on standard criterion. The function provides information of sample questions and the rubric of the question levels. The rubric of the questions levels was generated based on the concepts of Bloom's taxonomy, which consists of five different levels of questioning (Anderson et al., 2001). As shown in Fig. 2 and Fig. 3, the "Show star metric" button provides sample questions in terms of each different

levels and the "Star attribute" button offers information about the rubric in terms of different levels as shown in Fig. 3.

(2) A function of "What if" section

A function of "What if" allows learner to create an open-ended question, with no right or wrong answers. It allows learners to think of innovative ideas without limitations, constraints, or igniting their imagination of various possibilities. The "What if" question is a type of higher order questions and can vastly encourage the exploration of limitless possibilities (Berger, 2014; Bloom, 1956). As shown in Fig. 4, when the "What if" menu is clicked, a navigation bar also shows a writing box to input the reason.

In addition, the learners are able to choose one of the purposes about their "What If" questions. In order to activate a 'what if' community, according to the purpose of "What If" questions, the system gives a recommended alarm by sending Notifications for gathering "What If" community in Fig. 6. If the "What If" question is posted for finding someone to do the "What If" project together, the system automatically introduce the "What If" question to other learners, so that they can attend the project together.

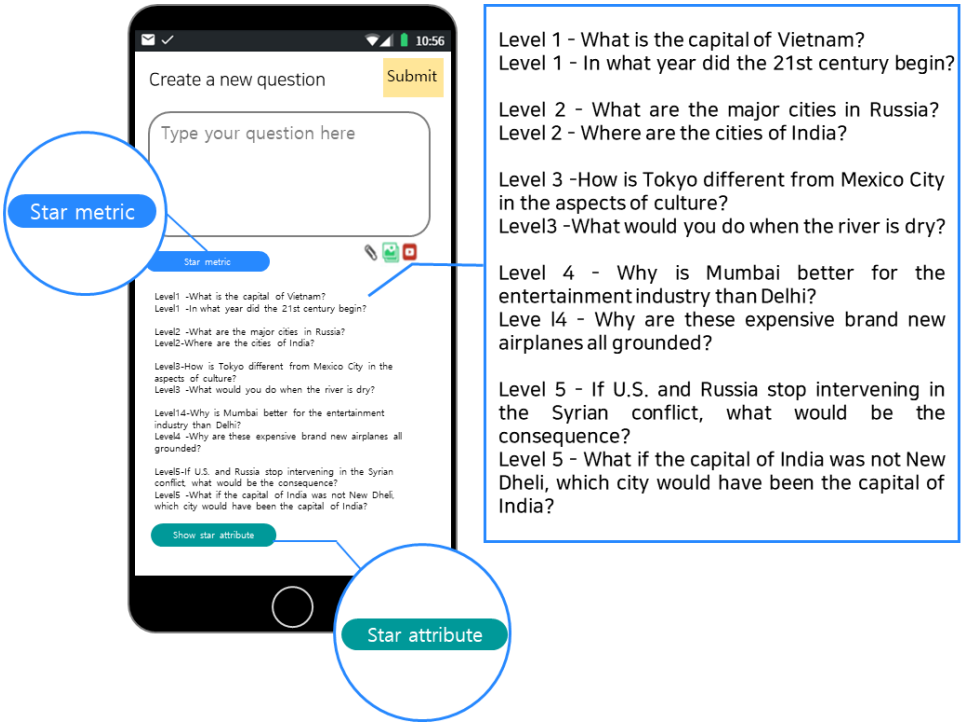

Fig. 2: A function of star metric

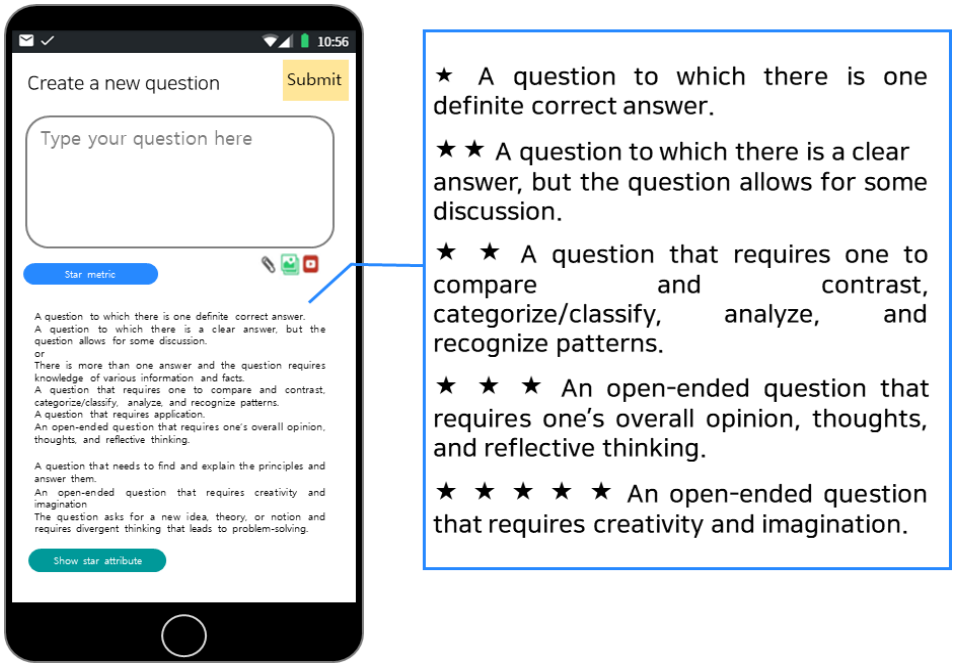

Fig.3: A function of star attribute

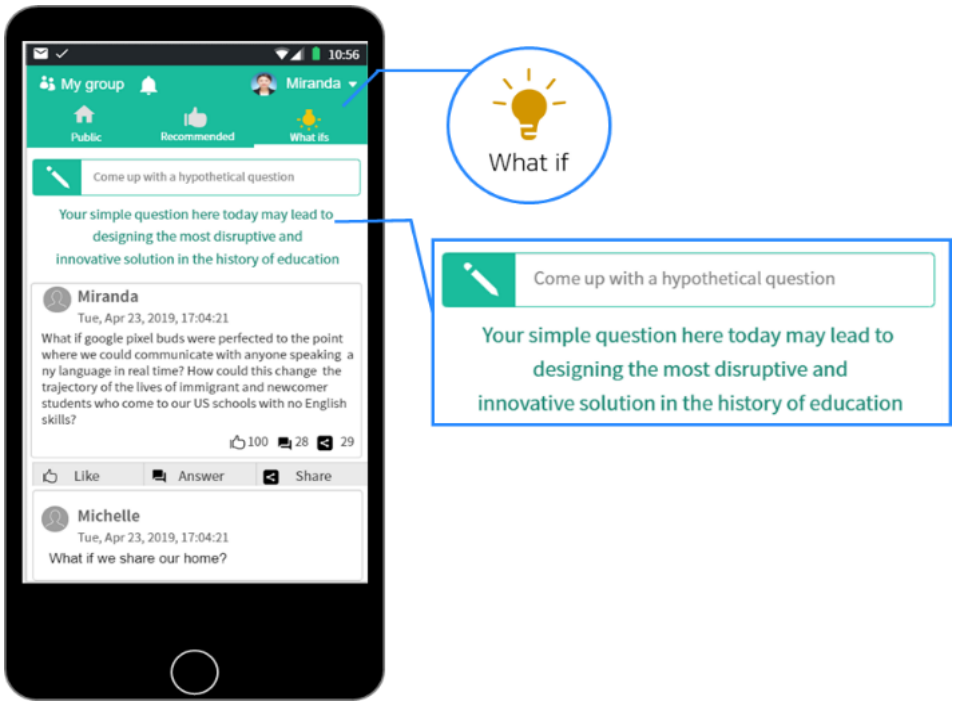

Fig.4: A function of 'what if' on the navigation bar

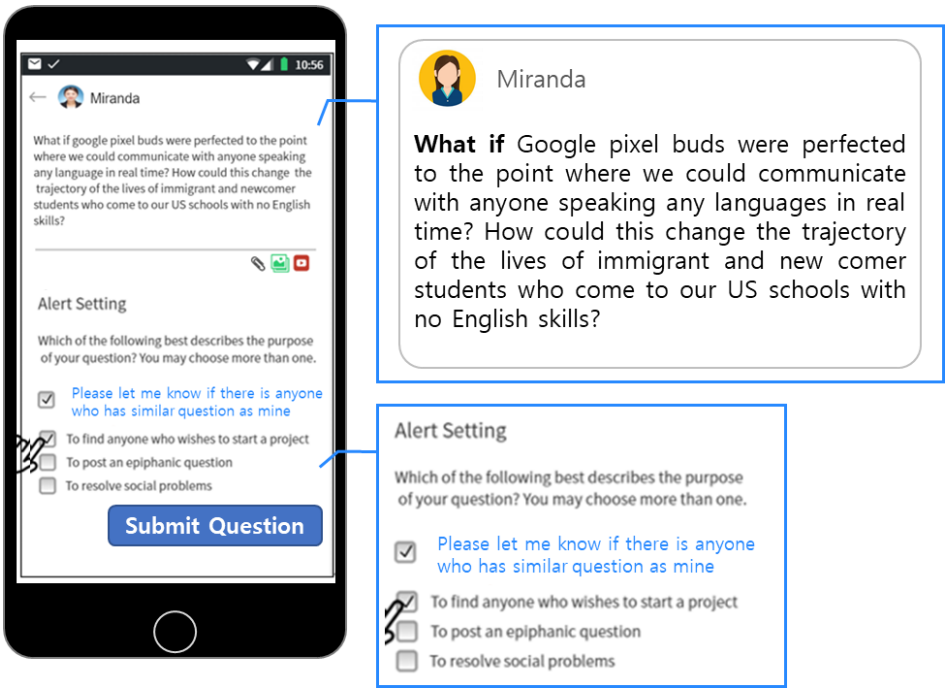

Fig. 5: Setting for the purpose of "what if" question

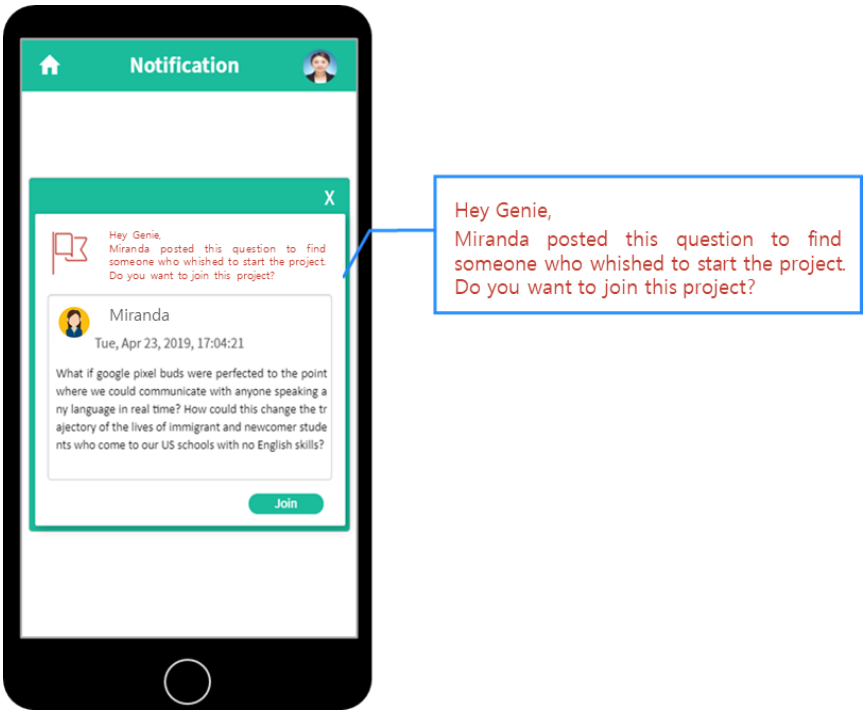

Fig. 6 A function of Notification of a new project

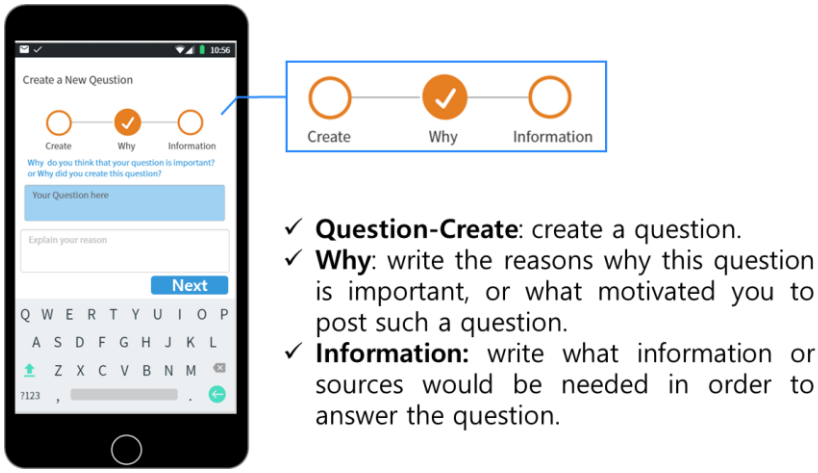

Fig. 7: A function of questioning 3 steps (Create – Why - Information)

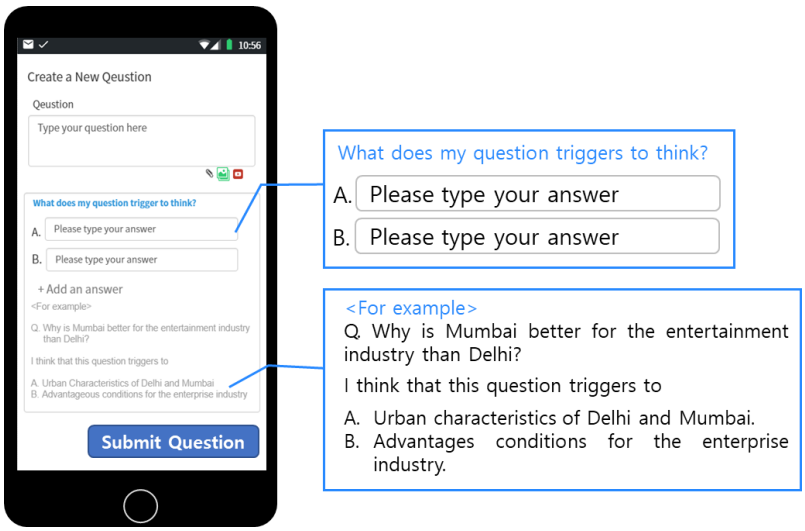

Fig. 8: A function of "Triggering" the question 'What does my question trigger you to think'

(3) A function of 'Questioning Steps'

The questioning scaffolding function was embodied to the HOQ platform with three-step activities including (1) create a question, (2) why, and (3) information in Fig. 7. The questioning scaffolding function is fundamentally grounded on the concepts of Socratic questioning. Socratic questioning stimulates students to be thinking, evaluating, and analyzing their ideas by two types of questioning. The first one is 'Questions about an initial question or issue'. For example, "Why is this question important"? Another type is 'Reason and evidence questions.' For example, "What other information do we need"? Therefore, the three-step activities in the

system can help learners continuously think of their own answers to the questions they created.

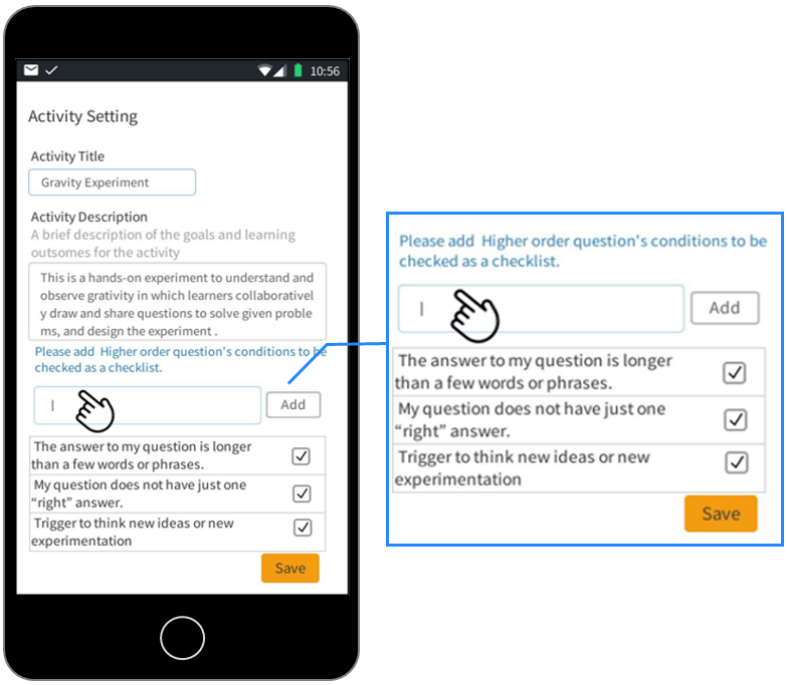

Fig. 9: A function of the "Add HOQs Checklist"

(4) A function of "Thinking Triggering"

A function of "Thinking Triggering" is also used in Socratic questioning strategies. As shown in Fig. 8, learners check what their question makes other peers think when they answer the question. As learners have opportunities to reflect on their question, they can once more examine whether it is a lower-order question that triggers them to memorize information, or one that requires a definite correct answer. The 'thinking-triggering' function enables learners to make effort to avoid creating lower-order questions and enhance their question levels.

(5) A function of "HOQs Checklist"

The checklist was embodied in the HOQ platform as a reference to create higher-order questions (Fig. 9). The checklist includes the characteristics of HOQs (Anderson et al., 2001). In addition, teachers also can set and add HOQs checklists based on what they think to be included.

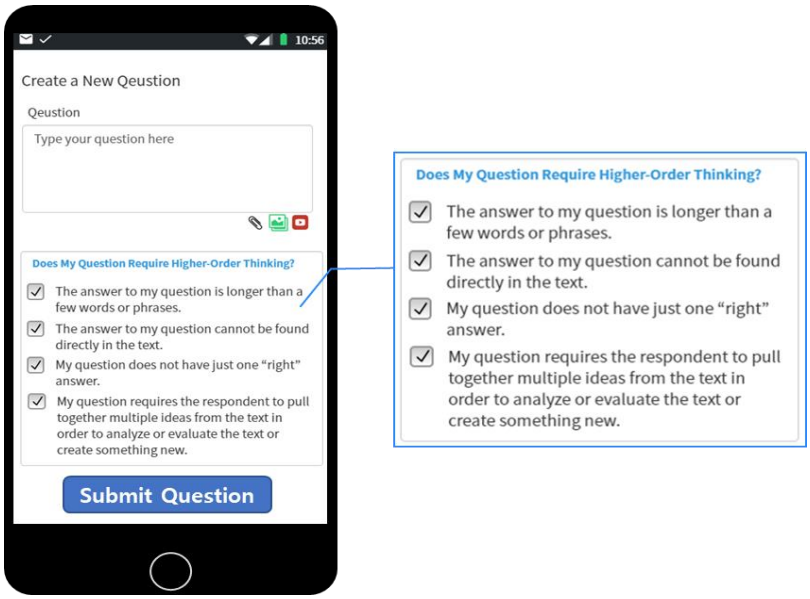

Fig. 10: A function of the "HOQs Checklist" activity

(6) A Function of "Rating" with stars

Peer feedback intends to enhance learning via critically evaluating others' works and synthesizing comments given by their peers (Yu et al., 2005). A peer feedback session serves as a scaffolding for collaboration and mutual learning among learners(Hansen & Liu, 2005). Peers select another user's question from the question list. After learners rate other learners' questions on a five-point scale ranging from ★ (not good) to ★★★★★(excellent), they can type in a detailed opinion to refine their feedback as in Fig. 11. This activity can help learners learn to be critically think about the type of questions. It can moreover help them learn to scaffold not only their own questioning skills but also their peers to develop HOQs skills.

Stage Five: Evaluation & Reflection from Experts

The reviews from eight experts about the final prototype of the HOQ were collected and summarized in the Stage Five. The eight experts who have knowledge and experiences about scaffolding at an online questioning platform and development of the related application were recruited. Reporting displays the levels of change in questioning skill, number of questions and answers that a learner has performed.

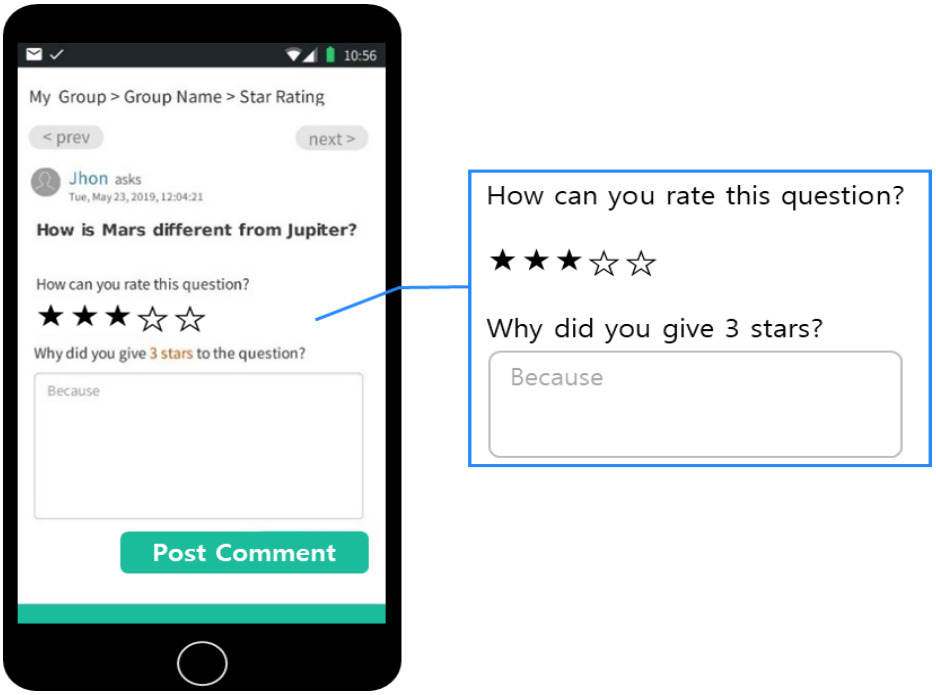

Fig. 11: A function of "Rating" with stars

It shows an average level of questioning skill as well, so that learners are able to compare their skills with others'.

Stage Six: Final prototyping design

The final HOQ prototype was created by adding the functions in Table II. These functions are (1) showing sample questions and rubric in terms of levels, (2) a part for "What If" question, (3) questioning step activities, (4) triggering function for thinking about question, (5) a checklist for HOQs, (6) Peer Feedback, and lastly from the expert suggestions, (7) Reporting. The detailed explanation about each function is provided in the above section. Table II displays the figures corresponding the functions.

5. Conclusion

The present study investigated the importance of higher-order questions. Because questioning skill is not considered as innate, learners need to obtain it through training. The skill of asking questions can be improved by intensely practicing through modeling and coaching.

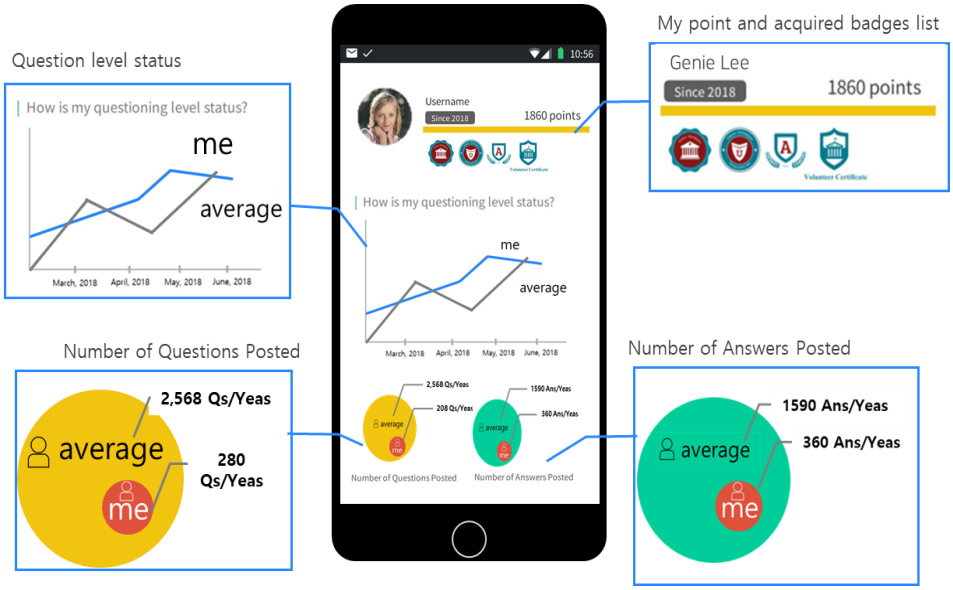

Fig. 12: Reporting

Table 2. Summary of HOQs scaffolding functions

Figure No.	Function
2,3	Show Question Level Rubric
4,5,6,	What if corner
7	Questioning Steps
8	Thinking Triggering
9,10	HOQs Checklist
11	Peer Feedback
12	Reporting

The study proposed an online questioning platform that consists of various functions designed to help learners to continuously practice generating higher-order questions. Utilizing the functions proposed in the study, learners could recognize that there are different levels of questions and they were able to cogitate about better questions, rather than simple ones that have no particular purposes. A deeper learning could occur through a process in which learners profoundly think why their questions are important and answer them, rather than immediately ending after simply posting questions. The scaffoldings that have been provided from this study's platform did

not only have learners generate questions that foster rote memorization or simple recalls. Instead, the functions played a role of helping learners to develop their critical thinking skills by consistently having them ask and answer questions such as whether what they observe are factual, whether there could be other intensions, and whether another means could exist. One notable limitation of the study is that the suggested platform was executed by implementing the UI prototyping tool, instead of using a real application that is developed by text-coding. This could have presented inadequate functions of the platform.

Scaffolding functions appeared to trigger learners to imagine a hypothetical situation and to generate questions that have not been introduced in the world, rather than having them ask questions that have fixed and definite answers. The functions can result in learners' design thinking skills that could generate creative outcomes. Researchers interested in the relevant theme are encouraged to investigate learning environments in which students continue creative thinking processes on platforms, and to further explore question analysis and scaffolding functions through artificial intelligence natural language processing.

Consequently, the functions provided learners with opportunities to challenge themselves without hesitation to new situations and topics. These also can help learners to attain new perspectives, and to become self-directed learners. Additionally, from the perspective of metacognition – one's ability to correctly acknowledge his or her own cognitive process and awareness – the study proposes an important implication. Namely, the scaffolding functions could help the learners result in higher levels of metacognition by having them examine the correctness and preciseness of their own questions as well as critical thinking.

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