8

AUGMENTEDWORLD

A location-based question-generating platform as a means of promoting 21st-century skills

Shadi Asakle and Miri Barak

Summary

This chapter introduces a new web-based platform named *AugmentedWorld* that was designed to allow science teachers and students to generate location-based multimedia-rich questions. A study among 98 pre-service science teachers indicated that deep learning of science concepts can be promoted by generating and solving interactive questions connected to a specific location and real-world applications. The use of *AugmentedWorld* may foster ICT literacy, critical thinking, contextualization, and creativity – four essential skills required for 21st-century education. Our study shows that the method is most effective when using a taxonomy for question generation.

Introduction

Science educators worldwide have devoted effort to promote dramatic changes in the design and use of new pedagogy (e.g., Barak, 2017a; Barak, 2018; Bell, Maeng, & Binns, 2013). These changes, in turn, require dramatic changes in the way teachers and students use educational technologies (Barak, 2017b). Web-based platforms have evolved, allowing learners worldwide to interact and collaborate with each other as creators of content in online environments. In the field of science education, web-based platforms facilitate learning through virtual field trips, scientific inquiry, simulations, and the formation of learning communities (e.g., Barak & Rafaeli, 2004; Crippen, Ellis, Dunckel, Hendy, & MacFadden, 2016; Ketelhut, Nelson, Schifter, & Kim, 2013). Such platforms have become a prominent component of science education practices in schools and universities, introducing a wide range of instructional approaches (Barak, 2014; 2018; Barak & Ziv, 2013; Crippen et al., 2016). Web-based technologies provide new learning environments that support the generation of high-level questions (Barak & Asakle, 2018; Barak & Ziv, 2013). These environments allow users to add multimedia components such as pictures, animations, videos, and interactive simulations to text-based questions. However, they still lack location-based features that allow the connection to authentic locations and events. In addition, location-based platforms, based on global positioning systems (GPS), facilitate authentic and collaborative learning (Barak & Asakle, 2018; Barak & Ziv, 2013); yet, they have not reached their full potential in the science classroom.

Web-based technologies in science education

Advanced web-based technologies facilitate science education through modeling, simulations, data analysis, and the generation of learning communities (Barak, 2017b; Barak & Ziv, 2013; Ketelhut et al., 2013). Web-based technologies in the form of virtual environments and social applications show promising possibilities for shifting from traditional teaching of scientific facts to active and interactive construction of knowledge (Barak, 2017a; Bell, et al., 2013; Crippen et al., 2016). As science education curricula and instructional materials are adapted to meet the new challenges of the 21st century, new questions arise, such as: What assessment methods are most appropriate for the new vision of K-12 science education? And how can science learning in rich and complex environments be measured? These important questions are at the center of several recent studies on web-based learning and assessment (Barak & Asakle, 2018; Crippen et al., 2016).

International programs for science education assessment have integrated computer-based assignments as part of students' testing practices. For example, since 2015, the Programme for International Student Assessment (PISA) included web-based assessments of the mathematics, science, and collaborative problem-solving skills of students (OECD, 2016). Namely, the PISA Computer-Based Assessment of Science (CBAS) was designed specifically to replace paper-and-pencil methods of assessment. Paper-and-pencil assessment, including exams, portfolios, and lab reports, is well grounded in science education curricula. In order to change the nature of assessment in the science classroom, teachers and students must have as many opportunities as possible to practice web-based assessment. In response to this idea, *AugmentedWorld* was designed as an open and adaptive system to enable teachers and students to generate their own multimedia and inquiry questions, and answer and assess questions generated by others (Barak & Asakle, 2018). The importance of generating questions has been recognized by educators in the past three decades (e.g., Brown & Walter, 2005; Dori & Herscovitz, 1999). Question generation was identified as a meaningful strategy for improving understanding and comprehension of mathematics topics (Brown & Walter, 2005), improving motivation to learn science (Chin, Brown, & Bruce, 2002); enhancing problem-solving abilities in chemistry (Dori & Herscovitz, 1999); encouraging independent learning in biology (Marbach-Ad & Sokolove, 2000); and providing an alternative assessment method as an authentic way for examining students' scientific understanding (Hardy et al., 2014; Herscovitz, Kaberman, Saar, & Dori, 2012).

Generating questions

Science education emphasizes inquiry-based learning and higher-order thinking. Therefore, posing high-level questions should be an integral part of the learning process (Barak & Rafaeli, 2004; Dori & Herscovitz, 1999; Hofstein, Navon, Kipnis, & Mamlok-Naaman, 2005; Marbach-Ad & Sokolove, 2000). Generating questions is an important skill for both teachers and students; yet, questions are usually thought of as fact-demanding queries that assessment experts pose, rather than as an authentic, thought-provoking assignment (Barak & Rafaeli, 2004). The literature distinguishes between *question-asking* activities and *question-generating* activities. Question-asking activities stimulate questions posed at the end of a learning session, when reading an article, or while conducting a lab experiment, when the learner does not know the answer or what to expect. On the other hand, question-generating activities encourage learners to create high-level, open- or closed-ended questions that are similar to those generated by educational experts. Question-generating activities are conducted as a means of reinforcing students' understanding of the subject matter (Barak & Rafaeli, 2004; Hardy et al., 2014) and of scaffolding cognitive growth (Barak & Asakle, 2018; Dori & Herscovitz, 1999; Marbach-Ad & Sokolove, 2000).

Question-generating assignments can be used as an alternative assessment method of students' learning (Barak & Rafaeli, 2004; Sanchez-Elez et al., 2014; Yu & Chen, 2013). Such assignments are an authentic way of revealing students' understanding (or lack thereof) of the study materials (Barak & Rafaeli, 2004; Dori & Herscovitz, 1999). Rather than assigning grades based on learners' ability to answer questions (e.g., tests and examinations), they are given according to the quality of the questions that the learners generate (Hardy et al., 2014; Marbach-Ad & Sokolove, 2000).

With the evolution of graphical user interfaces and web-based systems, sophisticated question-generating platforms have been created, allowing users (instructors and learners) to add pictures, animations, videos, and interactive simulations to text-based questions (e.g., Barak & Rafaeli, 2004; Sanchez-Elez et al., 2014; Yu & Chen, 2013). Web 2.0 question-generating platforms include social elements such as forums and recommendation systems (Barak & Rafaeli, 2004; Hardy et al., 2014). However, they lack applications such as location-based systems that allow the connection of questions to authentic locations and events. Location-based applications that use GPS and digital maps have the potential to generate new learning environments by adding new meaning to the term *learning in context*. The learning in context approach is a learning process in which students are able to connect scientific concepts to location-based events and construct meaning based on their own experiences (Barak & Asakle, 2018). In terms of technology, the learning in context approach emphasizes the contribution of advanced technologies to context awareness in education (Barak & Asakle, 2018; Bell et al., 2013). Hence, in this study we introduce *AugmentedWorld*, a web-based platform that uses location-based services to facilitate the generation of multimedia-rich scientific questions while connecting scientific topics to relevant locations and real-world events.

The *AugmentedWorld* platform

AugmentedWorld is an open, collaborative, and interactive location-based platform, designed to provide an easy to use tool for science teachers and students to generate multimedia-rich questions. It is based on the notion that questions are the source of all knowledge and that students should be skilled in generating questions and not only in answering them. *AugmentedWorld* was purposefully developed to offer educational solutions that other applications do not offer, or offer only partially. It allows science teachers and students to provide layers of information in a collaborative and accumulative way, hence the name "Augmented World" – having been made greater in size and value.

AugmentedWorld can be accessed using any internet-connected device (e.g., desktop computer, laptop, tablet, smartphone) and any HTTP-compliant browser. It is unique in that it is free, open, and democratic. All users, be they teachers or students, or even the general population, may create questions, collect and analyze data, and share results and ideas. The platform allows the formation of interactive assignments by clustering several related questions into a single learning task. *AugmentedWorld* is designed to foster science education through four pedagogical pillars: question generation (as the center of the learning process), collaborative learning, feedback and research, and information management. The four pedagogical pillars are presented below.

1. Question Generation is the central pedagogical pillar of *AugmentedWorld*. When users click on the "Sign In" button, the homepage wizard opens automatically with a textbox and content editor that allows users to formulate a question (Figure 8.1). *AugmentedWorld* facilitates two main types of questions: multimedia questions (multiple choice or numerical) and inquiry questions. The multimedia questions, are closed-ended multiple-choice or numerical questions that include multimedia features such as short videos, animations, and/or simulations. The inquiry questions are open-ended queries that are based on the citizen science approach; they encourage public participation in a scientific research (Price & Lee, 2013).

Based on a Google application, each question in *AugmentedWorld* includes a digital interactive map. On this interactive map, question generators (students, teachers, and researchers) can connect the scientific topics to authentic locations by adding virtual markers as location-based information points.

Figure 8.2 is an example of a multimedia question created by a pre-service science teacher who connected the topic of ocean acidification and jellyfish abundance to beaches in Israel. The question begins with a brief explanation of the

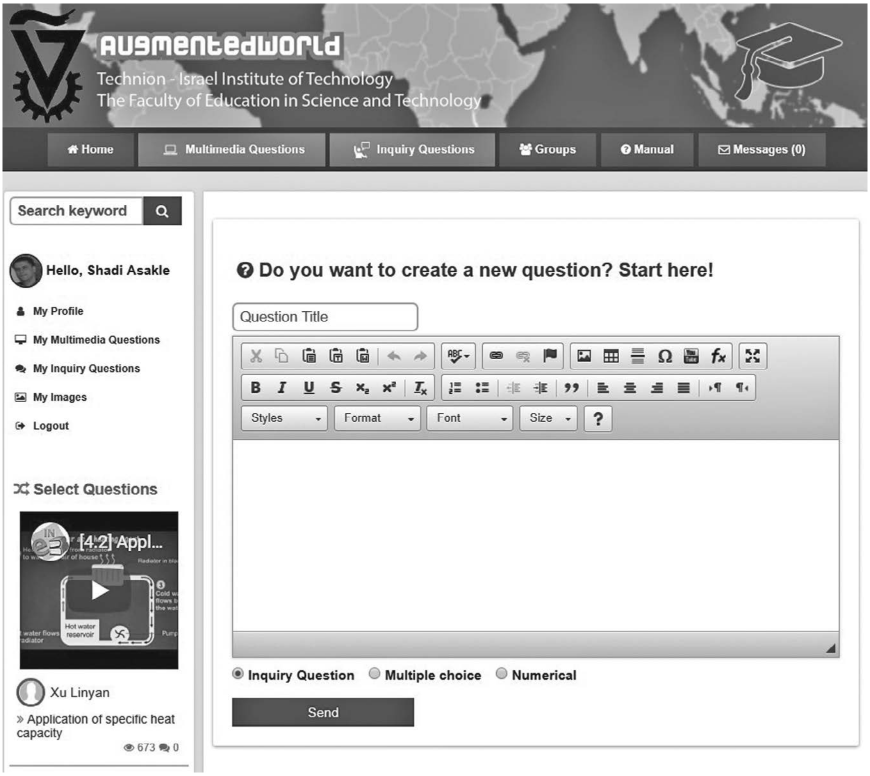

FIGURE 8.1 The *AugmentedWorld* content editor for writing questions.

phenomenon, supported by graphs that show the rising levels of carbon dioxide (CO_2) in the atmosphere, rising CO_2 levels in the ocean, and decreasing pH in the water. It includes a short video on how the phenomenon affects fish. Following this introduction, users are prompted to answer the following question:

How can ocean acidification impact jellyfish population?

- Jellyfish cannot survive in acidic ocean areas.
- Jellyfish proliferation is encouraged by high amount of CO_2 in ocean water.
- Fish population is decreased in acidic water and jellyfish fill the ecological niche.
- Vertebrate animals, which provide food to jellyfish, are abundant in acidic water.

Figure 8.3 is an example of an inquiry question that is based on the World Water Monitoring Challenge for raising public awareness and involvement in protecting water resources around the world. The inquiry question was: "What is the quality of local water bodies around the world, and how does it relate to its location?" Participants from the United States and Israel were prompted to use a

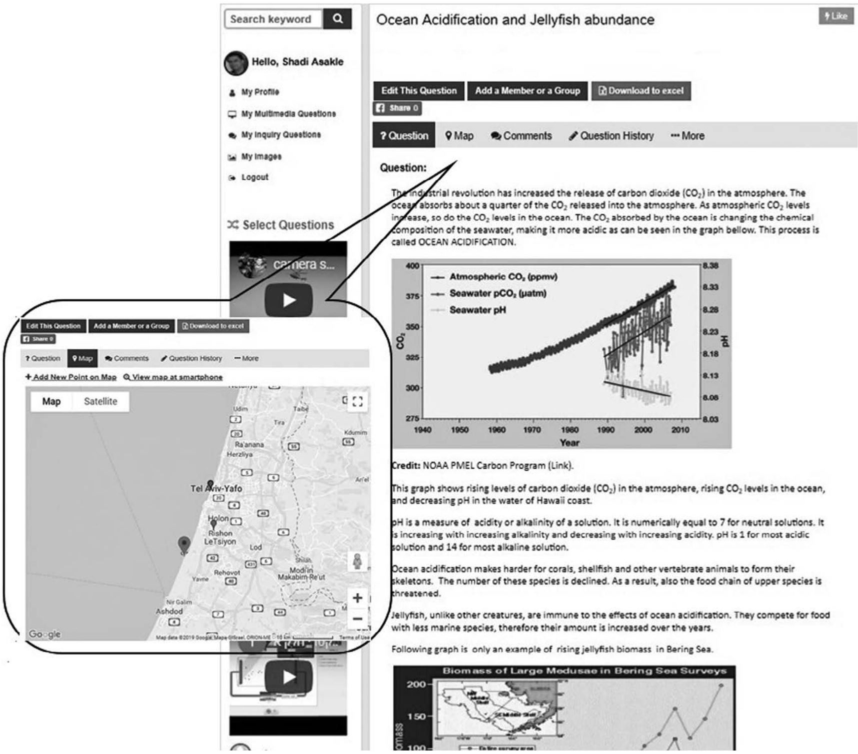

FIGURE 8.2 An example of a multimedia question.

water-testing kit to examine acidity, turbidity, temperature, and dissolved oxygen. They uploaded findings via text, pictures, and/or videos on the interactive map, according to the relevant location in which data was collected.

2. *Collaborative learning,* the second pedagogical pillar includes three components: question sharing, location-based information points, and peer assessment. Question sharing, the first collaborative component, refers to *AugmentedWorld*'s default "Public" mode. Accordingly, the questions that users generate are open online to the public, even to nonregistered users. Location-based information points, the second collaborative component, refer to virtual markers on an interactive digital map, which are linked to a specific question. Learners can become members of a scientific community in which they can share authentic events connected to scientific topics, engage in research, discuss new ideas, and reach consensus. Hence, by clicking on "Add a New Point on the Map" for the multimedia questions or on "Add Data" for the inquiry questions, students worldwide can add supplementary information that connects the scientific topics to authentic locations (e.g., nature reserves, mineral mines, museums, industrial factories), real-world applications (e.g., volcano eruption, earthquakes), and even everyday life situations (e.g., kitchen-based chemistry, domestic geometrical shapes). Peer

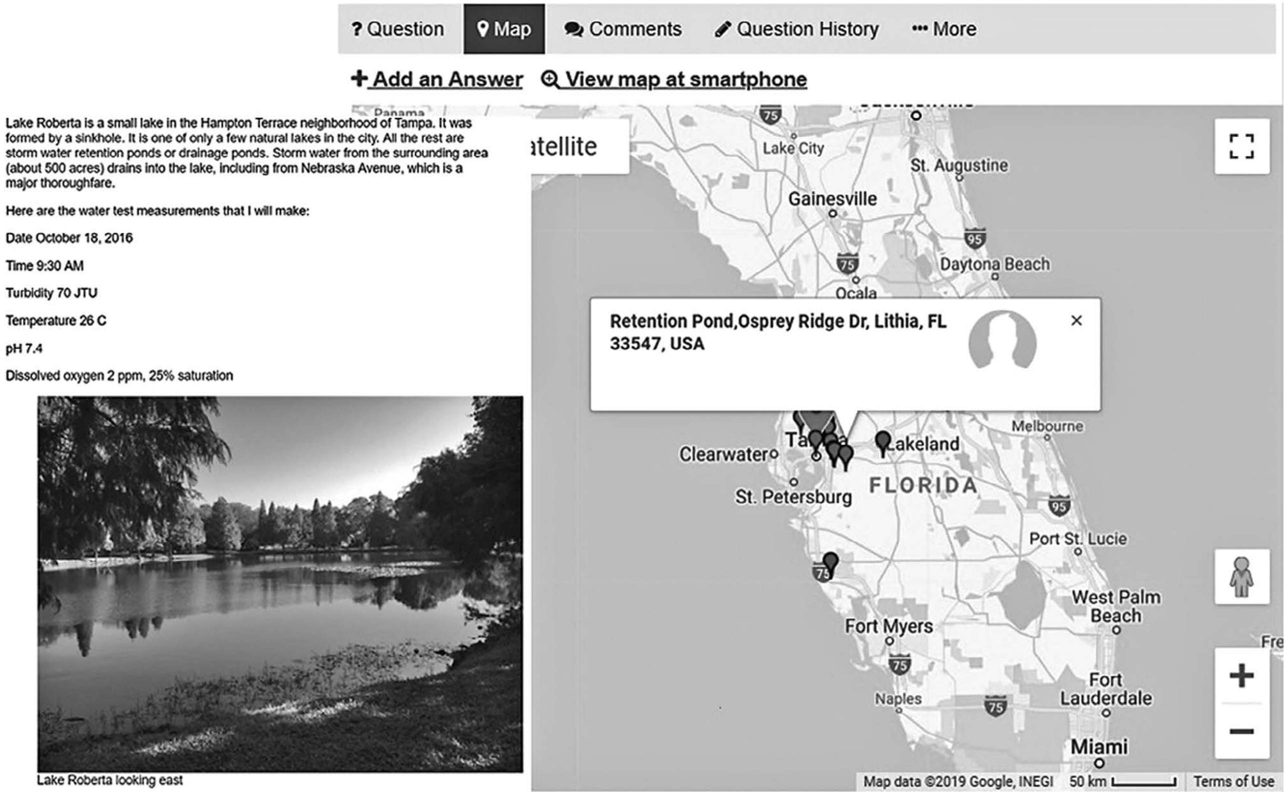

FIGURE 8.3 An example of collecting data for an inquiry question.

assessment, the third collaborative component, is an open forum that allows students to provide comments and constructive feedback. Comments can relate to the question's clarity and level of difficulty, as well as the quality of the multimedia and visualization features.

3. Feedback and research, the third pedagogical pillar, includes two types of responses: immediate feedback, which addresses multimedia (closed-ended) questions, and data collection and analysis, which relate to inquiry questions. Immediate feedback refers to the response learners receive when they try to solve multiple-choice or numerical questions: a wrong answer immediately results in the appearance of a red X, while a correct answer elicits a green check mark. In addition to the automated feedback, specific explanations and scaffolding may be provided for each distractor (i.e., a wrong answer within the multiple choices given). Data collection and analysis refers to the response learners are requested to provide to the inquiry questions. Following the citizen science approach, students are asked to collect data by conducting observations or performing short experiments. They are prompted to report the data (numbers, text, pictures, and/or video) by generating an information point on the digital map, at the location at which the experiment was conducted. The data, which is collected from multiple participants, can be downloaded to an electronic sheet, analyzed by the inquiry question generator, and presented to other users.

4. Information management, the fourth pedagogical pillar, comprises six components that together present the contents that each student generates. This includes building a personal profile, tagging and retrieving information, uploading and managing images and other visualization features, handling shared questions, and managing the generated multimedia and inquiry questions. The platform promotes ICT practice and literacy by encouraging students to use http protocols, and to upload, edit, or delete contents and multimedia features.

Overall, *AugmentedWorld* serves as an interactive learning platform for both question generators and question solvers (Figure 8.4). Question generators can create and share multimedia questions, write explanations for immediate feedback, and connect scientific topics to authentic locations on a digital interactive map. They can also generate and share inquiry questions, analyze data collected by others, and publish their results and conclusions. Question solvers can answer multimedia questions, provide peer assessment to help improve the questions, receive immediate feedback, and provide additional information upon the digital map. They can also participate in inquiry projects, based on citizen science, collect data, and upload it to the online platform.

Evidence for effectiveness

In the previous section, we described the *AugmentedWorld* platform and its pedagogical pillars. In this section, we report on the implementation of the platform among pre-service science teachers, prior to its implementation in schools. An exploratory study was conducted to provide insights into the way

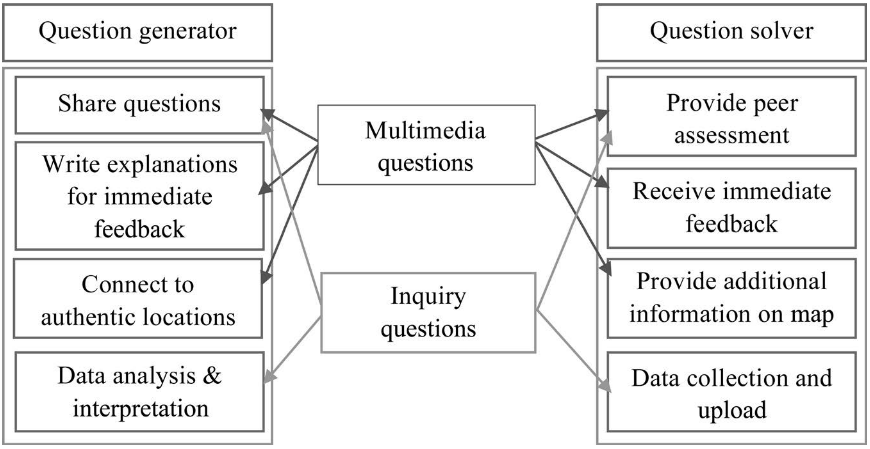

FIGURE 8.4 Activities of question generators and question solvers using *AugmentedWorld*.

pre-service science teachers generate location-based online questions. The study examined views on *AugmentedWorld*'s pedagogical attributes and on the impact a question-generating taxonomy has on the quality of the learning outcomes.

This goal raised the following research questions:

1. What are the views of pre-service science teachers about the *AugmentedWorld* platform?
2. What is the quality of location-based questions generated by pre-service science teachers?
3. What is the quality of peer-assessment performed by pre-service science teachers?

Participants and settings

The study included 98 pre-service science teachers, of which 64% were females and 36% were males. The teachers ranged in age between 20 and 31 years ($M = 24$, $SD = 3.7$). They were introduced to the *AugmentedWorld* platform in the framework of a science teaching methods course. They received explanations on how to generate multimedia questions and were exposed to examples from the PISA assessment tool (OECD, 2016). Their learning assignment included the generation of a multimedia-rich multiple-choice question on any topic from the science and technology curriculum, adding information points on a digital map, and providing peer assessment.

All the teacher participants worked on the same question-generating assignment via *AugmentedWorld*, which included four 2-hour classroom sessions and about 6 additional hours of online and outdoor activities. In order to make comparisons, the participants were randomly divided into two groups: those who were introduced to the question-generating taxonomy ($N = 58$) and those who were not ($N = 40$). The question-generating taxonomy is presented in the next section.

Question-generating taxonomy

A question-generating taxonomy, adapted from Barak and Rafaeli (2004), was used to evaluate and grade the participants' learning outcomes based on four components: authentic situation, multimedia, cognitive level, and relevant location (Table 8.1). Each component was graded on a 3-point scale with a maximum score of 12, which was weighted to 100 points.

Methodology, data collection, and analysis

The study employed the convergent parallel mixed methods approach (Creswell, 2014), merging quantitative and qualitative data to provide a comprehensive examination. Data were collected through semi-structured interviews and analysis of digital documents, consistent with the case study method in educational research (Stake, 1980). The semi-structured interviews took place in a computer classroom as informal conversations between the researchers and the pre-service science teachers, as the latter were generating multimedia-rich questions using the *AugmentedWorld* platform. The researchers examined the

TABLE 8.1 Components and learning outcomes of the question-generating taxonomy

Component	*Learning outcome (on a 3-point scale)*
Authentic situation	• Weak or no connection between the question and an authentic event (e.g., chemical energy and car accident) • Strong connection with no explanations (e.g., chemical energy and photosynthesis in plants) • Strong connection with elaborated explanations (e.g., chemical energy and an explanation of the photosynthesis process)
Multimedia	• Non-original videos, animations, or pictures, uploaded from web-based sources (e.g., Google apps) • Simulations from web-based sources (e.g., YouTube, Phet) • Original videos, animations, or simulations, created by the learner (self-production using digital cameras or smart phones, and graphical apps)
Cognitive level	• Memorization of scientific concepts (content knowledge) • Comprehension of scientific processes (procedural knowledge) • Application of scientific principles and constructs (epistemic knowledge)
Relevant location	• General location (e.g., ocean, desert, forest) • Specific location, remote from student environment (e.g., a certain museum, a certain pond) • Specific location, close to student environment (e.g., home, neighborhood)

participants' views by asking general questions, such as: "What are your views about the question-generating assignment?," "Can it contribute to science teaching and learning, and how?," "What science learning competencies can it develop among learners?"

The participants' answers were documented in researcher logs and analyzed using the inductive analysis method, which is an open-coding approach that enables themes to emerge from raw data (Hsieh & Shannon, 2005). The qualitative analysis included three main steps. First, we marked relevant text segments that (explicitly or implicitly) revealed the participants' views on the question-generating assignment. Second, the marked text segments were rearranged in new paragraphs according to four emerging themes. Third, an inter-rater reliability test was conducted, yielding Cohen's kappa of 0.81.

The digital documents included multimedia-rich questions and peer assessments. The multimedia-rich questions were examined by applying a deductive content analysis process that examined whether the question taxonomy contributed to the quality of questions, and how. The deductive analysis was based on the four components of the question-generating taxonomy: authentic situation, multimedia, cognitive level, and relevant location. For statistical purposes, the taxonomy's 3-point scale, with a maximum of 12 points, was weighted to 100 points, and averages for each component were calculated.

The peer assessment comments were analyzed according to four coding categories: Reinforcement, Statement, Verification, and Elaboration (Usher & Barak, 2018). *Reinforcement* refers to comments that provide a general praise or criticism that is not specifically directed at the project contents, and has little, if any, contribution to its improvement. S*tatement* refers to comments that include factors that are present or missing in the assessed work, with little explanation. *Verification* refers to comments that determine whether the work complies with the assignment requirements, and *Elaboration* refers to comments that identify scientific gaps in the assessed work and include suggestions for revision and improvement.

The Reinforcement and Statement categories both require some cognitive effort on the part of the assessor and provide peers with little means for improving their work. They are, therefore, considered to be lower-order thinking skills. Verification requires analytical capacity and, therefore, represents a medium-high level of thinking, whereas Elaboration requires synthesis and evaluation capabilities, indicating higher cognitive abilities. Three science education experts conducted analyses based on the above-mentioned categories. A series of inter-rater reliability tests, which included Cohen's kappa measurement, indicated a high agreement rate of 0.84.

We used IBM SPSS software, version 23, to analyze the quantitative data. Descriptive statistics (e.g., means and frequencies) were summarized, and inferential tests were performed. Statistically significant tests (e.g., independent *t*-tests and chi-square) were conducted to examine the differences between the two research groups.

Findings

Views of pre-service science teachers on AugmentedWorld

Interview transcripts indicated four main competencies that the *AugmentedWorld* assignment may promote: contextualization, creativity, critical thinking, and ICT literacy. The following paragraphs present detailed descriptions of each competency and selected excerpts from participant interviews.

Contextualization, the first competency, refers to the ability to understand science by making connections between scientific concepts and personal experience (Giamellaro, 2014; Lave & Wenger, 1991). According to the interviewees, this ability was advanced by generating questions that refer to real-world applications and relevant locations. Contextualization was not easy for the participants because they were not skilled in connecting scientific topics to authentic events or daily life. For example, H.A., a pre-service biology teacher, said: "We are constantly advised to teach while connecting scientific topics to authentic events. We are provided with examples from international tests such as PISA, but we do not practice creating questions. The AugmentedWorld assignment allowed us to apply theory in practice." D.L., a physics student who is studying for a teaching certificate, said: "Although I was aware to the fact that 'science is all around us', it was difficult for me to generate an interesting multimedia question on the Coriolis Effect and connect it to a relevant location on a map."

Creativity, the second competency, refers to the ability to think outside the box, to generate original ideas, and create new things (Osborne, et al., 2003). According to the participants, this ability was encouraged by creating and uploading multimedia features (videos, animations, simulations), since the creation of original multimedia features requires intuitive and associative cognitive operations on the part of the participants. For example, L.K., a pre-service science teacher, said: "I generated a question on the impact of changes in species diversity on dissolved oxygen in water. I added a graph that shows the change in global temperature and carbon dioxide concentration over a period of 120 years. I also added a video about the effect of global warming on the diversity of coral; all these features were connected in a creative way to form a high-level multiple-choice question." T.D., a pre-service chemistry teacher, was surprised by her ability to produce a creative question: "I am usually very creative in many areas, but to generate a scientific question in a creative way is a new challenge for me."

Critical thinking, the third competency, refers to the ability to think in a clear, rational, and informed way to form a knowledgeable judgement (Barak, Ben-Chaim, & Zoller, 2007). According to the participants, this ability was encouraged by the need to provide feedback and assess questions generated by their peers. For example, H.A., a pre-service biology teacher, stated: "In order to provide good feedback, I had to read each question and information point carefully and critically, see if all the requirements were met, examine whether the work complies with the scientific facts, and provide explanations about why the question is good or bad." J.O., a pre-service chemistry teacher, said: "During the peer assessment task, we were asked to provide comments to help our classmates improve their questions… one question, about air pollution, was poorly written as it included mistakes. The information point on the digital map was not contributing to the understanding of the scientific topic, but rather included general information. Instead, I offered other ideas related to local factories that installed a device to reduce the emission of carbon dioxide."

Information and communication technology (ICT) literacy, the fourth competency, refers to the ability to use online applications and digital devices to generate, evaluate, manage, and communicate information (Barak, 2017a; Barak & Asakle, 2018). Participants indicated the importance of practicing the use of location-based social technologies in order to promote scientific understanding as well as ICT literacy. For example, D.S., a pre-service biology teacher, stated: "The AugmentedWorld assignment is a good way to promote science education among school students, as they are already connected to smart phones and laptop computers… They can build their personal profile, tag and retrieve information, create and manage multimedia features… It was an educative experience for me and I am sure it will be a great experience for school students." G.K., a pre-service physics teacher stated: "I am not a technology expert so I approached this assignment with many concerns; I was afraid I would not be able to operate the platform or that it would take me too long. I was surprised to see how easy it was to generate a question, to upload and manage images, and to create and embed videos… I was exposed to new and exciting ways of conveying information. I think it is important to expose school students to the same experience."

Quality of questions generated by pre-service science teachers

A deductive analysis of the online multiple-choice questions indicated that creating high-level multimedia-rich questions is challenging and difficult, even for pre-service science teachers. The majority of participants (62%) generated medium- or low-level cognitive questions that require memorization of scientific concepts with an emphasis on content knowledge. Less than one-third (28%) of questions generated required the comprehension of scientific processes, emphasizing procedural knowledge. Only 10% required the application of scientific principles. Our analysis showed that participants were moderately successful in generating questions that present authentic situations, such as in the case of the agricultural researcher, presented above. Most questions were situated in remote and general locations (e.g., ocean, desert, forest) and only 13% represented authentic situations from everyday life (e.g., home, neighborhood).

Overall, the difference between the pre-service science teachers who were introduced to the question-generating taxonomy and their counterparts, was statistically significant ($t(96) = 4.79$, $p < .001$). Compared to their counterparts, the question Taxonomy group received significantly higher scores for cognitive level of questions, connection of scientific topic to authentic situation, and indication of relevant location ($t(96) = 4.46$, $p < .001$; $t(96) = 2.60$, $p = .011$; $t(96) = 2.93$, $p = .004$, respectively). However, no significant difference was found for multimedia application (Table 8.2).

TABLE 8.2 Means, SD, and t-tests of outcomes, by research groups

Question-generating components	*Question taxonomy (N = 58)*		*Counterparts (N = 40)*			
	Mean	*SD*	*Mean*	*SD*	*t*	*p*
Cognitive level	75.29	23.00	55.00	20.74	4.46	.000
Authentic situation	62.64	24.24	50.00	22.64	2.60	.011
Relevant location	60.34	22.04	46.67	23.63	2.93	.004
Multimedia application	51.15	17.90	47.50	19.81	0.95	.345

Table 8.2 indicates that the participants' weakest area was the use of multimedia. Overall, we analyzed 264 multimedia elements (i.e., pictures, videos, animations, and simulations) and while most multimedia elements were static images (65.0%), a third were videos (31.0%), and only a few were animations (2.7%) or simulations (1.3%). Only 19 participants created original pictures, and only two created original videos. One original video focused on kinetic and potential energy, showing playground swings and the other video showed a kitchen-based demonstration related to the effect of pressure on the boiling point of water. Original images appeared in 30% of questions generated by the Taxonomy group and in only 7% of the counterparts' questions [$\chi^2(2, N = 98) = 16.57, p = .020$].

Quality of peer-assessment performed by pre-service science teachers

A deductive content analysis of participants' peer feedback identified 253 comment segments written by the pre-service science teachers who were introduced to the question-generating taxonomy ($M = 4.36$, $SD = 1.30$) and 137 comment segments written by their counterparts ($M = 3.43$, $SD = 1.01$). A relatively low percentage of comments, from both groups, were classified as *Reinforcement,* providing general praise or criticism. For example, N.M., a pre-service chemistry teacher, said: "I really liked this topic and it was really fun to read about. I think you did a really great job. Well done!" Since Reinforcement comments are general statements that do not specifically refer to scientific contents, they require lower order-thinking on the part of the assessor. They contribute little or nothing to improving the question.

Participants from both groups exhibited similar percentages of Statement and Verification comments (about 30% and 24%, respectively). The Statement comments refer to factors that were present in or absent from the assessed question. For example, B.L., a pre-service engineering teacher, said: "The information that you added on the map is very useful and interesting, and relates to the main [scientific] topic of the question, but it doesn't really help solve the question … And the video, although it presents an authentic situation, doesn't add new information, it just presents the formula [of the chemical compound] in a different way."

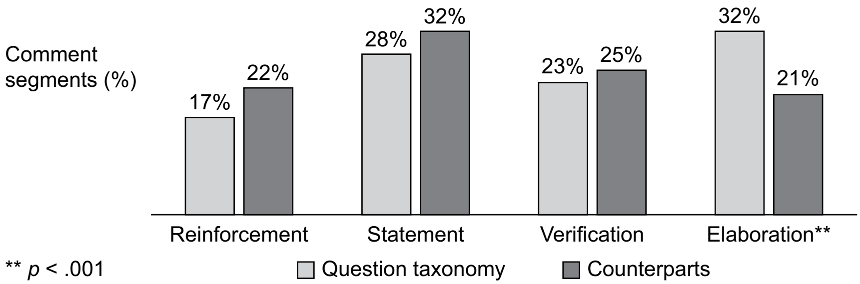

FIGURE 8.5 Distribution of the comment segments, by research group and feedback categories.

Verification comments refer to whether or not the question complies with the assignment requirements. For example, A.L., a pre-service physics teacher said: "After a lot of research and looking deeply into the [scientific] topic, I think this is an easy question, at least for me; it doesn't require higher-order thinking skills, and the right answer is quite obvious."

The Taxonomy group exhibited a high percentage of Elaboration comments, which identify deficiencies in the assessed work and include suggestions for improvement. For example, L.H., a pre-service physics teacher, stated: "I suggest adding two pictures of the same lake, one with the cyanobacteria in bloom and the other after the lake was treated, suppressing the proliferation of cyanobacteria. I also suggest that you replace the video with another one that explains how cyanobacteria bloom and how the dye restricts their proliferation… I think you should explain the term photosynthesis, because not all students are familiar with this term."

Figure 8.5 presents the distribution of the comment segments, by research group and feedback categories. The Elaboration-type comments, the highest level of feedback, were significantly more common among the Taxonomy group [$\chi^2(2, N = 98) = 23.83, p < .001$].

Conclusions and future studies

Question generation is the central pedagogical pillar of *AugmentedWorld*, facilitating two main types of questions: multimedia questions and inquiry questions. In recent decades, advanced technologies have facilitated question-generating activities (Barak & Rafaeli, 2004; Hardy et al., 2014), yet most online platforms are designed for the use of instructors and educational experts (e.g., Pundak, Shacham, & Herscovitz, 2013). Only a few encourage learners to take an active role as creators of content (e.g., Barak & Rafaeli, 2004; Hardy et al., 2014; Sanchez-Elez et al., 2014), and most lack features that support contextual learning using GPS. *AugmentedWorld* is unique in that it enables all users—students, teachers, and experts—to generate scientific questions and connect them to everyday life using interactive maps. It is also unique in that it enables users to collaborate (from remote locations), share their questions online, and provide peers with constructive assessment. Our study show that *AugmentedWorld* provides an innovative learning environment for the promotion of scientific thinking and the development of 21st-century skills. Our findings indicated that the question-generating assignment advances four competencies: contextualization, creativity, critical thinking, and ICT literacy.

The analysis of the cognitive level of the questions generated by the pre-service teachers showed that creating high-level multimedia-rich questions is a challenging and difficult task (even for pre-service science teachers). The majority of participants generated medium-level questions that required memorization of scientific facts. Only a small number of questions required the comprehension of scientific processes or the application of epistemic knowledge. Similar results were reported by Barak and Rafaeli (2004), who found that an online question-generating assignment can serve as both learning and assessment tools, but indicated that the level of the generated questions was less than expected.

Studies have indicated that generating a question that requires higher-order thinking is not a simple task (Hardy et al., 2014; Marbach-Ad & Sokolove, 2000). This can be explained by the fact that the generation of questions requires information processing and the activation of mental schemes that depend on a deep understanding of the topics at hand. To generate a high-level question, a learner must execute several cognitive and metacognitive operations, such as the identification of the core topic and the recognition of what information is required, and what one knows or needs to know (Barak & Asakle, 2018; Barak & Rafaeli, 2004). This study demonstrated that a possible way to raise the cognitive level of questions is by applying a question-generating taxonomy. The taxonomy presented in this study helped participants both produce better questions in terms of their cognitive level and connect the scientific concepts to everyday life situations. Our analysis showed that using the taxonomy, participants were relatively successful both in generating questions that present authentic situations and in connecting them to relevant locations on appropriate digital maps.

Regarding peer-assessment, the findings revealed that the pre-service science teachers applied critical thinking in providing helpful comments. The taxonomy group provided high-level comments that included constructive feedback and detailed suggestions for improvement. This reinforces the importance of providing participants with an elaborated question-generating taxonomy, as it assisted in the generation of meaningful feedback. Similar results were reported by Sanchez-Elez and colleagues (2014), who found that critical analysis skills can be enhanced by finding and solving possible mistakes in questions generated by fellow students. Based on our results and those obtained in previous studies (e.g., Barak et al., 2007; Sanchez-Elez et al., 2014), we can conclude that once required to provide a thorough assessment, learners are inclined to study the scientific topic more carefully and are more thoughtful in analyzing their peers' work.

Overall, the current study underlines the value of *AugmentedWorld* toward the cultivation of question generation and thinking skills. The use of *AugmentedWorld* provides teachers and students with the opportunity to generate multimedia-rich questions, following new trends in assessment (e.g., Barak & Asakle, 2018; OECD, 2016). However, providing a tool like *AugmentedWorld* might be insufficient on its own because we need to develop teachers' and students' cognitive and metacognitive operations necessary for high-level question generation and assessment skills. Such cultivation is possible and can be relatively simple with the provision of the question taxonomy, as demonstrated in this study. It may also be helpful to extend training to include additional practice that will put more emphasis on higher-order thinking skills and the creation and effective use of multimedia features.

Research on the generation of location-based multimedia-rich questions as a teaching strategy is still in its infancy (Barak & Rafaeli, 2004; Hardy et al., 2014; Sanchez-Elez et al., 2014). Given its importance to scientific thinking and to 21st-century skills, further research should examine cognitive and metacognitive processes of the creation of questions. Possible questions are: "How can student-generated questions be best implemented in various STEM fields and for various age ranges?," "Should the generated questions be used for practice and/or be incorporated into exams?," "Can such questions promote students' motivation to learn science by helping them connect the material to authentic locations and real-world events?"

References

Barak, M. (2014). Closing the gap between attitudes and perceptions about ICT-enhanced learning among pre-service STEM teachers. *Journal of Science Education and Technology*, *23*(1), 1–14.

Barak, M. (2017a). Science teacher education in the twenty-first century: A pedagogical framework for technology-integrated social constructivism. *Research in Science Education*, *47*(2), 283–303.

Barak, M. (2017b). Cloud pedagogy: Utilizing web-based technologies for the promotion of social constructivist learning in science teacher preparation courses. *Journal of Science Education and Technology*, *26*(5), 459–469.

Barak, M. (2018). Are digital natives open to change? Examining flexible thinking and resistance to change. *Computers & Education*, *121*, 115–123.

Barak, M., & Asakle S. (2018). *AugmentedWorld:* Facilitating the creation of location-based questions. Accepted pending modifications. *Computers & Education*, *121*, 89–99.

Barak, M., & Rafaeli, S. (2004). On-line question-posing and peer-assessment as means for web-based knowledge sharing in learning. *International Journal of Human-Computer Studies*, *61*(1), 84–103.

Barak, M., Ben-Chaim, D., & Zoller, U. (2007). Purposely teaching for the promotion of higher-order thinking skills: A case of critical thinking. *Research in Science Education*, *37*(4), 353–369.

Barak, M., & Ziv, S. (2013). Wandering: A web-based platform for the creation of location-based interactive learning objects. *Computers & Education*, *62*, 159–170.

Bell, R. L., Maeng, J. L., & Binns, I. C. (2013). Learning in context: Technology integration in a teacher preparation program informed by situated learning theory. *Journal of Research in Science Teaching*, *50*(3), 348–379.

Brown, S. I., & Walter, M. I. (2005). *The art of problem posing* (3rd ed.). Hillsdale, NJ: Lawrence Erlbaum.

Chin, C., Brown, D. E., & Bruce, B. C. (2002). Student-generated questions: A meaningful aspect of learning in science. *International Journal of Science Education*, *24*(5), 521–549.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Thousand Oaks, CA: SAGE.

Crippen, K. J., Ellis, S., Dunckel, B. A., Hendy, A. J. W., & MacFadden, B. J. (2016). Seeking shared practice: A juxtaposition of the attributes and activities of organized fossil groups with those of professional paleontology. *Journal of Science Education and Technology*, *25*(5), 731–746.

Dori, Y. J., & Herscovitz, O. (1999). Question-posing capability as an alternative evaluation method: Analysis of an environmental case study. *Journal of Research in Science Teaching*, *36*, 411–430.

Giamellaro, M. (2014). Primary contextualization of science learning through immersion in content-rich settings. *International Journal of Science Education*, *36*(17), 2848–2871.

Hardy, J., Bates, S. P., Casey, M. M., Galloway, K. W., Galloway, R. K., Kay, A. E., … McQueen, H. A. (2014). Student-generated content: Enhancing learning through sharing multiple-choice questions. *International Journal of Science Education*, *36*(13), 2180–2194.

Herscovitz, O., Kaberman, Z., Saar, L., & Dori, Y. J. (2012). The relationship between metacognition and the ability to pose questions in chemical education. In A. Zohar & Y. J. Dori (Eds.), *Metacognition in science education: Trends in current research* (pp. 165–195). Dordrecht, The Netherlands: Springer-Verlag.

Hofstein, A., Navon, O., Kipnis, M., & Mamlok-Naaman, R. (2005). Developing students' ability to ask more and better questions resulting from inquiry-type chemistry laboratories. *Journal of Research in Science Teaching*, *42*, 791–806.

Hsieh, H.-F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research*, *15*(9), 1277–1288.

Ketelhut, D. J., Nelson, B., Schifter, C., & Kim, Y. (2013). Improving science assessments by situating them in a virtual environment. *Education Sciences*, *3*(2), 172–192.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. New York: Cambridge University Press.

Marbach-Ad, G., & Sokolove, P.G. (2000). Can undergraduate biology students learn to ask higher questions? *Journal of Research in Science Teaching*, *37*, 854–870.

OECD (2016). Socio-economic status, student performance and students' attitudes towards science. In *PISA 2015 results (Vol. I): Excellence and equity in education*. Paris: OECD.

Osborne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003). What "ideas-about-science" should be taught in school? A Delphi study of the expert community. *Journal of Research in Science Teaching*, *40*, 692–720.

Price, C. A., & Lee, H-S (2013). Changes in participants' scientific attitudes and epistemological beliefs during an astronomical citizen science project. *Journal of Research in Science Teaching*, *50*(7), 773–801.

Pundak, D., Shacham, M., & Herscovitz, O. (2013). Integrating online assignments checking in introductory courses. *Journal of Information Technology Education: Research*, *12*, 191–202.

Sanchez-Elez, M., Pardines, I., Garcia, P., Miñana, G., Roman, S., Sanchez, M., & Risco, J. (2014). Enhancing students' learning process through self-generated tests. *Journal of Science Education and Technology*, *23*(1), 15–25.

Stake, R. (1980). The case study method in social inquiry. In H. Simons (Ed.), *Towards a science of the singular: Essays about case study in educational research and* *evaluation* (pp. 62–73). Norwich, England: Centre for Applied Research in Education, University of East Anglia.

Usher, M., & Barak, M. (2018). Peer assessment in a project-based engineering course: Comparing between on-campus and online learning environments. *Assessment and Evaluation in Higher Education*, *43*(5), 745–759.

Yu, F-Y., & Chen, Y-J. (2013). Effects of student-generated questions as the source of online drill-and-practice activities on learning. *British Journal of Educational Technology*, *45*(2), 316–329.