Location-Based Learning and Its Effect on Students’ Understanding of Newton’s Laws of Motion

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Abstract
Location-based learning refers to place-based education conducted online with the use of geographic information systems and mobile devices; with the shift to distance learning, its integration in science education warrants careful evaluation. The goal of this study was to examine the effect of location-based learning on students’ understanding of Newton’s laws of motion and to characterize the learning outcomes. The participants were 373 eighth-grade students, divided into two groups: control (n = 167) — teacher-centered, textbook-oriented instruction — and experimental (n = 206) — student-centered, location-based learning. The study applied a quasi-experimental research design, within a framework of a mixed-methods approach, in which data were collected through pre- and post-questionnaires and the analysis of students’ learning outcomes. The findings indicated a significant positive effect for the location-based learning approach on students’ ability to generate and answer science-related questions, provide reasoned explanations, and connect scientific topics to daily life. Significant relationships were indicated between students’ ability to generate questions and their ability to provide reasoned explanations. The study points to the importance of engaging students in location-based learning and in the process of generating science-related questions, information points on a digital map, and multimedia features.

Keywords Location-based technology · Newton’s laws · Middle school · Online learning · Student-generated contents

Introduction
In the last year, science teaching and learning experienced a shift to online education, due to COVID-19 closure of schools. The impact on learners is unprecedented, given that in 2020, there were over 1500 million students worldwide, from elementary to high school, who could not attend their classrooms (UNESCO, 2020). The transition to online learning requires the acquisition of new learning skills, such as digital content creation, remote collaboration, and online communication (Asakle & Barak, 2020; Lawrie et al., 2016). Although technology can provide learning continuity when students cannot be physically present in schools, it is necessary to introduce online tools that support science education and the required curricular outcomes. However, this can be challenging to many science teachers and students who were not trained to transfer best practices from the classroom to the online environment.

Even before the current crisis, national and international reports stress the need to improve students’ achievements in science education (NGSS Lead States, 2013; OECD, 2016; Schleicher, 2019). To this end, researchers advocate the involvement of school students in generating contents and questions as a way for reinforcing their scientific understanding (Hardy et al., 2014; Herscovitz et al., 2012; Sanchez-Elez et al., 2014). Researchers also maintain the importance of contextualization and the promotion of students’ ability to connect scientific concepts to daily life (Barak & Asakle, 2018; Bell et al., 2013). Indeed, the promotion of science education is one of the main challenges of the twenty-first century (NRC, 2012; Schleicher, 2019). It stems from the need for well-educated citizens who, among other skills, are able to think critically and generate informative questions.

“Questions” are usually thought of as something teachers impose on students while presenting fact-demanding...
Place-based education and location-based learning in science education

Place-based education is a pedagogical approach that features experiential learning rooted in local environments and cultures (Anderson, 2017; Gruenewald & Smith, 2008). It utilizes cultures, history, heritage, and local experiences, for learning various topics across the curriculum (Anderson, 2017). The students’ surroundings, such as the schoolyard, home, neighborhood, and/or town, are used as learning resources. In science education, place-based education refers to a situated method that involves learning about local issues in authentic settings (Feldman et al., 2018). Place-based science education builds on local problems to advance students’ understanding of scientific topics and environmental issues (Semken & Freeman, 2008). While place-based education is a well-established pedagogy (e.g., Anderson, 2017; Feldman et al., 2018), the use of location-based technologies is gaining interest due to the shift to online learning (Asakle & Barak, 2020; Chen et al., 2019).

Location-based technologies facilitate place-based education as they involve students in outdoor learning, allowing them to connect topics to local and cultural scenarios (Asakle & Barak, 2020; Chen et al., 2019). Location-based learning utilizes geographic information systems, mobile devices, and digital sensors to situate the learners in various geographical locations and provide them with both physical and virtual learning experiences (Asakle & Barak, 2020; Barak & Ziv, 2013; Chen et al., 2019). Location-based platforms facilitate science learning in an authentic and collaborative manner (Barak & Asakle, 2018; Barak & Ziv, 2013). They enable students to link scientific contents to daily life through the use of digital maps as a source for online active and interactive learning (Barak & Asakle, 2018; Barak & Ziv, 2013). Location-based platforms can situate learners in local scenarios, involving them in real-life learning situations, and promote contextualized learning (Asakle & Barak, 2020; Chen et al., 2019). As science education increasingly uses online technologies, the role of location-based learning among school students warrants examination (Barak & Asakle, 2018; Chen et al., 2019).

In the last decade, online technologies have facilitated science learning through modeling, simulations, data analysis, and the generation of learning communities (e.g., Barak, 2017; Kern & Crippen, 2016; Lawrie et al., 2016). Online technologies have shown promising possibilities for shifting from traditional teaching of scientific facts to active and interactive construction of knowledge (Barak, 2017; Bell et al., 2013; Kern & Crippen, 2016). In this regard, location-based platforms bring a new perspective as they are designed to utilize geographic information and global positioning systems, high-quality cameras, and social media to involve students in authentic and contextual learning (Asakle & Barak, 2020; Chen et al., 2019). They provide an inclusive learning experience through the use of digital maps and on-site investigations, allowing students to connect learning topics to phenomena that occur in the schoolyard, home, and/or community (Barak & Ziv, 2013; Chen et al., 2019). Studies show that location-based learning can create a sense of immersion by placing the students in authentic situations so that they learn in a practical and natural manner (Chen et al., 2019). It situates the students in authentic scenarios, with a potential of enhancing contextualization, creativity, critical thinking, and information and communication technology literacy (Barak & Asakle, 2018). However, monitoring school students’ online learning process and outcomes merits an in-depth examination of specific science topics.
In light of the aforesaid, the current study focused on school students’ location-based learning of Newton’s laws of motion. This corresponds with studies that examined novel instructional methods to promote students’ understanding of topics in physics (e.g., Hutchins et al., 2020; Anderson & Wall, 2016). The topic of Newton’s laws of motion was purposefully examined for two main reasons. First, it is a core topic in classical mechanics, basis for understanding motion, force, acceleration, displacement, gravity, etc. Second, it is a topic that many students find it difficult to understand (Atasoy & Ergin, 2017).

Methodology

Goal and Participants

The goal of this study was to examine the effect of location-based learning on students’ understanding of Newton’s laws of motion and to characterize the learning outcomes. This goal raised two research questions:

1. What is the effect of online location-based learning on students’ understanding of Newton’s laws?
2. What characterizes students’ location-based learning outcomes and their interrelationships?

In the current study, location-based learning was examined through students’ ability to generate and answer science-related questions, provide reasoned explanations, and connect scientific topics to daily life.

The study was conducted in four middle schools situated in Druze villages in Israel, among grade eight students (n = 373). The Druze community was purposely chosen as a case of a marginalized population. Druze children learn in a separate school system, in dispersed villages. Most Druze classrooms are based on traditional teacher-centered instruction; partially due to the traditional way of living and partially because of lack of resources and guidance. Throughout the years, not enough effort has been made to design relevant learning activities. In collaboration with the Ministry of Education and funded by the Ministry of Science and Technology, the current study provided students with access to technology. In addition, science teachers were engaged in professional development workshops. Thus, the current study is unique in providing Druze schools with resources to move toward twenty-first century education.

Method

The study applied a pre-test post-test quasi-experimental research design (Shadish et al., 2002), within a framework of a mixed-methods approach (Creswell, 2014). This method was used to provide a comprehensive response to the research goal and questions through the collection and analysis of both quantitative and qualitative data. The quantitative data were used to examine the effect of online location-based learning on school students; thus, responding to the first research question. The qualitative data were collected to characterize students’ location-based learning outcomes; thus, responding to the second research question.

In each school, grade eight classes were assigned to experimental and control groups, with randomization performed on the group level, not on the individual level (Shadish et al., 2002). The control group (n = 167) studied via traditional, teacher-centered, textbook-oriented instruction, while the experimental group (n = 206) studied via student-centered, location-based learning. Although the participants were assigned to groups equally, data were collected only from those who signed an informed consent form. In order to assess comparability, chi-square analysis indicated no statistically significant differences between the research groups in the distribution of gender, age, and socio-demographic background.

The current study ensured equity through close cooperation with the Ministry of Education, making sure that all the schools are equipped with computers and that all the students have access to technology. We provided free access to the online platform and free workshops for the science teachers in their schools. To ensure the research is conducted in an ethical manner, the participants were informed that participation is voluntary, and they were given the choice to withdraw at any time. To protect their anonymity, names and contact information were concealed by codes. The study was administered according to the university’s ethical guidelines, receiving an IRB approval, as well as an ethical clearance from the Office of the Chief Scientist at the Ministry of Education.

Settings

Following the national curriculum, the students in both groups studied the topic of Newton’s laws of force and motion for about 6 weeks and worked on homework assignments for about 2 h per week. This topic was chosen since it is a basic theme in classical mechanics that many students find difficult to understand (Atasoy & Ergin, 2017). Instruction included teacher’s explanations, describing the way in which an object moves when acted on by forces. The students discussed Newton’s first law and the practicality of the idea that an object at rest will remain at rest unless acted on by a force, and an object that is moving will continue moving in a straight line unless a force acts to change its speed or direction. The students also discussed Newton’s second and third laws of motion. They were exposed to situations where an object that is acted on by a force accelerates...
in the direction of that force. They were also exposed to situations that demonstrated that for every action force, there is an equal and opposite reaction force. The difference between the research groups was in the exercise activities. The control students were engaged in answering questions presented in a textbook or given by the teachers, while the experimental students were engaged in the location-based learning activity.

**The Location-Based Learning Activity**

The location-based learning activity was conducted via the AugmentedWorld platform (http://augmentedworld.site), which is an online tool for generating, sharing, solving, and evaluating science-related questions (Barak & Asakle, 2018). AugmentedWorld facilitates the creation and sharing of open-and closed-ended questions, allowing users to contribute location-related authentic contents. Building on Google Maps application, AugmentedWorld allows teachers and students to provide layers of scientific information, using text, images, and videos, in a collaborative and accumulative way, hence the name “Augmented World.”

The location-based learning activity included five stages:

1. **Generating a question:** Using the “Question” tab, the students generated a question on a topic related to Newton’s laws (e.g., forces, motion, energy, gravity). To reinforce their conceptual understanding of the topic, they were asked to write a scientific background for the chosen topic and then compose a multimedia-rich multiple-choice question that presents the scientific topic in a daily perspective. The students were instructed to write one correct answer and three distractors. For example, M.Y., an eighth-grade student, generated a question on balanced forces by presenting children playing tug-of-war (rope pulling), a common game played in his schoolyard. The question included a video that refers to zero acceleration under the action of balanced forces, where the effect of one force is cancelled by another (Fig. 1).

2. **Generating a location-based information point:** Using the “Map” tab, the students generated an information point on a digital map with explanations and visual representation of the scientific phenomenon at the center of their question (e.g., force, motion, energy, mass, gravity). They used a mobile device, such as a smart phone or tablet, to take a picture or a short video clip of a daily-life situation. Then, they were asked to write a description of the scientific phenomenon and place the text and the picture, or video, on a digital map, thus generating a location-based information point attached to their question.

3. **Sharing a question:** Clicking on the “Share” button, the students provided open access to their question. The students were asked to choose three or more questions generated by their classmates, read the introduction, watch the video, answer the question, and learn more on the scientific topic via the location-based information points located on the digital map.

4. **Adding a location-based information point:** Using the Map tab, the students added location-based information points to questions generated by their classmates. This required them to connect the scientific phenomenon that was at the center of their peers’ question to daily life. The students were encouraged to use a mobile device to take pictures or short video clips, and to add complementary scientific information, relevant to a specific location, on a digital map.

5. **Providing peer assessment:** Using the “Comments” tab, the students were able to provide feedback to the questions and information points that were generated by peers.

**Instruments**

Data collection was conducted by administrating pre- and post-questionnaires and the analysis of location-based learning outcomes, as detailed below.

The **Questionnaire** was administered before and after the intervention to both control and experimental students, in order to examine the effect of location-based learning on school students’ understanding of Newton’s laws of motion (i.e., answer the first research question). The questionnaire included an open question that examined students’ ability to generate a multiple-choice question on a scientific topic with
reference to daily life. It also included six multiple-choice questions on forces and motion, adapted from a standardized test for grade eight students. Examples of questions are: A father and son are pulling a force meter, each at a force of 100 Newtons. What does the force meter show? Different forces act on a toy car, as depicted in the photo. How will these forces affect the car? Forces acting on a ball cause it not to move at a constant speed. In order for the ball to move at a constant speed, additional force must be applied to it. In which direction should this force act?

For each multiple-choice question, the students were asked to (a) choose the correct answer, (b) explain their choice, and (c) connect the scientific topic to daily life. Choosing the answer was graded according to 0 (wrong answer) or 2 (correct answer). Providing a reasoned explanation and connecting the topic to daily life were each graded on a scale of 0 (no answer), 1 (partial answer), and 2 (good answer). Since there were six multiple-choice questions, each part received a maximum score of 12, which was converted to a scale of 100.

The questionnaire’s validity was established by five science teachers and seven experts in science education, with MSc or Ph.D. degrees. The content validity ratio (CVR) was calculated for each item, using Lawshe (1975) equation: CVR = (E – N/2)/(N/2), where N is the total number of assessors, and E is the number of assessors who rated the item as essential. The obtained CVR was 100%, conducting to examine the differences between the control and experimental research groups.

The analysis of the Location-based learning outcomes was conducted to characterize and assess the contents that the students generated while using the AugmentedWorld platform (i.e., answer the second research question). The study applied the deductive content analysis approach (Creswell, 2014) based on four indicators: cognitive level, authentic situation, relevant location, and multimedia design. The four indicators were specified and validated in previous study (Barak & Asakle, 2018). “Cognitive level” refers to students’ ability to understand a scientific topic by generating questions that require higher-order thinking. “Authentic situation” refers to students’ ability to connect a scientific topic to authentic events and/or personal experiences. “Relevant location” refers to students’ ability to make connections between scientific concepts and the locations where they are likely to occur. “Multimedia design” refers to students’ ability to generate and use multimedia-rich features that visualize a scientific topic. Each of the four indicators was graded on a 3-point performance scale: no answer = 0, low = 1, medium = 2, and high = 3. The maximum score was 12 points, which equals 3 points for each of the 4 indicators. For analysis purposes, the scale was converted to 100. An example of a question generated by K.L., an eighth-grade student, and its scoring, is presented below. The question was translated from Arabic.

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**In a car accident, which of the following statements follows Newton's third law of motion?**

- The action force is the cars hitting each other; the reaction is the equal forces sent back to each car [Correct answer]
- In a car accident, action and reaction affect only the smaller car, not the big car.
- The action and the reaction forces in a car accident are equal and have the same direction.
- When two cars crash, the big car applies more force on the small car.
- Action and reaction affect both crashing cars and have the different amount and same direction.

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The question’s quality was determined according to four indicators, on a scale of 1 to 3. “Cognitive level” received 3 points, since it presents a good question, a sound correct answer, and suitable incorrect alternatives that require the understanding of Newton’s third law. “Authentic situation” received 3 points, since the question presents a real-life situation. “Relevant location” received 2 points, since...
the information point was set on a road in K.L.’s village, but he did not provide any explanation (Fig. 2). We can only assume that a car accident happened on this road. “Multimedia design” received 2 points, since the question includes a non-original video, but the photo was original. Overall, the question received 10 points out of 12, obtaining 83 points out of 100.

The inter-rater reliability of the analysis and encoding process was established by two principle investigators who hold Ph.D. degrees in science education. Cohen’s kappa test showed a coefficient of 0.84, indicating a relatively high inter-rater agreement (Cohen, 1988). The construct validity of the analysis and encoding process was established by examining the association between the scale’s total score and the four subscales separately (Little, 2013). Pearson’s correlation analysis indicated statistically significant positive moderate-to-high correlations for cognitive level ($r(204) = 0.58, p = 0.001$) authentic situation ($r(204) = 0.72, p = 0.001$), relevant location ($r(204) = 0.78, p = 0.001$), and multimedia design ($r(204) = 0.48, p = 0.001$).

Findings

This section includes two parts, each provides an answer to one of the research questions. The first part presents the effect of online location-based learning on school students’ understanding of Newton’s laws, through their ability to generate and answer science-related questions, provide reasoned explanations, and connect scientific topics to daily life. The second part presents the students’ location-based learning outcomes, analyzed according to four indicators: cognitive level, authentic situation, relevant location, and multimedia design.

Location-Based Learning and Students’ Understanding of Newton’s Laws

The results of the pre-questionnaire indicated similar results for both the control and experimental groups, with low scores for the ability to connect a scientific topic to daily life ($M = 19.24, SD = 13.90; M = 20.42, SD = 12.94$, respectively), generate science-related questions ($M = 37.35, SD = 12.38; M = 38.18, SD = 12.45$, respectively), and provide reasoned explanations ($M = 34.68, SD = 16.54; M = 31.40, SD = 16.40$, respectively). Students from both groups received medium scores for their ability to answer questions in science ($M = 66.14, SD = 17.91; M = 62.90, SD = 16.33$, respectively).

In the post-questionnaire, the control group showed a significant gain only in the ability to answer questions related to Newton’s laws, whereas the experimental group showed significant gains in all four skills. Yet, despite the significant net gains, the experimental group students received medium scores for the ability to generate science-related questions and relatively low scores for connecting topics to daily life (Table 1).

Controlling the pre-scores, the results of the post-questionnaire indicated that the experimental group students obtained statistically significant higher scores, compared with their counterparts, with regard to generating science-related questions ($F(1, 372) = 37.40, p < 0.000, \eta_p^2 = 0.17$),
answering science-related questions \( (F(1, 372) = 267.30, p = 0.000, \eta_p^2 = 0.42) \), providing reasoned explanations \( (F(1, 372) = 108.82, p = 0.000, \eta_p^2 = 0.23) \), and connecting scientific topics to daily life \( (F(1, 372) = 20.98, p = 0.000, \eta_p^2 = 0.15) \). Using Eta-squared analysis, the effect size indicated moderate but significant results, ranging between 15 and 42%.

The Characteristics of Students’ Location-Based Learning Outcomes and Their Interrelationships

The eighth-grade students’ learning outcomes were analyzed and coded, according to the contents that were generated and uploaded to the AugmentedWorld platform. Overall, the students’ outcomes in terms of cognitive level, authentic situation, relevant location, and multimedia design showed medium results, on a scale of 100 (Table 2).

Cognitive level, which refers to students’ ability to generate questions that require higher-order thinking, received the highest average grade, but with a mean score of 53.10 (± 15.70). Authentic situation, which refers to students’ ability to understand scientific topics by connecting them to personal experience and/or daily life, received a mean score of 48.50 (± 14.90). Similarly, multimedia design, which refers to students’ ability to generate multimedia-rich contents by using photos, audio, and videos, received a mean score of 47.30 (± 13.80). The lowest mean score of 38.10 (± 13.70) was assigned to relevant location, which refers to students’ ability to make connections between a scientific phenomenon and locations where it is likely to occur.

Content analysis of the location-based learning outcomes, from a “cognitive level” perspective, indicated that most of the students (63%) generated questions that require comprehension of scientific concepts, less than a third (29%) generated questions that require application of scientific processes, and only few (8%) generated questions that require higher-order thinking skills such as analysis or evaluation of scientific principles. The students generally included an explanation of Newton’s laws. For example, one student who generated a question on Newton’s third law wrote “A truck hits a car. Even though the truck is three times bigger than the car, the two vehicles applied the same force on each other. What physical law describes this phenomenon?” [cognitive level, 2 points]. Another example is: “Two students sit on identical chairs, facing each other. One of the students puts his feet on the other student’s chair, pushes it, and causes the chair to move. Which of the following sentences describes what happens during the push, as long as the first student’s legs touch the other?” The two examples above indicate a medium cognitive level. An example for a more elaborated question is: “According to Newton’s third law, whenever objects A and B interact with each other, they exert equal forces upon each other. The direction of forces between two objects is opposite. For example, if a mother pushes a baby carriage, the baby carriage also applies force to the mother. Another example is a man pushing against a door with his hand. According to the presented data, what are the forces acting on the man’s hand and the door?” [cognitive level, 3 points].

Content analysis of the location-based learning outcomes, from an authentic situation perspective, indicated that half of the students (51%) provided general or banal examples such as pushing a wall, pushing a box on a slope, collision between two objects, etc. Other students provided more personal and interesting examples, such as their own experience

| Location-based learning outcomes | Min | Max | Mean | SD |
|---------------------------------|-----|-----|------|----|
| Cognitive level                 | 25.00 | 88.00 | 53.10 | 15.70 |
| Authentic situation             | 23.00 | 82.00 | 48.50 | 14.90 |
| Relevant location               | 20.00 | 76.00 | 38.10 | 13.70 |
| Multimedia design               | 22.00 | 78.00 | 47.30 | 13.80 |

Table 2 Means and standard deviations of location-based learning outcomes \( (N=206) \)
on a playground slide, kicking a ball during a soccer match, a tug-of-war competition, climbing a nearby mountain, or a car accident in their village. For example, a student wrote: “In my brother’s room, there’s a desk. When he places a book on the table, the table exerts the same force on the book as the book on the table…” [authentic situation, 3 points]. Another student wrote: “I went with my parents to the village market and we saw a truck hit a car. I imagined how the size of the force that the truck exerted on the car equals to the size of the force the car exerted on the truck” [authentic situation, 3 points].

Relevant location refers to students’ ability to make connections between scientific concepts and the locations where there are likely to occur. Less than half of the students (42%) situated the location-based information points in close proximity such as their school, neighborhood, or home, others pointed to in remote, and general locations. An example of a student who placed a location-based information point in her neighborhood playground wrote: “…that’s where I play with my sister, and when I push down, the seesaw chair pushes me up” [relevant location, 3 points]. Another student who located an information point at his school wrote: “In this place my teacher placed two balls on a surface to demonstrate conservation of momentum and energy” [relevant location, 3 points]. An example of a remote location is the National Aeronautics and Space Administration in the USA (Fig. 3), where a student added a description of the spacecraft’s operation [relevant location, 2 points].

Multimedia design refers to students’ ability to generate and use multimedia-rich features that visualize a scientific topic. About 60% of the students’ location-based contents integrated multimedia, but only 5% included original images or video clips created by the students. The students used the videos as a way to add information, explain the scientific topic, and illustrate a particular situation. For example, a student uploaded a video she took at her home, describing an experiment of pulling a metal ball with a rope and the forces acting on the ball, she wrote: “Watch the next video and answer the question: What forces are shown?” [multimedia design, 3 points]. Another student used an original picture of a punching bag to illustrate a particular situation: “a boxer gives punches to a punching bag as shown in the following figure, what force is the punching bag reacting on the boxer’s hand?” [multimedia design, 2 points].

Pearson’s correlation identified a significant positive relationship between the students’ ability to generate questions and provide explanations in the post-questionnaire ($r=0.179$, $p<0.010$). This shows that the better they were able to explain their answer to a multiple-choice question, the better they were able to generate a question of their own. Significant positive correlations were also identified between

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**Fig. 3** Student-generated contents on aeronautics and space
the students’ ability to generate questions and the cognitive level of their learning outcomes \( r = 0.511, p < 0.000 \), as well as the quality of their multimedia design \( r = 0.152, p < 0.035 \). Analysis also identified a positive correlation between the students’ ability to provide explanations in the post questionnaire and the cognitive level of their learning outcomes \( r = 0.149, p < 0.033 \). A positive relationship was identified between the students’ ability to connect scientific topics to daily life in the post questionnaire and their relevant location score \( r = 0.733, p < 0.000 \). These significant relationships point to the importance of involving students in the generation of science-related questions, location-based information points, and multimedia features.

Discussion

Studies identified the educational potential of location-based learning, as it utilizes geographic information systems with the use of mobile devices (Barak & Asakle, 2018; Barak & Ziv, 2013; Chen et al., 2019). In the current study, location-based learning was conducted via AugmentedWorld platform (http://augmentedworldsite), by involving students in generating multimedia-rich questions and connecting them to daily life through the creation of digital information points. The findings of the study indicated a significant positive effect for location-based learning on eighth-grade students’ understanding of Newton’s laws. The following paragraphs discuss the experimental students’ gained abilities, with reference to the literature.

First, the experimental students’ significant development in their ability to generate questions on Newton’s laws of motion may point to successful construction of conceptual understanding of the scientific topic. Study maintains that the generation of questions involves cognitive operations such as the identification of the core topics, the recognition of what is known and unknown, and closing knowledge gaps by reviewing the learning materials (Barak & Rafaeli, 2004; Herscovitz et al., 2012; Kaberman & Dori, 2009; Sanchez-Elez et al., 2014). Accordingly, learning activities in which the learners generate location-based questions may enable students to learn and apply content at a deeper level. Hence, studies used location-based technologies to supplement and expand students’ learning experience (e.g., Barak & Ziv, 2013; Chen et al., 2019). Yet, in the current study, although the experimental students received significant higher scores compared with the control group, their average scores were less than expected. This supports the idea that student-generated content is a complex cognitive operation that requires modeling and repetitive practice (Asakle & Barak, 2020; Barak & Rafaeli, 2004).

Second, the experimental students’ significant development in their ability to provide reasoned explanations may point to the induction of cognitive and metacognitive processes. This is supported by the significant correlation that was identified in the current study between students’ ability to provide explanations and the cognitive level of their learning outcomes. The importance of engaging students in scientific explanation activities is well recognized as it requires the examination of data from different perspectives, looking for patterns, and connecting data to claims, evidence, and theory (Donnelly et al., 2016; McNeill & Krajcik, 2012). In this study, the students were engaged in looking for patterns while creating optional answers for the multiple-choice questions and in providing feedback during the peer assessment process. These activities require students to think about a justification for their feedback and provide clear and rationalized comments (Barak & Rafaeli, 2004; Fu-Yun & Wan-Shan, 2020; Hardy et al., 2014). Providing explanations requires information processing and the activation of mental schemes that depend on a deep understanding of the scientific topic (Barak & Rafaeli, 2004; Donnelly et al., 2016; Herscovitz et al., 2012). Our results correspond with studies that showed that the promotion of students’ scientific explanations is a complex process which requires a higher degree of participation and reinforcement (Donnelly et al., 2016; McNeill & Krajcik, 2012; Zhu et al., 2020).

Third, the experimental students’ significant development in their ability to connect scientific topics to daily life may point to a deep understanding of the scientific topic, not only theoretically but also practically, through personal experiences (e.g., Barak & Ziv, 2013; Bell et al., 2013; Mandrikas et al., 2017). In this study, the students used an interactive digital map to organize the learning contents according to locations where a phenomenon or a certain event happened (e.g., home, school, village). The use of digital maps on mobile devices creates a new way for contextualization by linking science contents with geographic locations (Barak & Asakle, 2018; Chen et al., 2019). Studies indicated that location-based learning is advantageous in creating interactive learning environment where the learning content is contextualized in concrete and authentic situations (Barak & Asakle, 2018; Chen et al., 2019). Indeed, it is well established that meaningful learning takes place through authentic experiences and learners’ understanding of daily life (Bell et al., 2013; Chen et al., 2019; Mandrikas et al., 2017). Yet, although the current study showed promise results, the experimental students’ overall average scores indicating that connecting scientific concepts to daily life is challenging for many students. The students were more inclined to connect topics related to Newton’s laws to general events with universal examples, as presented in textbooks, than find a more personal and culturally related event in a nearby location.
Conclusions Limitations and Further Research

The current study discusses the contribution of location-based learning to students' understanding of Newton's laws by engaging them in generating questions, providing reasoned explanations, and connecting topics to daily life. The study shows that location-based learning, through the use of the AugmentedWorld platform, can serve as a means to practice and develop these skills. This is particularly important in times where education is moving to the online environments, and teachers should be provided with validated ways to apply best practices (Barak & Asakle, 2018; Lawrie et al., 2016). Examining location-based learning from an evidence-based perspective, we identified significant positive relationships between the students' ability to generate questions and their ability to provide reasoned explanations. Significant connections were also found between the ability to generate questions, the cognitive level of the learning outcomes, and the quality of multimedia design. Thus, location-based learning has the potential to address science education challenges, such as the need to improve school students' achievements (OECD, 2016; Schleicher, 2019), involve students in generating science-related questions (Hardy et al., 2014; Kaberman & Dori, 2009), and connect scientific concepts to daily life (Barak & Asakle, 2018; Bell et al., 2013).

The current study applied a rigorous approach to data collection and analysis; however, limitations should be noted, as well as recommendations for further research. One limitation relates to the research participants, which included eighth-grade students learning one scientific topic, i.e., Newton's laws of motion. For generalization purposes, further studies should be conducted by applying location-based learning across grade cohorts and in a wide range of scientific topics. Such studies will provide further information about ways for promoting scientific thinking through question generation and the integration of outdoor and online learning. Another limitation is that the present study focal point was on the generation of multimedia-rich multiple-choice questions. It may be interesting to conduct studies in which the students are involved in generating open-inquiry questions, based on science-related phenomena in their close environment. Despite these limitations, we believe that our study provides an insightful perspective on location-based learning and students' understanding of Newton's laws. Science teachers and students may benefit from this study by applying the location-based learning approach via the free and adaptive AugmentedWorld platform.

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Declarations

Ethics Approval The authors confirm that the study was conducted according to the university's ethical guidelines, approved by the institutional review board (IRB) and the Office of the Chief Scientist at the Ministry of Education. The study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Consent Statement The authors affirm that informed consent was obtained from legal guardians.

Conflict of Interest The authors declare no competing interests.

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