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EduQuestioning mobile learning application: a catalyst for developing HOTS-based assessment questions referring to Revised Bloom's Taxonomy

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Abstract

Mobile learning application for assisting teachers or preservice teachers to develop questions based on higher-order thinking skills had not been widely invented. Thus, this study aimed to develop EduQuestioning mobile learning application that could help teachers or teacher candidates create assessment questions based on higher-order thinking skills (HOTS). The present study used research and development design by involving developmental stages of analysis, design, development, implementation, and evaluation (ADDIE). This study involved qualitative and quantitative data. There were eight lecturers and sixty-one preservice teachers majoring in mathematics, natural science, social science, and Indonesian language education involved as the participants. They were chosen using inclusion criteria such as being involved in assessment course. Data were collected using forum group discussion, student-needs analysis questionnaire, Aiken and Expanded Gregorian Index content validity sheet, face validity sheet, and structured response questionnaire. The obtained qualitative data were analyzed using Miles and Huberman's theory and the quantitative data were analyzed using descriptive statistics and Swanson's quartile categorization. Results showed that EduQuestioning mobile learning application could be developed through ADDIE stages with a very high content and face validity. In addition, the participants gave positive response on the use of EduQuestioning with $M\% > 75\%$ and $Q = 4$. This study suggested that EduQuestioning mobile learning application could be accessed freely and used to train developing HOTS-based learning assessment questions.

Keywords: HOTS-based questions, Learning assessment, Mobile learning, Revised Bloom's Taxonomy

Introduction

The importance of implementing Higher-Order Thinking Skills (HOTS) in the Society 5.0 era is highly emphasized in education (Mytra et al., 2021). In this era, people are mandatory to be able to overcome various challenges and social problems by utilizing information and communication technology to the fullest (Spiteri & Chang Rundgren, 2020). In the context of education, the implementation of HOTS, a thought process that involves analyzing, synthesizing, and evaluating information systematically and critically to achieve deeper and broader knowledge (Mytra et al., 2021), is considered an important step to prepare students to face the demands of the Society 5.0 era, which requires higher-level thinking skills such as structured and complex thinking (Wibawa & Agustina, 2019). This is absolutely in accordance with the implementation of Merdeka Curriculum in Indonesia that accentuates the importance of developing innovative models in education (Lestari et al., 2023). Given the importance of HOTS in the era of Society 5.0, further, teachers are expected to master HOTS in order to guide and assist their students in resolving complex problems and becoming problem solvers for themselves and others (Fakhomah & Utami, 2019). Teachers who perceive HOTS can also improve their students' ability to think critically, not only in a small scope but also in social life and the surrounding environment (Tyas et al., 2019). Thus, teachers who master HOTS are considered key in preparing the younger generation to face the challenges and changes that occur in the Society 5.0 era.

Consequently, the habituation of HOTS practices and exposures for preservice teachers is very vital as they become the agents of guiding, assisting, and leading students' critical thinking skills. During the teacher training process, preservice teachers should be facilitated by numbers of supporting HOTS-based learning media for upgrading their perceived critical thinking skills (Artika & Nurmaliah, 2023). In the case of Indonesian preservice teachers, exposures and guidance to practicing HOTS is necessary as these teachers had almost circular rhetoric system (Pratama, 2018). For those in circular rhetoric, it is absolutely difficult to actualize HOTS and straight-forward thinking deliveries since HOTS is majorly interconnected with those in English culture (Kaplan, 2005; Pratama, 2018). To provide HOTS-based practices, atmosphere, and exposures, university or relevant higher educational institutions should understand these needs and involve every educational event or agenda with more critical thinking skills. The institutions could provide relevant learning media that could be used inside or outside classroom activities to practice HOTS.

Furthermore, preservice teachers should not only master HOTS for themselves but also give assistance for their future students to master the skills (Setyarini et al., 2023). This could be achieved by, first, habituating students with case-based learning (Nkhoma et al., 2017; Wikanta & Susilo, 2022), inquiry learning (Mubarok et al., 2019), project-based learning (Zain et al., 2022), problem-based learning (Hamidah et al., 2023), or discovery learning (Ristanto et al., 2022). The chosen learning models should accommodate the HOTS practice and deliver the materials relevantly. Second, the assessment process should consider the usage of HOTS-based questions, regardless the process and product assessment types (Suwarma & Apriyani, 2022). HOTS-based questions will stimulate the students to recall their memory and use their comprehension in solving problems (Sarah et al., 2022). These typical questions further measures whether students' current education grade is in relevance with the HOTS level they perceive. When there is a problem match between students' current education grade and compulsory HOTS level after the assessment, the teachers might evaluate the materials as well as the HOTS-teaching practices.

In Indonesia, teachers determine HOTS-based question level based on the categorization of thinking skills offered by Revised Bloom's Taxonomy (RBT). RBT includes six levels of thinking levels, following the lowest to highest thinking levels: remember (C1), understand (C2), apply (C3), analyze (C4), evaluate (C5), and create (C6). The levels of C1 to C3 are majorly called as lower thinking skills whereas C4 to C6 are more into higher-order thinking skills (Gopalan & Hashim, 2021). Teachers need to be given sustainable assistance related to the creation of HOTS-based questions by providing space for them to actualize autonomous learning, because after all, understanding the material through one's own way will be more memorable and lasting. One form of support for autonomous learning is the availability of learning media that can be used anywhere easily, such as in the use of mobile learning (MoLearn). MoLearn apps are software designed to be used by learners on devices such as mobile phones or tablets, and created using specialized desktop software (Grant, 2019). MoLearn apps are designed according to the learner's needs, providing high-quality educational content and a versatile platform to keep the learner interested (Curum & Khedo, 2021; Distura, 2023). They are also personalized and adaptable to learners' individual needs and preferences, making learning more inclusive (Rasmitadila et al., 2020). Many studies believed that mobile learning application help promote autonomous learning so the students can be more independent in learning what they need (Jeno et al., 2019; Kacetl & Klímová, 2019; Talan, 2020).

Unfortunately, regarding material and assistance in making HOTS-based questions, to the best of the researchers' knowledge, there is no similar MoLearn yet. Thus, the present study aims to develop HOTS-based mobile learning application for assisting preservice teachers to develop HOTS-based questions for their learning assessment during the real classroom teaching. The application called EduQuestioning is only limited to preservice teachers whose study programs are in Departments of Mathematics, Natural Science, Social Science, and Indonesian. The four study programs are chosen due to the four essential subjects to be taught in Indonesia for the high school levels. Even it is limited to the context of Indonesia and the four subject matters, the developed application can be a reference for preservice teachers with dissimilar subject taught as it consists of the materials of HOTS, how to create HOTS for each C-level, and the examples of various types of HOTS-based questions. This unique and innovative application has been this study's novelty.

Literature review

Teacher questioning

Teachers with strong questioning abilities can boost student participation in the learning process and improve the quality of class discussions. Effective questioning enables teachers to comprehend their students' perspectives and track their learning development. Teachers who are adept at questioning can help students develop critical and analytical thinking abilities (Gunawan et al., 2022). Teachers can use strategic questioning to detect student issues and provide appropriate assistance (Al-Zahrani & Al-Bargi, 2017; Heritage & Heritage, 2013). Those who are good at asking questions can increase communication and interaction with their students (Chin, 2007; Naz et al., 2013). Effective inquiry can help teachers create content that is both relevant and enjoyable. Teachers who are skilled at questioning can improve their teaching and students' learning outcomes. Hamiloğlu and Temiz (2012) found that there is an impact of teacher questioning on students' learning process. This is due to the fact that the questions proposed by teachers encourage the students to think analytically and comprehend the materials better. This finding is supported by Tofade et al. (2013) where question quality for assessment made by teachers could determine the success of student learning process. Thus, teachers are suggested to understand and master questioning skills to support effective learning process.

There are two types of questioning skills regarding the intention of revealing the active participation in learning process namely student-centered and teacher-centered (Oliveira, 2010). Teachers who employ student-centered questions can boost student engagement in the learning process and improve the quality of class interactions (Chin, 2007). Student-centered inquiries, such as "What do you think about..." or "How do you see...", can assist teachers comprehend their students' perspectives and track their learning progress (Kim & Silver, 2021). In contrast, teacher-centered questions like "What do you know about…" or "How can you explain…" may prioritize the teacher's knowledge over student participation (Chin, 2007; Elder & Paul, 1998; Oliveira, 2010). Teachers who employ student-centered questions can help students develop critical and analytical thinking abilities (Oliveira, 2010). They also improve their communication and interaction skills with the students (Chin, 2007). On the other hands, teachers who implement teacher-centered questions can focus on teaching rather than allowing students to actively participate (Oliveira, 2010). Teacher-centered questioning lets teachers keep control of the learning process, ensuring that students receive the knowledge and assistance they require to progress effectively. This strategy also allows teachers to measure their student comprehension and alter their instruction accordingly.

In addition, teacher questioning can be disseminated by the thinking levels, namely higher-order questioning and lower-order questioning (Chin, 2007). First, teachers that employ lower-order questioning can assess their student's capacity to retain and repeat what they have learned. Lower-order questions, such as "What do you know about..." or "Who is...", can help teachers assess student knowledge and identify whether they understand the content being studied (Chin, 2007). Teachers who are adept in using lower-order questions can improve students' capacity to remember and repeat knowledge, as well as the quality of teaching. Second, teachers who utilize higher-order questioning can help students enhance their critical, analytical, and creative thinking skills (Salmon & Barrera, 2021; Sasson et al., 2018). Higher-order questions, such as "How can you explain..." or "What are the implications of...", can assist teachers in fostering higher-order thinking skills in students (Barnett & Francis, 2012). Teachers who are professionals in using higher-order questioning can boost students' ability to discover solutions, make decisions, and think independently (Abosalem, 2016). Many studies have agreed that postulating questions based on higher-order thinking skills (HOTS) should be habituated by teachers to students in order to producing more critical and solutive individuals (Artika & Nurmaliah, 2023; Utaminingsih & Murtono, 2019). The practice of higher-order questioning should be considered important since teachers should be able to measure subject knowledge as well as give their students exposure of analyzing, synthesizing, and evaluating skills (Sagala & Andriani, 2019). Since the sub-skills of HOTS are numerous, many researches propose the difficulty of appropriating HOTS as the seminal research gap (Pratama & Lestari, 2015; Susantini et al., 2022; Syafryadin et al., 2021). Therefore, many educational experts believed that higher-order questioning skills should be mastered by teachers and could be practiced as the classroom assessment questions.

Revised Bloom's Taxonomy: clarifying HOTS levels

Revised Bloom's Taxonomy is an updated version of Bloom's Taxonomy, which classifies learning stages from remembering facts to creating new ideas based on the acquired knowledge. It emphasizes cognitive learning domain (knowledge) (Adijaya et al., 2023; Subiyantoro & Ashari, 2020; Zhao et al., 2022). The revised taxonomy focuses on six levels, namely remember, understand, apply, analyze, evaluate, and create (Krathwohl, 2002). Remember level (C1) retrieves, recalls, or recognizes relevant knowledge from long-term memory, such as recalling the dates of events before Indonesian Independence Day. Understand level (C2) comprehends the meaning of information and concepts including the ability to explain and interpret them. Apply level (C3) uses the knowledge in new situations, demonstrating the ability to carry out tasks or solve problems. Analyze level (C4) breaks material into its constituent parts and determines how the parts relate to one another, such as analyzing the relationship between different characters in a story. Evaluate level (C5) rationalizes based on the educational information and criteria presented, justifying a fictional court ruling or considering the strengths and weaknesses of a particular idea. And, create level (C6) generates new ideas or constructs a new product, such as writing a scientific report.

In addition, C1 to C3 levels are often categorized as lower thinking skills while C4 to C6 levels are included in higher-order thinking skills (Gopalan & Hashim, 2021). Consequently, teachers should understand how to reveal student's each thinking level. One of the assisting techniques in revealing student's thinking levels to disseminate C1 to C6 levels is the usage of particular verbs or gerunds to label categories and sub-categories, emphasizing the importance of action in the learning process (Awiria et al., 2022; Jantaros et al., 2021; Rini et al., 2021; Saptaningrum et al., 2019). Somehow, teachers or preservice teachers are confused in determining the verbs or gerunds used, thus, they get some problems in developing questions that are relevant to certain HOTS levels. To determine the C1 level, the questions can consider the following verbs or gerunds: recall, retrieve, recognize, list, name, identify, reproduce, quote, recite, and memorize. In connection with determining the C2 level, teachers can use these verbs or gerunds: explain, describe, interpret, summarize, classify, compare, differentiate, discuss, distinguish, extend, and predict. The C3 level can be determined by using these verbs: solve, apply, illustrate, modify, use, calculate, change, choose, demonstrate, discover, experiment, relate, show, and sketch. Regarding the C4 level, some verbs can be also used such as analyze, compare, classify, contrast, distinguish, infer, separate, explain, select, categorize, connect, differentiate, divide, order, prioritize, and survey. The C5 level can be determined by using these verbs: evaluate, appraise, judge, support, compare, decide, discriminate, recommend, summarize, assess, choose, convince, defend, estimate, grade, measure, predict, rank, score, select, and test. And, the C6 level can be used by the following verbs: design, compose, generate, plan, produce, invent, develop, formulate, construct, organize, arrange, combine, integrate, reorganize, revise, and rewrite. These verbs are used to describe the activities required for achieving educational objectives and to help learners navigate what they should do to demonstrate their learning outcomes.

Mobile learning for HOTS

Mobile learning applications are in the form of software that allows users to access educational content and tools from anywhere and at any time (Sun & Looi, 2016). These applications often integrate multimedia information, interactive quizzes, and real-time feedback to improve the learning experience and increase engagement. In practical development, mobile learning application developers confront hurdles in combining effective and efficient features to improve learning quality while also overcoming access speed and resource constraints on mobile devices. They also face the problem of creating relevant and compelling information while simultaneously ensuring that programs are accessible to users of varying abilities. This, consequently, creates different models of mobile learning application. For instance, Liu et al. (2021) had analyzed users feedback after utilizing several mobile learning applications in learning science. Most of the reviews depicted that some applications confront the issues of irrelevant operating system (OS), thus, making them upset and unable to use the applications for accompanying their learning process. Ni et al. (2020) developed a mobile learning using IoS operating system. This study determines the use of IoS due to the fact that all students' mobile phone used IoS operating system. Indeed, this application suggests future research to develop the Android version to make the application more tangible for many others. At last, many studies show that developing mobile learning application using Android-based operating system could be more useful as the Android users are many compared to other OS users (Aldya & Arifendi, 2021; Darwin et al., 2022; Handoyono, 2020; Sunarto et al., 2020).

Several previous studies on MoLearn development were only stuck at learning HOTS realm but had not yet provided assistance in creating HOTS questions for various HOTS levels based on advised RBT (Antara & Dewantara, 2022; Eliyasni et al., 2019; Pratiwi et al., 2019). As another example, Susantini et al. (2022) developed HOTS-based learning application to assist preservice teachers in devising HOTS-based lesson plan. This application helped structuring the order of the problems solved and skills learned by preservice teachers, thus, the material delivery can be chronologically achieved. This application absolutely does not help preservice teachers creating HOTS-based questions for different thinking levels (C4-C6). Hariadi et al. (2021) developed Blended Web Mobile Learning (BWML) to improve senior high school students' higher-order thinking skills in which the results showed that BWML model can enhance students' critical thinking skills. Many similar studies also only developed typical MoLearn to enhance one's critical thinking skills (Chang et al., 2022; Darmayanti et al., 2022; Ichsan et al., 2019). Other studies, moreover, only focused on the analysis of teachers' HOTS level (Janssen et al., 2019; Pratiwi et al., 2019; Suwarma & Apriyani, 2022) or the ability of teachers to construct HOTS questions (Jannah, 2021; Tyas et al., 2019) Thus, to the best of the researchers' knowledge, MoLearn for assisting preservice teachers to develop HOTS-based questions for their assessments had not been widely invented.

Research purpose and questions

This study aimed to develop EduQuestioning mobile learning application that could help teachers or teacher candidates create assessment questions based on higher-order thinking skills (HOTS). To address this objective, the study postulates a research question namely: How is the development process of EduQuestioning mobile learning application using ADDIE model?

Methods

The mobile learning application design and development with ADDIE model

This study used analysis, design, development, implementation, and evaluation (ADDIE) model (Molenda, 2003) to develop EduQuestioning mobile learning application. The study used both qualitative and quantitative research approach, however, it more used quantitative research approach in analyzing the main data of developing the HOTS-based application. The present study was limited to the materials of the mathematics, natural science, social science, and Indonesian language subjects. The four subjects were chosen because they had been the essential subjects for elementary to high school education in Indonesia. The student achievement in the four subjects were often considered for university admission or higher school admission for granting scholarship for new year enrollment. Moreover, the four subjects were considered essential when applying for school scholarship. Thus, the developed e-assessment mobile learning application ‘EduQuestioning’ consisted of HOTS materials for the four subjects.

Participants

There were eight lecturers and sixty-one preservice teachers involved as the participants, who were enrolled in four study programs namely Departments of Mathematics, Natural Science, Social Science, and Indonesian at one of the teacher training universities in Indonesia.

Data collection

Data were obtained by using forum group discussion (FGD), needs-analysis questionnaire, Gregorian Index and Aiken’s validity sheet, content and face validity sheet, and structured response questionnaire.

Data analysis

Table 1 shows how the obtained data were analyzed.

Table 1 Scheme of research instrument, data type, and data analysis technique

Research Instrument	Data Type	Data Analysis Technique
FGD (adapted from Wulandari et al., 2024) - Administered to eight lecturers from Departments of Mathematics, Natural Science, Social Science, and Indonesian language - Revealing the needs of the required learning media	Qualitative	Data reduction, data display, and generating conclusion (Miles & Huberman, 1994)
Needs-analysis questionnaire (adapted from Susantini et al., 2022; Wulandari et al., 2024) - Administered to sixty-one preservice teachers to reveal current learning media and expected learning media with five aspects, namely flexibility, usability, material completeness, design and interface, and digitalization - Six-point Likert's scale from strongly disagree (1) to strongly agree (6)	Quantitative	Descriptive statistics (using IBM SPSS) with adapted Swanson's quartile categorization (Q): Q1/very low agreement ($M\% < 25\%$), Q2/low agreement ($25\% \leq M\% < 50\%$), Q3/high agreement ($50\% \leq M\% < 75\%$), and Q4/very high agreement ($M\% \geq 75\%$) (Pallant, 2020; Swanson, 2014)
Aiken's validity and Gregorian Index validity sheet (adopted from Aiken, 1980; Geringer et al., 2004) - Administered to twelve validators to measure the contents of HOTS (C1-C6) - Four-point Likert's scale from insufficient (1) to very good (4)	Quantitative	Aiken's validity was analyzed using the following formula: $$\mathrm{V} = \frac{\sum \mathrm{s}}{[\mathrm{n}\ (\mathrm{C}-1)]}$$ Gregorian index was analyzed using the following formula: Mean = $\frac{\sum \textbf{The value obtained}}{\sum \textbf{The maximum value}}$ Aiken's V and Gregorian M score used the following categorization: $V/M < 0.4$ = less valid, $0.4 \leq V/M < 0.8$ = moderately valid, and $V/M \geq 0.8$ = valid. (Aiken, 1980; Geringer et al., 2004)
Content and face validity sheet (adapted from Pratama et al., 2024) - Administered to twelve validators to measure the readability, design, home interface, and feature interface of the developed application - Five-point score from strongly disagree (1) to strongly agree (5)	Quantitative	Descriptive statistics (using manual mathematical operation) with the following criteria of categorization: $\bar{x} < 2.5$ = not valid $2.5 \leq \bar{x} < 3.5$ = moderately valid $\bar{x} \geq 3.5$ = valid
Structured response questionnaire (adapted from Susantini et al., 2022) - Administered to sixty-one preservice teachers to reveal their responses after the use of the developed application - Six-point Likert's scale from strongly disagree (1) to strongly agree (6)	Quantitative	Descriptive statistics (using IBM SPSS) with adapted Swanson's quartile categorization (Q): Q1/very low ($M\% < 25\%$), Q2/low ($25\% \leq M\% < 50\%$), Q3/high ($50\% \leq M\% < 75\%$), and Q4/very high ($M\% \geq 75\%$) (Pallant, 2020; Swanson, 2014)

Procedures of developing e-assessment mobile learning application: ADDIE stages

There were five stages in developing the e-assessment mobile learning application called EduQuestioning namely analysis, design, development, implementation, and evaluation. In analysis stage, there were two needs analyses undertaken through forum group discussion (FGD) and distributing student-needs questionnaire. The FGD was conducted with 12 lecturers from Departments of Mathematics, Natural Science, Social Science, and Indonesian with 4 lecturers from each department. The inclusion criteria for the FGD lecturers were having experience in teaching assessment, instructional design, and microteaching, having been participating teacher best practice, and having been supervisor for teaching practice program. The FGD was undertaken to reveal the current competence and obstacles of preservice teachers in developing HOTS-based questions for learning assessment during the teaching and learning activities. It was conducted to also determine the learning media that could support their competence in developing HOTS-based questions and facilitate their autonomous learning exposure and practice. The results of this FGD would be used to justify types of learning media developed under the views of lecturers or education experts. In addition, student-needs questionnaire was administered to 61 preservice teachers from the four departments who were enrolled in assessment class to reveal their needs of learning media that could facilitate them to make and practice of developing HOTS-based questions. The results of this questionnaire were categorized into low to very high agreements towards the given statements of items.

The second stage was design where the first prototype of EduQuestioning was developed. The design encompassed the color tone of the application, the font and language usage, and the features offered. Among those considered aspects, the present study focused on the features offered due to the fact that this aspect comprised how the materials were chronologically delivered, how the users experienced the learning of developing HOTS-based questions easily, and how the users got sustainable practice and guidance from the experts. The whole application, especially the interactive features such as consultation and quiz with feedbacks, were designed by the assistance of IT experts, who would also assist the development of EduQuestioning. The next stage was development, where the design was developed into real Android-based application. In this stage, validation of the application was conducted by twelve validators whose backgrounds were relevant to the application realm in which three validators came from each department. The twelve validators would assess four HOTS materials for different subjects. For instance, validators 1 to 3 would be in charge in validating HOTS materials for mathematics subject, validators 4 to 6 would validate HOTS materials for natural science subject, validators 7 to 9 would validate HOTS materials for social science subject, and validators 10 to 12 would validate

HOTS materials for Indonesian language subject. However, all validators would also do face validity to look at how the overall mobile learning application performed.

The next stages were implementation and evaluation. Implementation stage consisted of a class trial of the developed EduQuestioning and the evaluation stage included the administration of response questionnaire to the sixty-one preservice teachers. The class trial was undertaken by the researchers with the focus of practicing of generating HOTS-based questions for assessment. The response questionnaire was administered once at the end of the class trial process to look at their feelings, experience, and thoughts during the use of EduQuestioning application. After the evaluation, the improvement of the application was undertaken if necessary.

Trial class procedure of developing HOTS-based questions using EduQuestioning

The lecturers conducted the class trial in 100 minutes with the opening, main, and closing learning activities. In the opening learning activities, lecturers opened the class and ensured the attendance of each preservice teacher along with asking for their feelings and class readiness. Afterward, the lecturers explained the importance of creating HOTS-based questions for assessment and introduced the application. At a glance, the lecturers explained the contents and features of the application and asked the preservice teachers to install the application. While the preservice teachers installed it and registered their account, the lecturers gave assistance when there was an installation problem. After all preservice teachers were ensured successful installing the application, the lecturers began explaining each feature in the application. As the main learning activities, the lecturers explained how to make HOTS-based questions in order and how to differentiate HOTS-based questions from LOTS-based questions (lower-order thinking skills). The lecturers then came to the feature 'Material' to give time for preservice teachers to read the detailed information. After the independent reading, the lecturers opened question-answer session for ensuring the preservice teachers' understanding. Once they had understood the materials, the lecturers then asked them to open the feature 'Example of Questions'. In the feature 'Example of Questions', there were four subjects in which the preservice teachers must choose to the subject they were going to teach. Some examples of questions were displayed to give insights on LOTS (C1 to C3) and HOTS (C4 to C6) questions. There was also description of the rationale to make the preservice teachers easier to understand why the example question was categorized as LOTS or HOTS. After exploring numbers of example questions, the lecturers then challenged the preservice teachers' mastery in the feature 'Quiz'. In this feature, the lecturers would know how far their preservice teachers comprehended the materials. Some discussions were also opened to elicit misunderstanding and strengthen the comprehension for each question in Quiz. This Quiz activity was carried out in group so that the preservice teachers had opportunities to communicate and collaborate. After that, the lecturers gave them autonomous practice through the feature ‘Assignment’. Here, the preservice teachers should accomplish the task individually and the lecturers used the score as the formative assessment score. In the closing learning activities, the lecturers made a small talk regarding how the score they got and did some relaxing activities. Before closing the trial class, the lecturers distributed the response questionnaire and asked the preservice teachers to complete it according to their feelings, experience, and thoughts. The lecturers also guaranteed that the given response would not affect the course score.

Ethical issues

Since there was no committee of issuing research ethics, the present study created a research ethic rule developed by the researchers. To get the data, the study needed a research permission under the Department, Faculty, and University since the participants were varying based on study programs. This letter became a legal proof to engage with the participants. To obtain the data, the study socialized the purpose of the study along with the inclusion of the participants’ participation. They were ensured that the sensitive individual data (e.g., name, study program, gender) obtained from the online questionnaire and stored to researcher’s data bank in Google were not disclosed. This study also guaranteed that the data displayed were not in connection with their personal identity information (e.g., name, study program, gender). Moreover, the participants were informed that the data which were consciously given to the researchers did not affect their learning performance as well as their course score. The aim of initial research socialization was to educate the participants that they could contribute to the research, broadly to the field of education. In addition, the socialization along with the efforts of disclosing participants’ personal identity information were to protect human subjects. The present study also emphasized that the potential impact of the study’s findings might occur within society. As this application was freely accessible, wider societies could use it as a learning reference. However, this application needs a guidance from the course lecturer to attain maximum learning performance.

Results

Participants’ demographic data

There were sixty-one preservice teachers involved as the participants with these inclusion criteria: currently enrolled in assessment class and experienced in participating in theory of teaching and learning course. Table 2 shows the preservice teachers’ demographic data.

Table 2 Preservice teachers' demographic data

Aspects	Categories	Percentage
Gender	- Male	44.26%
	- Female	55.74%
Current Semester	Fifth semester	100%
Department	- Mathematics	24.59%
	- Natural Science	26.22%
	- Social Science	27.86%
	- Indonesian	21.33%

In accordance with Table 2, the preservice teachers from each department had shared similar numbers. This implied that every data connected to preservice teachers could be generalized regardless of the difference of departments. Moreover, the results did not consider the gender as influential to the results of the present study as it was extraneous to the research focus. In connection with the lecturer participants who participated in the FGD session, Table 3 portrays the demographic data.

Table 3 describes that most lecturers participating in the FGD session were male lecturers and all the lecturers had an experience in teaching assessment, instructional design, and microteaching courses. Moreover, they had been involved in teacher best practice and had been assigned as supervisor for teaching practice program in their respective department. All lecturers were from four departments in which each department was represented by two lecturers. This implied that the FGD results were not violating the principle of objectivity, thus, no department was upper handed than the others.

Table 3 Lecturers' demographic data

Aspects	Categories	Percentage
Gender	- Male	62.5%
	- Female	38.5%
Department	- Mathematics	25%
	- Natural Science	25%
	- Social Science	25%
	- Indonesian	25%
Experience in teaching instructional courses	- Teaching assessment	100%
	- Teaching instructional design	100%
	- Microteaching	100%
Experience in teacher best practice	- Yes	100%
	- No	-
Being supervisor for teaching practice program	- Yes	100%
	- No	-

Developing EduQuestioning mobile learning application

There were five stages in developing EduQuestioning mobile learning application covering analysis, design, development, implementation, and evaluation. First, the analysis was carried out through FGD and student-needs questionnaire. The FGD was undertaken in 90 minutes participated by eight lecturers from four departments. Table 4 conveys the results of the FGD specifically for each discussion aspect.

Table 4 Results of lecturer across department's FGD on HOTS learning media

Aspect	Current Situation	Expected Situation
Preservice teachers' HOTS competence	Preservice teachers only knew the difference between LOTS and HOTS in surface level and, most of them still performed LOTS proven by their circular rhetoric style essay or report. Majority also did not know the thinking level.	Preservice teachers conceived HOTS for themselves and knew the detailed differences between LOTS and HOTS. They should carry HOTS in every assignment so they could be accustomed to it and, thus, they could showcase better critical thinking skills.
Knowledge of HOTS-based questions for assessment	They did not know how to activate higher-order thinking skills when they did assessment. They only knew that HOTS-based questions should not be in a form of multiple choice, whereas question types did not influence too much when creating HOTS-based questions.	Once they had perceived HOTS, they should be able to use their knowledge to assess others, in this case their future students. They can use HOTS in formulating questions regardless of the types. Thus, they would have advance instructional skills too.
Practice and Exposure to developing HOTS-based questions	They lacked opportunities to learn how to make HOTS-based questions due to limited learning resources and assistance. Current online and offline references were irrelevant to their expertise and sounded not authentic. This desperately affected their learning motivation, knowledge mastery, and learning progression.	They were expected to have habits in connection with HOTS-based question development. They could easily practice when they encountered new subject materials and sustain the exposure of learning it using relevant and supporting media.
Learning media	They only learned from several books that were almost impracticable for Indonesian preservice teachers. When they encountered some problems, they could not consult them to the experts. Thus, learning media was still minima.	They must have handy learning resource that they could use it regardless of the place and time. They could access online while they also could read the materials offline. They could do it autonomously but when needed, they could use consultation feature. Thus, mobile learning application could be one of the best forms to the case.

The FGD resulted on four important findings, namely preservice teachers' HOTS competence, knowledge of HOTS-based questions for assessment, practice and exposure to developing HOTS-based questions, and learning media. Table 4 implies that there was a need of new model of learning media since the current learning media was outdated and irrelevant to the millennial or digitalization value. Mobile learning application was the best troubleshot for this practical gap with the philosophy of being handy, easy-to-use, effective and efficient, complete, collaborative, and communicative, where this application supported the skills required in the 21st-century education model. To support the results of the lecturer across department's FGD, Table 5 shows the results of students' needs analysis.

Table 5 describes that the current learning media was not favored by the preservice teachers (Q1 = very low agreement). The least score of the current learning media was digitalization (M = 1.0164). This showcased that the preservice teachers agreed that the current learning media did not support the exposure of digital era, where nowadays learning should lead pupils to skills required in Society 5.0. This supported the FGD results on learning media where the lecturers agreed that the learning media was too limited to books where preservice teachers must consult with numbers of books as reference. This must also not be effective because preservice teachers would have a lot of reference books on their table and connect every information and practice from the books by themselves. Moreover, the majority of books were written and published in countries where English is the L1, where the rhetoric pattern was straightforward, whereas, the lecturers believed that the books were difficult to learn due to the fact that Indonesian preservice teachers had background of circular rhetoric pattern. Consequently, this condition made them less interested since they have to use impracticable books with less exposure to digitalization. In addition, the preservice teachers agreed that they expected digital-based media (M = 5.8852) that had easy-to-use feature (M = 5.8525) and complete materials (M = 5.9557) in one hand.

Table 5 Results of preservice teachers' needs analysis

Aspects	N	SD	M	M%	Category
Current Learning Media	61	.15506	1.1279	18.79%	Q1
- Flexibility	61	.40082	1.1967	19.94%	Q1
- Usability	61	.30027	1.0984	18.30%	Q1
- Material completeness	61	.34036	1.1311	18.85%	Q1
- Design and interface	61	.32462	1.1188	18.64%	Q1
- Digitalization	61	.12804	1.0164	16.94%	Q1
Expected Learning Media	61	.17821	5.8393	97.32%	Q4
- Flexibility	61	.35759	5.8525	97.54%	Q4
- Usability	61	.37097	5.9557	99.26%	Q4
- Material completeness	61	.17956	5.9672	99.45%	Q4
- Design and interface	61	.37329	5.8361	97.26%	Q4
- Digitalization	61	.32137	5.8852	98.08%	Q4

After revealing the type of learning media needed to assist preservice teachers in developing HOTS-based questions, the researchers along with the IT experts designed the prototype of EduQuestioning mobile learning application. The design consisted of color tone of the application, interface, home page, and features' page. According to the discussion between the researchers and IT experts, the colors of white and purple were chosen to represent knowledge and education and the beginning page was the university symbol to showcase the university's program in accelerating its teacher training quality. The home page was design easy to look and use so it led the user to the features straightforwardly. Each feature also consisted the required materials with some interesting, meaningful, and relevant illustrations. After this design stage, the researchers with the IT experts developed the design prototype into real mobile learning application using Android operation system where the application could be freely downloaded. Figure 1 shows some interfaces of EduQuestioning mobile learning application.

After the development of the application was completed, the validators were asked to validate the application. There were two validity tests namely content and face validity. The data of content validity were analyzed using Aiken and Expanded Gregorian Index validity. Table 6 portrays the results of Aiken and Gregorian Index validity test.

The results of the content validation analysis from twelve experts showed that both LOTS and HOTS items from four subjects, namely Indonesian, Mathematics, Natural Science, and Social Science obtained Aiken scores of 0.8 - 1.0. It meant that the overall content of the items had met acceptable validation standards. In connection with the results of Expanded Gregorian Index method, the average validity index results were above 0.80. Hence, it was concluded that the entire content of the question items had met very high content validation standards.

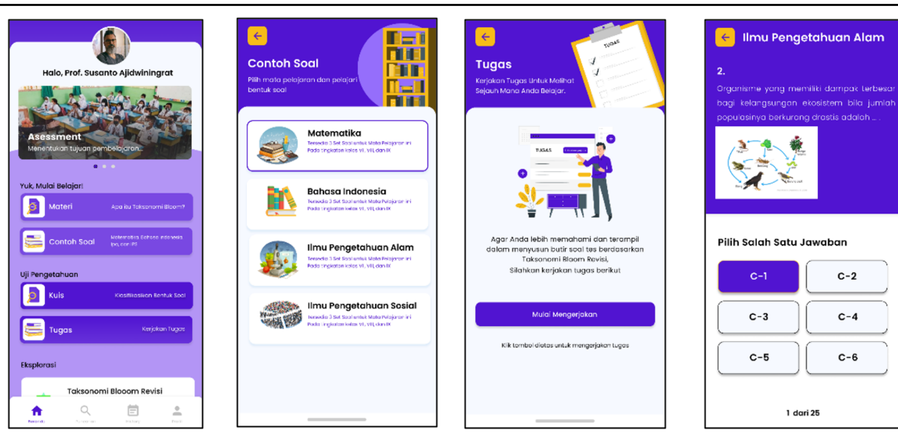

Fig. 1 Some pages in EduQuestioning mobile learning application

Table 6 Results of Aiken and Expanded Gregorian Index validity tests

Topic	Data Analysis	Revised Bloom's Taxonomy					
		C1	C2	C3	C4	C5	C6
Indonesian Language	Expanded Gregorian Index	1.00	1.00	1.00	1.00	1.00	1.00
	Aiken Validity	0.99	0.98	0.98	1.00	0.98	0.94
Mathematics	Expanded Gregorian Index	1.00	1.00	1.00	0.80	1.00	1.00
	Aiken Validity	0.90	0.90	0.90	0.80	0.86	0.86
Natural Sciences	Expanded Gregorian Index	0.89	1.00	1.00	0.90	0.80	0.90
	Aiken Validity	0.93	0.94	0.95	0.91	0.88	0.90
Social Studies	Expanded Gregorian Index	1.00	0.89	0.89	1.00	1.00	0.80
	Aiken Validity	0.96	0.90	0.90	0.98	0.95	0.90

Table 7 Results of face validity test

Aspect	Validator's Score												x̄
	1	2	3	4	5	6	7	8	9	10	11	12	
The use of the colors is meaningful and eye-friendly.	5	5	5	5	4	5	5	5	5	5	5	5	4.9
The font used in the application is readable and clear.	5	5	5	5	5	5	5	5	5	5	5	5	5
The sentence is well-structured and effective in carrying out information.	5	4	5	5	4	5	4	5	4	5	4	5	4.5
The registration feature is not complicated and easy to complete.	5	5	5	5	5	5	5	5	5	5	5	5	5
The login feature is easy to use.	5	5	5	5	5	5	5	5	5	5	5	5	5
The home page provides the whole application contents and features.	5	5	5	5	5	5	5	5	5	5	5	5	5
The features are easy to access and to comprehend.	5	5	5	5	5	5	5	5	5	5	5	5	5
The overall design is interesting.	5	5	5	5	4	5	5	5	5	5	5	5	4.9
x̄	5	4.8	5	5	4.6	5	4.8	5	4.8	5	4.8	5	4.9

Regarding the results of face validity in the Table 7, all validators agreed that the EduQuestioning mobile learning application was valid ($\bar{x} \geq 3.5$). Validator 5 gave the lowest score among others ($\bar{x} = 4.6$) since she had some considerations in term of the use of the color, the sentence structure, and the overall design. She argued that these three aspects could be enhanced, especially the sentence structure where some repetitions occurred. She claimed that the color and design were subjective to personal preference but the design of EduQuestioning was categorized very good. In addition, the aspect of sentence structure was also the lowest among other aspects ($\bar{x}$ = 4.5). This made the researchers review the use of the sentence and invite the Indonesian language expert to help revise it. After some changes, the application was ready to be trialed in the class during the implementation stage and it must be evaluated for the improvement.

Preservice teachers' responses on the use of EduQuestioning mobile learning application

Once the trial class was over, the preservice teachers were asked to voluntarily complete the response questionnaire to look at how they experienced the learning process using EduQuestioning mobile learning application. There were four sub-topics revealed, namely the ease of using the application, the effectiveness in distinguishing LOTS-based and HOTS-based questions, the ease of understanding HOTS proposed by Revised Bloom's Taxonomy (RBT), and the application performance and reliability. Table 8 portrays the results of the response questionnaire.

Based on Table 8, preservice teachers showed their very high agreement of the given items (Q4). This implied that they gave positive response toward the use of EduQuestioning in learning of developing HOTS-based questions. The three highest aspects covered easily to find features (M = 5.9836), learning motivation to deepen HOTS concept (M = 5.9672), and gaining new insight of HOTS-based questions (M = 5.9508). This showed that the preservice teachers agreed that EduQuestioning was easily to use so the value of user-friendly was upper handed. Moreover, they strongly agreed that EduQuestioning gave them opportunity to learn HOTS concept in details so that their learning motivation was high. This consequently made them perceive insights on HOTS-based questions. By looking at this response, the evaluation stage remained important since the preservice teachers gave the opportunity to expose autonomous learning the lowest score among other response aspects (M = 5.7869). Even it got the lowest score, it was still categorized in Q4 where almost all of preservice teachers agreed that EduQuestioning provided space to explore and learn the materials self-sufficiently.

Table 8 Results of preservice teachers' response on EduQuestioning

Items	SD*	M	M%	Category
I can easily start and use this app autonomously.	.41291	5.7869	96.44%	Q4
The application interface is easy to understand.	.40082	5.8033	96.72%	Q4
The instructions and hints provided in the app are clear and easy to understand.	.32137	5.8852	98.08%	Q4
I can quickly find the features or functions I need.	.12804	5.9836	99.72%	Q4
This app helps me clearly differentiate between LOTS and HOTS questions.	.24959	5.9344	98.90%	Q4
The criteria the application uses to distinguish between LOTS and HOTS are accurate.	.27659	5.9180	98.63%	Q4
I feel more confident in differentiating LOTS and HOTS questions after using this application.	.30027	5.9016	98.36%	Q4
Supports mastery of the Revised Bloom's Taxonomy.	.34036	5.8689	97.81%	Q4
Supports mastery of how to compose good test questions.	.41291	5.7869	96.44%	Q4
Supports the ability to analyze Mathematics, Indonesian, Natural Sciences and Social Sciences questions based on the Revised Bloom's Taxonomy.	.37329	5.8361	97.26%	Q4
Improving the skills of teachers or student teachers in creating Mathematics/Indonesian/Science/IPS questions.	.40082	5.8033	96.72%	Q4
This application provides examples of LOTS and HOTS questions that are relevant and useful.	.41291	5.7869	97.81%	Q4
I gained new insight into the differences between LOTS and HOTS questions from this application.	.21804	5.9508	99.18%	Q4
This application motivates me to deepen the concept of LOTS and HOTS.	.17956	5.9672	99.45%	Q4
Navigation between content in the application can be accessed quickly.	.38765	5.8197	96.99%	Q4
Simple application design using contrasting color combinations.	.27659	5.9180	98.63%	Q4
The size of the letters can be read clearly.	.30027	5.9016	98.36%	Q4
The entire application can be seen in full on the screen (not cropped).	.21804	5.9508	99.18%	Q4
The 'Tutorial' menu can help users when accessing the application.	.30027	5.9016	98.36%	Q4
There is a combination of image content to clarify concepts.	.41291	5.7869	97.81%	Q4

*N = 61

Discussion

The ADDIE (Analysis, Design, Development, Implementation, and Evaluation) approach is a development model that can be used to create interactive multi-media applications, including learning and recognition applications (Adriani et al, 2020; Putra et al., 2022; Ranuharja et al., 2021; Wijaya & Devianto, 2019). This model provides stages which can support the application development process. In the present study, the ADDIE model is used to develop EduQuestioning as a learning media in developing HOTS-based questions for essential subjects, namely mathematics, natural science, social science, and Indonesian. In some previous studies, the ADDIE model has been widely used in developing mobile learning application such as the development of Legasi (Murdiono et al., 2020), M-Learning (Cahya et al., 2020), and DysleRead (Ping et al., 2022). Thus, the ADDIE model has been used as a learning media development approach since around 1970.

The results of the development of EduQuestioning comprised several interactive and helpful features. There was a tutorial feature of using the application to ease the user surfed in the application. This important feature was familiar so that almost every mobile learning had it to help the users explore the application (Kumar & Mohite, 2016; Yahaya & Zaini, 2020). Another important feature carried out by EduQuestioning was the existence of materials, examples, practices, quizzes, and assignments where these chronologically ordered features helped the users learn effectively. Similar to the present study, many mobile learning applications provided such chronological learning order (Cahya et al., 2020; Murdiono et al., 2020; Ping et al., 2022), but some applications might not split quiz and assignment such as in these applications. The important feature of this application was the interactive consultancy and assistance. The users could consult their problems in relation with HOTS-based question development. Moreover, this caring feature might ease the learning process as the interaction and discussion could happen anywhere and anytime. The application also showed the results of the quizzes and assignments along with the expert comments. These benefits had been the outstanding service offered by EduQuestioning application. To the best of the researchers' knowledge, few mobile learning applications provided such interactive, communicative, and collaborative aspects and, thus, this had been the present study's novelty.

The present study used Aiken and Expanded Gregorian Index validity tests to assess the contents of the developed EduQuestioning mobile learning application. These tests were categorized as a classic validity test for they had been used since 1978 in validating learning media. Moreover, Aiken and Expanded Gregorian Index validity showed easier application but more precise outcome. The use of these two content validity tests made the validity results more truthful. In addition, the present study also validated its interface by carrying out face validity test. Both content and face validity tests showed a valid category, thus, the application could be used in assisting the learning activities. Some previous studies also used Aiken (Muamar et al., 2021; Nasrulloh et al., 2022; Retnawati, 2016) and Expanded Gregorian Index validity test (Desstya et al., 2019; Retnawati, 2016) to validate the learning media, however, they did not carry face validity to assess the look of the developed learning media. Lam et al. (2018) and Rueda Esteban et al. (2023) believed that content and face validity tests should be undertaken to validate the newly developed learning media.

Since the EduQuestioning mobile learning application used Android operating system, it promoted digital learning experience. This typical learning media let the users learn regardless times and places, so the learning process could be carried out flexibly (Spiteri & Chang Rundgren, 2020). Digital learning media had been important since the implementation of distance and blended learning mode (Spiteri & Chang Rundgren, 2020). This made easier knowledge transfer when both instructors and students were apart. The assistance of digital learning media might ease the responsibility of educators as they should not be burdened by printing many learning materials and assessments. Many studies also showed that digital learning media could increase students' learning motivation and achievement (Sari et al., 2023; Yu, 2022; Zhang & Yu, 2022). Meaning that, millennial students were more assisted with the use of digital learning media to comprehend materials and conceive particular skills, such as HOTS (Prameswaro et al., 2023). Some previous studies had also developed digital learning media to improve HOTS (Tyas & Naibaho, 2021), but to the best of the researchers' knowledge, only EduQuestioning provided HOTS materials as well as skills in developing HOTS-based questions for teachers conducting class assessment.

In addition to the benefits offered by EduQuestioning, the present study found that preservice teachers got insight of HOTS easily as this application was user friendly and included the existing consultancy feature. The present study focused on the implementation of HOTS used in making questions for learning assessment. This study referred HOTS as the involving stages of analyzing (C4), evaluating (C5), and creating (C6) (Krathwohl, 2002). This study found that participants were encouraged to understand the concepts of higher-order and lower-order thinking skills. They were also suggested to understand the typical questions that could practice HOTS. This study used Revised Bloom's Taxonomy (RBT) because its HOTS stages were easily differentiated but interconnected. For instance, analysis and evaluation stages were two prominent traits before producing or creating a conclusion or product, for instance. This interconnection made the learners easily understand the logic flow of scientific thinking process (Syafryadin et al., 2021). Among the benefits, this study pointed out few limitations where this RBT could be implemented. First, it was only limited in developing learners' learning process of critical thinking skills in educational settings (Darwazeh & Branch, 2015; Tutkun et al., 2012). Meaning that, it might lead to different amplification when dealing with business analysis and management overview. Second, it was able to enhance communication skills due to the ability of analyzing, evaluating, and creating or communicating (Tutkun et al., 2012). For instance, a student could give critical responses toward a phenomenon because he knew the core issues and understood their impacts on other sectors. This critical response could be a manifestation of good creating stage of communicating stage. Thus, this study also found that preservice teachers' creating skills were also higher.

This study also found that EduQuestioning mobile learning application promoted better experience of developing teacher questioning skills (*M%* > 95%). This implied that the application provided an opportunity for preservice teachers to practice their questioning skills. Since the study focused on developing assessment questions based on higher-order thinking skills (HOTS), the study found that preservice teachers were exposed more on student-centered and higher-order questioning skills. Teachers who employ student-centered questions can help students develop critical and analytical thinking abilities (Oliveira, 2010). They also improve their communication and interaction skills with the students (Chin, 2007). Teachers who utilize higher-order questioning can help students enhance their critical, analytical, and creative thinking skills (Salmon & Barrera, 2021; Sasson et al., 2018). Many studies have agreed that postulating questions based on higher-order thinking skills (HOTS) should be habituated by teachers to students in order to producing more critical and solutive individuals (Artika & Nurmaliah, 2023; Utaminingsih & Murtono, 2019).

Since it could be operated independently, the users were indeed more exposed to autonomous learning habituation. Autonomous learning had been a crucial model since pupils could use their discovery and thinking skills to connect information, to find out cause-effect relationship, and to activate the sense of creative and critical thinking skills (Manuaba et al., 2022). Moreover, Fitzgerald et al., (2022) said that autonomous learning gave student’s self an opportunity to experience learning flexibility, control, pacing, motivation, preparation, and engagement. Similar to the present study, other digital learning media also asked the users to be autonomous (Nurmalisa et al., 2023; Widiantari et al., 2023), but few of them overstressed the learning of connecting information, understanding cause-effect relationship, and activating thinking skills. EduQuestioning had provided access to understand why such developed questions included in C1 or C6, how such verbs and gerunds could not be used to reveal C1 or C6 level, and vice versa. This showcased how the present study invented EduQuestioning with unlimited benefits for autonomous learning coverage.

The present study found that preservice teachers were highly exposed to autonomous learning (*M* = 5.7869, *M%* = 96.44%). This implied that EduQuestioning considered autonomous learning as a crucial learning mode. However, compared to other aspects, autonomous learning got the least score. There could be several problems including but not limited to lecturer assistance as the first trial class and not supporting operating system of the mobile phone. First, the exposure to autonomous learning got the least score because it could be influenced by the first trial that had been assisted and guided by the lecturers. In this case, the preservice teachers might not have been accustomed to using it so they thought they still could not learn by themselves. Actually, when they had understood how to use the application, they could easily use it and only benefit from the consultancy feature for self-development. Second, some preservice teachers' mobile phone did not use Android operating system, thus, this situation made them difficult to learn and operate EduQuestioning. They had to share phones with those whose operating system was Android. This situation did not promote full autonomous learning because there was still dependency to other traits. This problem was addressed by the researchers as not a big problem, rather, a suggestion for the application improvement so it could be accessed by various operating system and could accommodate more subjects and languages.

Conclusion

The present study developed EduQuestioning mobile learning application that could address the absenteeism of autonomous learning of teachers' or teacher candidates' student-centered and higher-order questioning skills. The presence of EduQuestioning mobile learning application might ease educators especially in the field of mathematics, natural science, social science, and Indonesian language to generate assessment questions based on higher-order thinking skills (HOTS) for their students. Through the use of the application, teachers are not only successful in showcasing good teacher questioning skills, but also successful in conceiving comprehension on the difference between HOTS and lower-order thinking. In this study, EduQuestioning mobile learning application can be developed through ADDIE stages and considered valid to be used as learning media to develop HOTS-based assessment questions. Even if this application is limited to four essential subjects, namely mathematics, natural science, social science, and Indonesian, the content of EduQuestioning regarding HOTS and HOTS-based questions can be a reference for other fields of science. Based on Aiken and Expanded Gregorian Index content validity tests, the application was considered highly valid. The twelve validators also agreed that the application has met the face validity standard. In addition, this application has been responded positively by preservice teachers where it helps them comprehend HOTS materials as well as develop HOTS-based questions. The preservice teachers are also benefitted with interactive consultancy where there is a space for them to have a discussion with the experts. This creates better autonomous learning atmosphere. Through the use of EduQuestioning, the users will definitely experience the exposure of required skills in the 21st century education, such as communication, collaboration, critical thinking, and creative thinking skills. This study suggests that EduQuestioning can be used to help teachers or teacher candidates to develop HOTS-based assessment questions. For future research, this study suggests that EduQuestioning could be enhanced for its subject coverage and language options so that it could be used by educators across countries. Future studies are also expected to measure the effectiveness of the mobile learning application on advancing the comprehension of HOTS sub-skills as well as increasing the teacher-questioning skills.

Abbreviations

HOTS: Higher-Order Thinking Skills; ADDIE: Analysis, Design, Development, Implementation, and Evaluation; MoLearn: Mobile Learning; RBT: Revised Bloom's Taxonomy; OS: Operating System; BWML: Blended Web Mobile Learning; FGD: Forum Group Discussion; LOTS: Lower-Order Thinking Skills.

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Authors' contributions

Endang Susantini: leading the research and development, generating main idea, collecting data, and composing introduction; Yurizka Melia Sari: reviewing and writing related literatures, collecting data, coordinating with application designer and developer; Muhammad Ilyas Marzuqi: composing methods and results, collecting data, and analyzing data; Prima Vidya Asteria: composing discussion and conclusion, referencing styling, collecting data, developing instruments, and making sure the language use.

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