



Technology-Enhanced Learning and Its Association with Motivation to Learn Science from a Cross-Cultural Perspective

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Accepted: 27 April 2023 / Published online: 12 May 2023
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Abstract

Fostering technology-enhanced science learning in elementary schools is an ongoing challenge as young students are not always motivated to engage with science lessons. The use of technology, such as digital sensors and data recorders, has been found to result in higher engagement with science. However, the association between technology-enhanced science learning and students' motivation to learn, from a cross-cultural viewpoint, is still discussed among researchers. Thus, the goal of this study was twofold: (a) to examine the motivation to learn science of elementary school students from different countries and cultural backgrounds; (b) to identify phases of technology-enhanced science learning and their association with students' motivation. Applying the sequential mixed-methods research design, data were collected via questionnaires, semi-structured interviews, and online observations. The study included seven experienced science teachers from the USA and Israel and 109 sixth-grade students: English speakers ($N=43$), Arabic speakers ($N=26$), and Hebrew speakers ($N=40$). The findings indicated differences in students' internal motivation, in terms of "interest and enjoyment," "connection to daily-life," and "cross-cultural interactions," with medium ratings for "self-efficacy." The study identified and characterized two consecutive phases of technology-enhanced science learning—"divergence" and "convergence"—that can be associated with motivation to learn science. Overall, the study's results highlight the importance of seamlessly embedding technology to support cross-cultural learning of scientific practices.

Keywords Cross-cultural · Elementary school · Motivation to learn · Technology-enhanced learning

Introduction

In today's post-pandemic world, educational experts are debating on the appropriate learning environments, with a basic concern of promoting students' motivation to learn science (e.g., Avargil, 2022; Dixon & Wendt, 2021). Research has stressed the benefits of engaging young students in science education for the well-being of society in a complex and uncertain world (NSTA, 2018; Sharples et al., 2015). Yet, student motivation to learn science continues to fall behind (e.g., Shin et al., 2019; Shwartz et al., 2021). Even prior to

the COVID-19 crisis, motivation to learn science and science as a career of choice has seen a constant decline (Lederman et al., 2019; Roller et al., 2020). Motivation to learn science is often regarded as the factors stimulating the students to gain scientific knowledge (Dixon & Wendt, 2021; Shin et al., 2019; Vedder-Weiss & Fortus, 2012). These factors can be internal or external drivers that stimulate learning and give it meaning. The subject of motivation to learn science has been tackled from various angles, including emphasizing the connectedness to real life (Barak & Asakle, 2018; Cetin-Dindar, 2015), involving gamification (Avargil, 2022; Yildirim, 2017), applying inquiry learning (Barak & Asakle, 2018; Furtak et al., 2012), and using learning technologies (Crippen & Archambault, 2012; Dixon & Wendt, 2021; Srisawasdi & Panjaburee, 2019).

Science education in elementary schools can be effective when it builds on children's intrinsic interest, capitalizes on the initial concepts and strategies children have acquired, and provides a suitable educational environment to nurture these concepts and strategies (NSTA, 2018). Research shows

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that learning science in the early years can foster children's curiosity and enjoyment in exploring the world around them (Barak & Dori, 2011; NSTA, 2018; Schellinger et al., 2019). High-quality elementary science education is necessary for establishing a strong foundation of learning in later grades, instilling enthusiasm for science, and addressing the need for a well-informed society (Sharples et al., 2015; NSTA, 2018). Various methods of teaching science in elementary schools have been developed and tested. The general conclusion is that when provided with high-quality science instruction, students can advance from curiosity to interest to reasoning and thus enhance their motivation to learn and scientific knowledge (e.g., Barak & Dori, 2011; Kang et al., 2016). Researchers have argued that to learn science one must do science by exploring how the world around us looks, sounds, smells, feels, and behaves (Cheng et al., 2019). Willingness to learn science can be achieved by utilizing interesting and motivating material (Barak & Dori, 2011; Srisawasdi & Panjaburee, 2019).

To understand what motivates elementary school students to learn science, we need to understand what characterizes this generation (Shin et al., 2019; Vedder-Weiss & Fortus, 2012). Elementary school students were born in an age when the internet, social media, and mobile devices have always existed. They regularly use online applications and are comfortable with network games that involve players from all over the world. Due to the pandemic, they were exposed to remote learning from a young age. This raises questions, such as: How can technology facilitate cross-cultural interactions in the service of science education? And whether and how can technology foster young students' motivation to learn science?

Technology as a Motivating Factor in Science Education

Discovery learning through inquiry is an established instructional strategy for the promotion of meaningful learning (Crippen & Archambault, 2012; Lederman et al., 2019). It involves students in asking questions, planning investigations, recording data, and discussing findings (NGSS Lead States, 2013; NRC, 2012). This has been a continuing trend in elementary school science curriculums around the world (Ben-Eliyahu et al., 2020; Harlen & Qualter, 2018). In science classrooms, students follow methods practiced by scientists in order to construct scientific knowledge (Harlen & Qualter, 2018; Lederman et al., 2019). With the shift to remote learning, technology, such as digital sensors and data spreadsheets, can support inquiry by helping students cultivate their ability to define a scientific question and work toward its solution (Barak & Shahab, 2022; Crippen & Archambault, 2012). Personalized technology can be designed to facilitate flexible

learning, adaptable to students' academic level and rate of progress (Barak & Asakle, 2018; Crippen & Archambault, 2012). Furthermore, technology places the learner in the center of the learning process and can promote active learning (Schellinger et al., 2019; Schwartz et al., 2021). Thereby, technology enables students to conduct investigations and discover scientific ideas and concepts that are new to them (Crippen & Archambault, 2012; Schellinger et al., 2019).

Despite the promising technology-enhanced practices described above, a study has indicated that students around the world have a limited understanding of scientific inquiry after completing elementary school (Lederman et al., 2019). These results raise the need for further exploration of science learning in this age group.

The emergency remote learning during the unexpected pandemic limits the reliance on prior science education research that was mainly conducted in the classroom environment (e.g., Crawford, 2014; Furtak, et al., 2012; Lamb et al., 2015). Thus, there is a growing need to explore the way technology may support elementary school students' remote learning. Science education in particular requires redefining learning to incorporate digital technologies as a leverage for motivation to learn. This is important since the technology may foster various forms of social constructivist learning, including cross-cultural collaborations (Schwartz et al., 2021).

Technology-Enhanced Science Learning in a Cross-Cultural Setting

Digital technologies provide many opportunities to shape educational systems to become suitable for today's global challenges (Cheng et al., 2019; Kohen, 2019; Schellinger et al., 2019). One of these opportunities relies on cross-cultural interactions, which can facilitate collaboration between learners from different countries and backgrounds. Leveraging technology to support cross-cultural interactions can address the need for collaborative and culturally inclusive learning (Barak & Shahab, 2022). Technology-enhanced science learning that is culturally sensitive can facilitate collaborative teamwork and expose students to diverse thinking skills (Barak & Shahab, 2022). Since thinking reflects the unique characteristics that a culture has transmitted to its members, technology-enhanced learning in a cross-cultural setting might help generate students' interest in learning. Our supposition is that the use of technology can support inquiry learning not only by facilitating the collection and analysis of data, but also by generating opportunities for international and cross-cultural collaborations.

Learning in collaboration, sharing information, and working in teams are enabled by online platforms and applications (Barak & Asakle, 2018; Barak & Shahab, 2022; Crippen & Archambault, 2012). Technology is mentioned in the

literature as a tool for supporting students with explicit instruction through peer collaboration and social knowledge construction (Schellinger et al., 2019; Schwartz et al., 2021). Researches maintain that informed decisions about the integration of technology in classrooms should be based on the value it adds to students' learning (Barak, 2014; Kohen, 2019). An effective inquiry learning design and implementation may increase students' motivation to learn science (Crawford, 2014; Lamb et al., 2015; Sharples et al., 2015). However, incorporating technology-enhanced learning frameworks in elementary school science is still limited, even though researchers agree that inquiry learning should start at an early age (Barak & Dori, 2011; Schellinger et al., 2019).

Research Goal

Thus, the goal of this study was twofold: (a) to examine the motivation to learn the science of elementary school students from different countries and cultural backgrounds; (b) to identify phases of technology-enhanced science learning and their association with students' motivation.

This goal raised the following questions:

- 1) What is the motivation of elementary school students, from different cultural backgrounds, to learn science?
- 2) What are the phases of the technology-enhanced science learning process and their association with motivation?

Settings and Participants

The study was conducted in the context of science education in elementary schools, during the pandemic closure. The study included two stages, each answering one of the research questions. The first stage included sixth-grade students ($N=109$) from the USA and Israel. This included English-speaking students ($N=43$), Arabic-speaking students ($N=26$), and Hebrew-speaking students ($N=40$). The students' sample consisted of 56% females and 44% males.

The second stage of the study included seven experienced science teachers from different national and academic backgrounds (Table 1).

Methods and Data Collection

The study applied the sequential mixed-methods design for data collection and analysis, using both quantitative and qualitative approaches (Creswell & Miller, 2000). This design enabled a quantitative examination of elementary school students' motivation to learn science, comparing participants from diverse countries and cultural backgrounds. Then, we conducted a qualitative examination of the features of technology-enhanced learning, based on science teachers' teaching experience and observations of online lessons. Data were collected via a motivation questionnaire, semi-structured interviews, and online observations, as detailed in the following paragraphs.

1. A motivation questionnaire was administered online to examine the motivation to learn science of elementary school students, thus answering the first research question. The questionnaire was an adaptation from previous research (Barak & Dori, 2011), with an additional category of cross-cultural interactions. It was administered in three languages, according to the students' mother tongue (English, Arabic, Hebrew). The questionnaire was comprised of 20 items on a Likert-type scale of 1-to-5 (with 5 representing the highest level of agreement). The items were grouped into four categories of intrinsic motivation: (1) self-efficacy, which refers to students' belief in their ability to achieve a learning outcome; (2) interest and enjoyment, which refers to students' desire to know or learn about something and the pleasure that is involved; (3) connection to daily life, which refers to students' belief in the relevancy of the learning materials to their life and future career aspirations; and (4) cross-cultural interactions, which refers to students' desire to learning together with peers from

Table 1 Participants' demographics

Science teacher	Country	Spoken language	Highest degree	Seniority in years	Number of students
D.B	USA	English	BA	24	10
R.M.B	USA	English	MA	30	24
A.S	USA	English	EdD	13	9
R.G	Israel	Arabic	BSc	16	18
A.G	Israel	Arabic	MA	17	8
A.K	Israel	Hebrew	MA	27	29
S.F	Israel	Hebrew	MA	14	11
					109

other schools and cultures. The questionnaire's items are detailed in Table 2. Internal consistency measured by Cronbach's alpha was 0.94 for all items for each category: self-efficacy ($\alpha=0.76$), interest and enjoyment ($\alpha=0.88$), connection to daily life ($\alpha=0.78$), and cross-cultural interactions ($\alpha=0.86$). Two experts in science education with PhD and MSc degrees, and four experienced elementary school science teachers validated the questionnaire.

2. Semi-structured interviews were conducted among experienced science teachers in the USA and Israel to identify features of technology-enhanced learning, thus answering the second research question. The interviews started with open and general questions, followed by probe questions to allow new ideas to be brought up. The starting questions were: How would you characterize teaching and learning through technology-enhanced science instruction? Can technology-enhanced science instruction be associated with students' motivation to learn science? If so, how? The interviews were audio recorded, transcribed, and analyzed inductively according to the thematic analysis methodology (Creswell & Miller, 2000), detailed in the "Data analysis" section.
3. Online observations were conducted to examine students' science learning in an online environment, thus providing additional data for answering the second research question. The observations were conducted in

four online lessons that included "discovery" activities. The first lesson was about the way scientists observe natural phenomena and measure things. The students worked in online learning groups to explore and find information about different data collection instruments. The second online lesson was about changing states of matter, in which students were investigating this topic by making chocolate treats at home. They were asked to melt chocolate bars into candy molds and cool them until solidified. The students shared their experience using web cameras and then discussed the topic of matter conservation. The third online lesson was about pollution, in which students investigated soil, air, and water pollution. Then they discussed the pros and cons of technology usage and presented their ideas to their classmates. In the fourth online lesson, the students investigated the topic of predator–prey relationships through an online polling activity and the presentation of arguments.

Data Analysis

The quantitative analysis was done using the IBM SPSS statistical platform, computing t-tests and ANOVA models, to compare between students from various cultural backgrounds and determine the significance of differences with

Table 2 Internal motivation questionnaire: categories and items

Category	Items
Self-efficacy	Science lessons are easy for me to study I have confidence in my ability to succeed in science studies I can succeed in science even without help I help others in science lessons It is difficult for me to learn science*
Interest and enjoyment	I think that science is a very interesting subject Science lessons fascinate me Science lessons bore me* I enjoy learning science I am interested in explanations of scientific phenomenon
Connection to daily life	In science lessons I can get answers to daily life questions In science, lessons are connected to daily life experience In the future I would like to be a scientist I read articles and watch broadcasts that present science topics Science has no connection to my daily life*
Cross-cultural interactions	I am interested to know what students in other countries learn in science Science lessons would be more interesting if we learn together with students from other countries Learning science with students from other countries can expand knowledge Learning science with students from other countries enables better contextualization Cross-cultural interactions in science lessons facilitate communication skills

*Negative statements that were recoded for statistical analysis

regards to the motivating factors. The qualitative analysis was conducted using the thematic analysis methodology in six stages. First, repetitive reading of the interviews and observation transcripts, searching for patterns, and reaching familiarity with the data. Second, the production of initial categories from the data and organizing them into meaningful groups. Third, sorting the different categories into potential themes and collating the relevant coded data extracts within the identified themes. Fourth, refining the themes and making identifiable distinctions between them to form a coherent pattern and a thematic map. Fifth, identifying the “essence” of what each theme is about and determining and writing what aspect of the data each theme captures. Sixth, writing an analytic narrative that illustrates the data and making an argument in relation to the research questions.

Trustworthiness of the data analysis and interpretation was established through two triangulation strategies: data and investigator. Data triangulation was achieved by using data from semi-structured interview transcripts and observation notes to converge and support each other. Investigator triangulation was achieved by two experts in science education with PhD and MSc degrees, who cross-checked data sources and suggested interpretation that cohered with the data.

Findings

This chapter includes two main sections, each corresponding to one of the research questions.

Students’ Motivation to Learn Science

The sixth-grade students indicated overall medium levels of motivation to learn science ($M=3.51$, $SD=1.37$). The highest ratings on a scale of 1 to 5 were indicated for the “Cross-cultural interactions” category ($M=3.83$, $SD=1.01$), among which the highest indicated item was “science lessons would

be more interesting if we learn together with students from other countries” ($M=4.11$, $SD=1.09$). Medium ratings were assigned for “Interest and enjoyment” and “Self-efficacy” ($M=3.52$, $SD=1.07$; $M=3.42$, $SD=0.87$, respectively). Whereas, the lowest ratings were indicated for the “Connection to daily-life” category ($M=3.12$, $SD=0.96$), among which the lowest indicated item was “in the future I would like to be a scientist” ($M=2.11$, $SD=1.31$); surprisingly indicating relatively low motivation to pursue a scientific profession. Table 3 presents the means, standard deviations, and t-test comparing the motivation to learn science of Israeli students versus USA students.

A t-test analysis indicated a significant difference in the “Cross-cultural interactions” category ($t_{108}=2.067$, $p=0.042$), under which the Israeli students indicated higher motivation to learn science than the USA students did. The comparison also indicated a borderline difference in the “Interest and enjoyment” category ($t_{108}=1.670$, $p=0.098$), under which the USA students indicated higher motivation than the Israelis did. In other words, the USA students experience greater interest and greater feelings of enjoyment that may motivate exploration and information seeking. Those students might be more motivated to learn science, even when faced with new or puzzling situations.

A breakdown of the student population to three cultural background groups, based on their native language, i.e., Israeli Hebrew speakers, Israeli Arabic speakers, and USA English speakers, was done to further explore differences. One-way ANOVA showed that the association with a cultural background was significant in three motivation categories: “Interest and enjoyment” ($F_{2,106}=4.127$, $p<0.05$), “Connection to daily-life” ($F_{2,106}=6.588$, $p<0.01$), and “Cross-cultural interactions” ($F_{2,106}=3.271$, $p<0.05$). Scheffé post hoc analysis indicated three significant differences: (1) motivation in terms of ‘Interest and enjoyment’ was significantly higher among the Arabic speaking students ($M=3.77$, $SD=1.10$) than among the Hebrew speaking students ($M=3.15$, $SD=1.15$); (2) motivation in terms of

Table 3 Motivation to learn by ratings of elementary school students in Israel and the USA

	Israeli students ($N=66$)		USA students ($N=43$)		t	p
	Mean	SD	Mean	SD		
Overall motivation to learn science	3.49	1.43	3.50	1.25	0.176	0.861
1. Self-efficacy	3.49	0.90	3.33	0.83	0.928	0.355
2. Interest and enjoyment	3.39	1.16	3.72	0.89	1.670	0.098
3. Connection to daily life	3.02	1.08	3.27	0.74	1.439	0.153
4. Cross-cultural interactions	3.95	0.95	3.41	1.15	2.067	0.042

“Connection to daily-life” was significantly lower among the Israeli Hebrew speaking students ($M=2.72$, $SD=1.10$) than among the other two groups; (3) motivation in terms of “Cross-cultural interactions” was significantly higher among the Arabic speaking students ($M=4.17$, $SD=0.81$) than among the American students ($M=3.41$, $SD=1.15$). On a scale of 1 to 5, Fig. 1 presents the level of motivation to learn science by category and research groups.

The Characteristics of Technology-Enhanced Learning and Their Association with Motivation

The analysis of the interviews and observations resulted in the characterization of technology-enhanced science learning and its association with motivation to learn science. Two phases were identified, each presenting a distinct stage in students’ learning process. Each phase was associated with one or more of the four internal motivation categories (i.e., self-efficacy, interest and enjoyment, connection to daily life, and cross-cultural interactions), specified in square brackets, detailed below.

Phase 1—the “divergence” phase, portrays technology-enhanced science learning as a “messy” process of online exploration, in which ideas are examined in a free-flowing non-linear way. The students are encouraged to search for information and learn through their own interest, thus gaining confidence in their science learning ability. For example, D.B., a science teacher from the USA stated: “inquiry teaching should enable the exploration of scientific methods and tools and help build the students’ motivation and confidence” [self-efficacy]. R.G. an Arabic-speaking science

teacher stated: “Inquiry-based learning should engage students in authentic discovery relevant to their lives and promote their belief in their ability to investigate things on their own” [self-efficacy; connection to daily life]. A.K. a Hebrew-speaking Israeli science teacher stated: “...inquiry-based learning should challenge and accommodate both low and high performers... children should feel comfortable and confident in their ability to solve authentic and contextualized scientific questions...” [self-efficacy; connection to daily life]. Similarly, the online observations depicted students’ engagement and enthusiasm while working in groups. For example, D.B. stated: “...we use the smartphones to conduct authentic investigations, search for related videos, pictures, and descriptions of scientists in real world situations” [connection to daily life].

Technology can serve as an instrumental tool for driving enthusiasm and increasing enjoyment, as mentioned by D.B.: “they really enjoy problem solving and thinking out of the box” [interest and enjoyment]. Along this phase of learning, teachers describe students’ interest in the activities, and technology adds to their excitement. For example, S.F. an Israeli science teacher stated: “Involving technology can drive their [students] enthusiasm because they are so connected to it” [interest and enjoyment]. Interest and enjoyment were also observed in an online lesson related to matter changing state. Students were making their own treats at home by melting chocolate, adding it to candy molds, and freezing it back into a solid. Seeing the different states, through which the chocolate goes, was accompanied by excitement and students asking questions that signal their interest. They were also interested in seeing what happens in their peers’ kitchens, using the Web cameras to share their doings and results. D.B. described the “messy” stages of

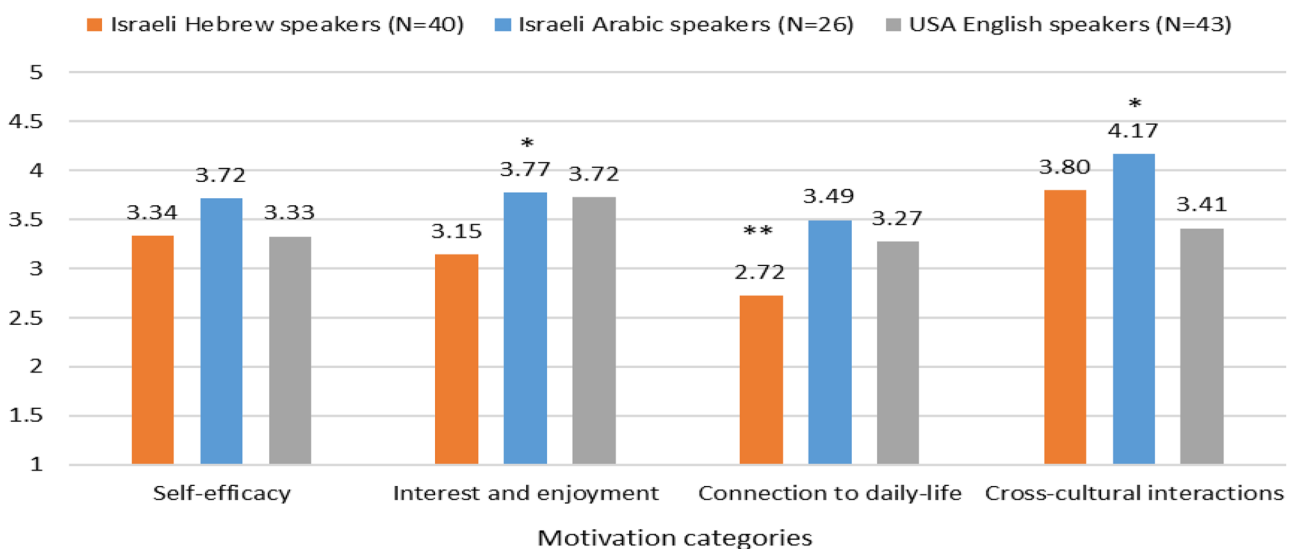


Fig. 1 Motivation to learn science by category and research groups. * significant at $p < .05$ level; ** significant at $p < .01$ level

inquiry activity: “We do a lot of hands-on science, observations, collecting data... students start with an authentic problem and plan an investigation to figure it out... the teacher needs to let kids make mistakes” [Connection to daily life; Interest and enjoyment].

Phase 2—the “convergence” phase, portrays technology-enhanced science learning as a process of merging ideas to attain the best possible solution to an investigation. The teachers’ role in this phase is to provide students with guidance in synthesizing and combining ideas to form accurate scientific understanding. This is a vital stage as it should ward off misconceptions that may arise in the “divergence” phase. During this phase, students are expected to filter the information that is relevant to the investigation and integrate ideas into a coherent whole: “I encourage students to merge different ideas and come up with a solution as part of the investigation” (A.G.); “After I let students ‘throw ideas’ I encourage them to focus on combining them into new forms of knowledge” (A.S.). Avoiding misconceptions was described by the participants as an essential part of this phase, realized by identifying and addressing inaccurate perceptions. As S.F., an Israeli science teacher stated: “I encourage the students to use scientific language and find trustworthy information, building their confidence in evidence-based investigation” [self-efficacy]. Similarly, in an online lesson, A.K. promoted a discussion among her students to challenge each other’s misconceptions. She introduced the topic of predator–prey relationships and asked whether humans should get involved to defend against predation. After presenting the results of an online polling activity, she opened the discussion for a debate between the “for” and “against.” At the end, she summarized the debate by presenting the scientific concept of predation as a biological interaction, its role, and its effect on ecosystems [connection to daily life]. During this phase, learning is conducted through the use of deduction: “...the students conducted observations on crickets and frogs, and were asked to deduce the food-chains and food-webs according to various ecosystems, and reflect on their answers” [connection to daily life; self-efficacy].

The participants highlighted the feeling of satisfaction in the self-discovery of scientific concepts. D.B. asserted: “They really enjoyed figuring things out and understanding something new” [interest and enjoyment]. A.K. added: “One of my students shared with the class that when she went hiking she used a plant recognition app... It is a way of building students’ self-confidence, contextualizing learning, and first and foremost it is enjoyable!” [connection to daily life; self-efficacy; interest and enjoyment]. Through this process, the teacher’s guidance should help the students navigate and develop inquiry skills. As was described by A.G.: “It’s important to be available, provide resources, but also being able to say how you can find something out without me giving it to you” [self-efficacy]; “The teacher’s

role is to guide, simplify things, explain, translate” (S.F.). In this phase, students are encouraged to share inquiry results with peers: “students can share results through Zoom, Meet, Teams, etc., as this is the best way to learn from each other” (D.B.); “students share ideas and gain fresh perspectives and insights; this helps them generate new ideas” (A.K.). Although perceived as essential to science learning, the online observations showed that teachers’ attempt to synthesize students’ ideas while filtering out misconceptions were challenging. In particular, difficulties were observed in attending to all students’ ideas, questions, and needs for reassurance. With regards to motivation in terms of “cross-cultural interactions,” none of the teachers experienced it, but they asserted a desire to collaborate with science teachers from other schools and countries. Some mentioned the importance of involving students in online collaborative writing and video meetings with peers from abroad, for example: “...cross-cultural experience opens students minds to other cultures and diverse ways of thinking... if we can overcome the language barrier, we can collaborate by collecting biotic and abiotic data from various places in the world and jointly analyzing them” (D.B.).

Overall, the analysis of the interviews and observations showed that technology-enhanced science learning can be characterized by a two-phase process. Phase 1 captures the idea of “divergence”—involving students in expressing different ideas to reflect diverse ways for examining scientific issues. Phase 2 captures the idea of “convergence”—merging ideas to attain the best possible solutions to an investigation. The findings show a yet unfulfilled interest in interacting with peers from other cultures and countries, with the support of online technology.

Discussion and Conclusions

This study was conducted to examine the motivation to learn science of elementary school students from the USA and Israel. Similar to recent studies (e.g., Anderson et al., 2019; Roller et al., 2020; Shwartz et al., 2021), our results indicated overall medium levels of motivation to learn science, among all student groups. The lowest motivation rating was observed for the “connection to daily-life” category, among which the lowest indicated item was “in the future I would like to be a scientist.” This finding further stresses the necessity to capture elementary school students’ curiosity and engagement with science while learning remotely. The literature shows that children already actively explore career options by the time they reach 10–12 years of age (Hartung et al., 2005), stressing the urgency to connect the material they learn at school to questions that intrigue them in their everyday life (Barak & Asakle, 2018; Barak & Shahab, 2022).

The higher motivation levels were observed for “cross-cultural interactions.” In addition, we have observed the willingness of teachers to enhance their teaching with cross-cultural learning experiences. These results correspond with studies that encourage deliberation on how to encourage motivation to learn science among school students (Dixon & Wendt, 2021; Shin et al., 2019; Song & Wen, 2018). When designing technology-enhanced instructional materials, studies recommend enhancement of connections and interactions among students (Barak & Dori, 2011; Barak & Shahab, 2022; Schellinger et al., 2019; Schwartz et al., 2021), especially at times of school closures and social distancing, as was experienced during the COVID-19 pandemic (Gerard et al., 2022). Technology, such as chat and video platforms, web cameras, and shared documents, can help in creating this supportive environment that fosters teamwork and connections between students within the class and beyond (Barak & Asakle, 2018; Barak & Shahab, 2022; Crippen & Archambault, 2012). Taking a step forward and creating cross-cultural interactions between students from different countries might serve as a motivating approach to learning science in a global post-pandemic world. This approach may empower students, starting at an early age, to recognize and consider the power of divergent perspectives, communicate effectively with diverse audiences, and translate their ideas into actions that make a difference in their communities and in the world.

A comparison across cultures revealed significant differences in three out of the four motivation categories. First, Israeli Arabic-speaking students are more motivated to learn science out of interest and enjoyment compared to Israeli Hebrew-speaking students. This finding indicates that Arabic-speaking students’ interest in science learning may motivate exploration and information seeking, thus making them more inclined to face new situations. Second, Israeli Hebrew-speaking students are not as motivated as Israeli Arabic-speaking students and USA English-speaking students by connection to daily life and career. In other words, it seems that Israeli Hebrew-speaking students tend to conceptualize science as less related to questions that intrigue them in their daily life or as means to express their ideas. This might explain why the Israeli Hebrew-speaking students are relatively less motivated by science career aspirations, when compared to the other two groups. Third, although cross-cultural interactions are the most motivating category, Israeli Arabic-speaking students are more motivated than their USA peers, when learning with other cultures is involved. Overall, Israelis (Arabic speaking and Hebrew speaking) find cross-cultural learning interactions more compelling than their USA peers do. This difference in inclination to cross-cultural interactions requires further investigation, as both Israel and the USA are often described as immigration countries and “melting pots,” in which different cultures have contributed

their own distinct characteristics to the country’s spirit. According to these findings, it seems that Israeli students experience greater curiosity in other cultures and in how other students learn science. Therefore, they might be more motivated when faced with opportunities for interactions and collaboration in science learning with students from different backgrounds.

The worldwide lockdown required emergency remote learning and was accompanied with a decline in motivation. Thus, our study was set to identify phases of technology-enhanced learning that can be associated with students’ motivation to learn science. According to students, one way of engaging curiosity is through collaborations with peers from different countries and cultural backgrounds. This corresponds with the literature that points to science learning as a social endeavor (Barak & Shahab, 2022; Harlen & Qualter, 2018). Social activities that include cross-cultural interactions can be enabled by various platforms of online technology (e.g., Barak & Dori, 2011; Barak & Asakle, 2018). Furthermore, previous research has indicated the need for providing students with opportunities to be engaged in science investigations within and beyond the classroom (Sharples et al., 2015). Engaging in meaningful and satisfying investigations of the locally accessible world is often missing from school science (Sharples et al., 2015). Hence, the study suggests the utilization of online technology to foster cross-cultural exploration activities.

In recent years, studies have recommended various technological-pedagogical models for science education (Barak, 2017; Crippen & Archambault, 2012; Schellinger et al., 2019); yet, frameworks for online cross-cultural learning, specifically designed for elementary schools, are still limited. In this study, the inductive analysis of the interviews and online observations enabled the breaking down of the process of online discovery learning into two phases. First, the teachers created an environment where students could explore scientific concepts, allowing ideas to flow spontaneously. This was identified as the “Divergence phase,” in which students were encouraged to search for information in reliable sources and think “out of the box.” In this phase, Zoom meetings, online teamwork, and the use of Google Drive for collaborative writing served as instrumental tools for driving enthusiasm and enhancing the social aspects of learning. In the second phase, the teachers provided students with guidance in synthesizing and combining ideas to form accurate scientific understanding. This was identified as the “Convergence phase,” in which students were encouraged to discover the scientific principles through deduction and thus avoid scientific misconceptions. Both phases were associated with four categories of internal motivation: self-efficacy, interest and

enjoyment, connection to daily life, and cross-cultural interactions.

The findings of the current study confirm arguments in the literature that learning science through discovery requires creative thinking skills to extend our understanding of the natural world (Antink-Meyer & Lederman, 2015; NRC, 2012). In the divergence phase, creativity is required for idea generation when prompted with an open-ended task. In the convergence phase, creativity is required for synthesizing ideas into new form of knowledge. Teachers' perception of online science learning as incorporating both phases with their equally important components of creativity bears important implications for the design of a technology-enhanced framework. Such a framework may assist in bridging the gap that exists in the literature: on one hand, research points to the challenges of pre-service science teachers in their inclination to use online technologies in the classrooms (Barak & Shahab, 2022; Crippen & Archambault, 2012; Schellinger et al., 2019); on the other hand, other studies indicate that with advances in online technologies, science learning can become more effective and consequently more common (Pedaste et al., 2015; Song & Wen, 2018).

Countries around the world are facing a decline in science as a career of choice (Avargil, 2022; Roller et al., 2020). Our study points to opportunities for advancing motivation to learn science through technology-based cross-cultural interactions. This kind of instruction could be supported by teachers' desire to enhance science learning with new experiences enabled by technology. The study points to some differences across cultures in what motivates learning, findings that could lead to further studies of specific cultural motivators. Further investigation is warranted around the phases of technology-enhanced science learning, breaking down the divergence and convergence phases to integral components. A further study could assess how the enactment of such a design impacts young students' motivation and how successful it is in mitigating the decline in science as a career of choice.

Acknowledgements Thanks are due to the schools, teachers, and students who have made this project possible.

Funding The research was funded by the Irwin and Joan Jacobs Graduate School, Technion—Israel Institute of Technology.

Declarations

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Conflict of Interest The authors declare no competing interests.

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