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The Seeing Science Project: Using Design-Based Research to Develop a Transformative Experience Intervention

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Abstract

Drawing on transformative experience theory (Pugh, 2011) and in collaboration with high school science teachers, the authors developed an intervention (Seeing Science project) leveraging everyday mobile technology as a tool for integrating in-school and out-of-school experience. Students were instructed to take pictures when they noticed connections to unit content and post these with a caption on a class site. The current study used design-based research methods to revise and evaluate the Seeing Science project over a 2-year period. Revisions to the project were informed by year one data and principles of the Teaching for Transformative Experiences in Science (TTES) instructional model. Data sources included project artifacts, student interviews, and teacher interviews. Revisions to the project resulted in higher quality posts in pre-AP biology classes and greater participation in regular biology classes. Furthermore, an analysis of posts, classroom observations, and student interviews revealed that the project helped some students connect in-school learning to out-of-school experience and undergo transformative experiences. The current study contributes to transformative experience theory by identifying and developing strategies for fostering transformative experiences. These strategies further inform the TTES model and may support depth of learning and career identification.

Keywords Transformative experience · Engagement · Science education · Design-based research · Mobile technology

The connection between in-school and out-of-school experience is critical to deep-level, life-long learning. For example, ecological perspectives have shown that learning and interest development take place across a range of interacting in-school and out-of-school contexts (e.g., Barron, 2004, 2006; Bell et al., 2012; National Research Council, 2009). Unfortunately, researchers have also found that there are often disconnects between in-school learning and everyday experience (Pugh & Bergin, 2005). Deliberate instructional design is necessary to support students in making connections, particularly when the concern is with getting students to apply their school learning in everyday contexts. For example, Engle and colleagues (Engle, 2006; Engle et al., 2012) developed an expansive framing model that helps students establish continuities between contexts and transfer school learning to everyday contexts.

In our work, we have used transformative experience theory (e.g., Pugh, 2011) as a framework for designing an instructional activity to support connecting in-school learning to out-of-school experience. Transformative experience theory defines a transformative experience as one in which students use in-school learning to enrich and expand their everyday, out-of-school experience (Pugh, 2011). Applied, classroom-based research has been used to identify strategies effective at fostering transformative experiences resulting in a proposed Teaching for Transformative Experiences in Science (TTES) instructional model (Pugh et al., 2017a; Pugh, 2020). One principle of the TTES model is scaffolding re-seeing, which refers to supporting students in seeing the world through the lens of science ideas during their everyday, out-of-school experience (Girod et al., 2003; Pugh et al., 2017a, b). A potentially fruitful area of research that has not been investigated is the role technology may play in scaffolding re-seeing, particularly everyday mobile technologies, such as cell phones, tablets, or laptop computers that bridge in-school and out-of-school experience.

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In the mode of design-based research (Anderson & Shattuck, 2012; the design-based research collective, 2003), we collaborated with a high school biology teacher ("Mrs. Morgan") to design, investigate, and refine an activity leveraging technology to scaffold students' re-seeing of biology content. This activity, dubbed the Seeing Science project, involved asking students to take pictures with mobile technology during their out-of-school experience when they noticed connections to science content they were learning in school and then post the picture with an explanatory caption to a class site. The initial implementation yielded some promising results but also revealed that most students engaged in superficial ways (Cropp et al., 2022). Accordingly, the purpose of the current study was to further develop and investigate the Seeing Science project in a series of subsequent implementations. We were particularly interested in understanding (a) how and the degree to which students engaged with the project, (b) how (if at all) the project supported students in undergoing transformative experiences, and (c) what pedagogical and contextual factors are associated with the effectiveness of the project. Our broad goal was to develop a project effective at supporting transformative experiences in a particular context and, from this work, identify or refine design principles associated with the TTES model.

Theoretical Framework

Transformative Experience Theory

Pugh (2011, 2020) and colleagues (Wong et al., 2001) developed transformative experience theory, which defines a particular type of science learning experience based on Dewey's philosophy of education, art, and experience. Such experience, termed transformative experience, involves using school content in everyday life to see and experience the world in meaningful, new ways. Specifically, Pugh (2011) defined transformative experience in terms of three characteristics: (a) motivated use, the application of school content in contexts where such use is not required; (b) expansion of perception, coming to see objects, events, or issues through the lens of the science content; and (c) experiential value, valuing the content for the way it expands perceptions and developing a deeper interest in or appreciation for those objects, events or issues that are re-seen. For example, after a meteorology unit, a middle school student reported that she thought about the content in her everyday life when noticing weather or watching weather reports (motivated use). In fact, she commented, "I think about weather all the time…I can't get it out of my head" (Pugh et al., 2017b, p. 387). This application of school content in her everyday life was accompanied by an expansion of perception, "Well I used to think, oh, it's just a cloud, you know, who cares…But now it's…like rain is happening because of air pressure and heat and…a bunch of stuff, and it's really affected me" (Pugh et al., 2017b, p. 387). In addition, such application of content contributed meaning and value to her world; that is, she developed experiential value. For instance, when speaking of how she applied the concept of air pressure in her everyday life, she commented, "it really fascinated me, like, it was really cool…how it did it and why, and it was really cool" (Pugh et al., 2017b, p. 387).

Transformative experiences have been linked to important learning and engagement outcomes such as conceptual change (Alongi et al., 2016; Heddy & Sinatra, 2013; Pugh, 2002), far transfer (Pugh et al., 2010a, b), applied understanding (Pugh et al., 2017a), enduring learning (e.g., Girod et al., 2010; Pugh, 2002), interest in science (Girod et al., 2010; Heddy & Sinatra, 2013, 2017; Heddy et al., 2017), and an inclination to major and pursue a career in science (Pugh, et al., 2019, 2021).

The Teaching for Transformative Experiences in Science (TTES) Model

Researchers have identified strategies successful at fostering transformative experiences (e.g., Girod et al., 2003; Heddy & Sinatra, 2013; Pugh, 2002; Pugh et al., 2010b) and organized these into a set of design principles (see Table 1) comprising the Teaching for Transformative Experiences in Science (TTES) instructional model (Pugh, 2020; Pugh et al., 2017a; Pugh & Girod, 2007). The current study focuses on the experiential apprenticeship design principle, which involves the use of modeling and scaffolding to apprentice students into particular ways of experiencing the world in terms of specific science content. *Scaffolding re-seeing* is an experiential apprenticeship strategy involving helping students see the world through the lens of science ideas during their everyday, out-of-school experience (Girod et al., 2003; Pugh et al., 2017a). Scaffolding re-seeing includes specific practices such as helping students identify re-seeing opportunities, providing time for students to share re-seeing experiences, and supporting deep-level re-seeing (Pugh, 2020). For example, a middle school teacher teaching a unit on meteorology had his students brainstorm everyday opportunities to apply the content, provided time for them to share their own "wild weather" experiences, and helped the students see these experiences through the lens of unit content by pressing them to do so in class discussion and using the students' experiences as case studies for inquiry learning (Pugh et al., 2017a). These scaffolding strategies were found to foster transformative experiences (Pugh et al., 2017a; see also Girod et al., 2003; Heddy & Sinatra, 2013; Pugh, 2002; Pugh et al., 2010b). In the current work, we desired to build on these past studies by investigating the potential of pairing

Table 1 Teaching for transformative experiences in science (TTES) design principles

ARTISTIC SELECTION AND CRAFTING OF CONTENT
Select content worth teaching
(1) Select *big ideas* (i.e., core disciplinary ideas), (2) ideas with *powerful affordances* (i.e., real-world relevance for a particular student population), and (3) *ideas in the Deweyan sense* (i.e., compelling possibilities that one anticipates trying out in everyday experience)
Craft content as *ideas*
(1) Use *anticipation and experiential value statements* (i.e., statements generating anticipation about applying content in everyday life), (2) emphasize *"having the journey"* (i.e., using content to experience the world anew), (3) present *compelling metaphors*, (4) restore concepts to the *experience in which they had their origin and significance*, and (5) evoke a sense of *wonder, suspense, and the sublime*
EXPERIENTIAL APPRENTICESHIP
Model transformative engagement
(1) *Share your own transformative experiences* and (2) *express passion* for the content
Scaffold student experience
(1) *Prompt scientific thinking, perceiving, and valuing* inside and outside of school, (2) hold *use-change-value (UCV) conversations* (i.e., conversation in which students share how they use content, how it has changed their perception, and the value they get out of the content, and (3) make use of *boundary-crossing objects* (i.e., objects like mobile technology that cross in-school and out-of-school domains)
Scaffold re-seeing
(1) *Identify* re-seeing opportunities, (2) *share* re-seeing experiences, (3) utilize *real-world updates* (i.e., regular practice at re-seeing ongoing phenomena), and (4) implement *experientially anchored instruction* (i.e., develop students' re-seeing experiences into curricular materials for learning the content)
DOING AND UNDERGOING
Put students in the role of explorers
(1) Engage students in *inquiry*, (2) have students *create*, and (3) try out *service learning* or *expeditionary learning*
Create a culture in which students feel safe to "surrender"
(1) Teach and foster *mindfulness*, (2) establish a *mastery goal environment*, and (3) support *autonomous motivation*

Adapted from Pugh (2020)

boundary-crossing technology with scaffolding re-seeing strategies. The use of boundary-crossing technology had been proposed as a TTES strategy and initially explored in the first phase of design-based research (Cropp et al., 2022). The current study extends this design-based research.

Boundary-Crossing Technology as a Tool for Scaffolding Re-Seeing

Technology has a broad capacity to scaffold student learning and engagement (e.g., James et al., 2020; Kim & Hannafin, 2011; Lai et al., 2007; Sammel, 2014). Mobile technology (e.g., cell phones, tablets) and associated apps may play a particular role in scaffolding connections between in-school learning and out-of-school experience. In a basic sense, mobile technologies are boundary-crossing in that they bridge in-school and out-of-school experience by allowing students to use their everyday devices to learn while in school and engage in school learning at any time and anywhere when not in school (Baş & Sarıgöz, 2018; Goodwin, 2012; Zheng et al., 2016). Teachers can take advantage of mobile technology to support learning and engagement in out-of-school contexts. For example, Terkowsky et al. (2013) used mobile technology to create remote laboratories by which students could engage with science content in their out-of-school lives and collaborate over distance. Kong (2011) found that mobile technology helped personalize the exploration of content by providing students with a tool for collaboration outside the class. Pimmer (2016) found that using social media via mobile technology allowed nursing students to experience informal educative experiences outside the classroom through boundary-crossing interdisciplinary online peer groups in which they compared and contrasted their approaches and practices to learn from each other's perspectives. Social media was also useful for providing prompts to which the nursing students could reflect on and make new connections.

This research suggests mobile technologies can support engagement across contexts and function like other boundary-crossing technologies (Akkerman & Bakker, 2011) that have been found to support transformative experiences (see Atkins & Frank, 2013). However, researchers have yet to explore the potential of pairing mobile technology with the TTES framework.

The Seeing Science Project

The Seeing Science project was developed in collaboration with a high school earth science teacher (Cropp et al., 2022). The project involved asking students to take pictures with mobile technology during their out-of-school experience when they noticed connections to science content they were learning in school. Furthermore, they were instructed to use a social media app (GroupMe) to post these pictures along with an explanatory caption. Some students responded positively to this project, explaining that it made them more interested in the content and helped them see its connection to the real world. However, an analysis of the posts revealed that most participation was not in line with project goals. Overall, 65% of the posts were coded as memes, pictures, or comments unrelated to the content. Even most of the content-relevant posts were memes or pictures from the Internet with minimal to no explanation and no clarification of how the student was re-seeing the world. Only a few posts (8.1%) included students' own pictures, and none of these were accompanied by captions clearly indicating that students were undergoing a re-seeing experience (i.e., using school science content to perceive the world in a meaningful, new way). Consequently, we used feedback from the teacher and students to refine the project and continue the research in the mode of design-based research.

Design-Based Research

Design-based research (DBR) centrally involves a combination of theory building and the design of effective learning environments and practical applications (Anderson & Shattuck, 2012). Additional qualities of DBR include collaborations between researchers and practitioners, design and implementation of interventions in real educational contexts, iterations (i.e., cycles of design, implementation, evaluation, and redesign), accounts of how particular designs function in context, and the development and evolution of design principles and practical theories (Anderson & Shattuck, 2012; The Design-Based Research Collective, 2003). In line with DBR, our research has the joint focus of further developing a theory of transformative experience applicable to the science classroom and designing an intervention effective at fostering transformative experiences. In addition, our research involves partnerships with practitioners and cycles of design, implementation, evaluation, and redesign in a real educational setting. The current study analyzes the results of these efforts in context and develops design principles.

Current Study

During the 2018–2019 and 2019–2020 academic years, we worked with a high school biology teacher ("Mrs. Morgan") to refine, implement, evaluate, and redesign the Seeing Science project. Mrs. Morgan was new to the project as the prior teacher transferred to a new school. In this paper, we report on how the framing and implementation of the project were modified over the 2-year period and analyze the effects of such modification on the quality of posts. Furthermore, we analyze ways in which the project facilitated connections between in-school learning and out-of-school experience. Accordingly, the purpose of this research was to understand the functioning of the Seeing Science project in a particular context and refine design principles that contribute to the theory of teaching for transformative experiences.

Table 2 Number of participants by year and class type

Class type	Year 1	Year 2
Regular	38[a](4)[b]	45(17)
Pre-AP	28(22)	31(18)
Total	66(26)	76(35)

[a]Number who consented to participate in the study

[b]Number who participated in the seeing science activity

Methods

Approval to conduct the research was received from the relevant university institutional review board, and ethical guidelines were followed in conducting this research. Informed consent was obtained from all participants.

Participants and Context

Mrs. Morgan had six years of experience teaching high school biology at the start of the study, with five years of experience at the current school. In addition, she earned a master's in biological science at the end of our first year of collaboration. We invited all students enrolled in her two regular and two pre-advanced placement (AP)[1] biology classes to participate during the 2018–2019 and 2019–2020 academic years. A total of 142 students participated (see Table 2 for a breakdown by year and class type). Students were primarily sophomores with 50% ($n=71$) being female, 62% ($n=88$) Caucasian, 12% ($n=17$) Latinx, and 26% ($n=37$) from other racial/ethnic backgrounds. The public high school in the western United States serves about 1,300 students and has a 35% reduced/free lunch rate, meaning 35% of children attending the school come from families whose income is less than the federal poverty level.

Seeing Science Intervention and Modifications

Many aspects of the Seeing Science project were implemented the same as in the first implementation efforts with a different teacher (Cropp et al., 2022). Specifically, students

[1] Advanced placement courses offer college-level curricula and an opportunity to earn college credit. The pre-AP biology course is more advanced than the regular biology course and recommended to students planning to take AP biology in the future.

were asked to take pictures with their cell phones or tablets when they noticed connections to course content and post these along with a caption to a class GroupMe chat. In addition, the teacher had a few brief class discussions centered on the Seeing Science posts as in the prior implementation. These activities reflected the *scaffolding re-seeing* and *make use of boundary-crossing objects* principle from the TTES model. In addition, some modifications were made to the project and its implementation based on the results. In addition, further modifications were made in year 2 of the current study in response to year 1 results. These modifications are described below and summarized in Table 3.

One modification simply involved further clarification of expectations. In the prior implementation, students primarily posted memes and pictures from the Internet, and it appeared students were just doing searches to find something to post for the assignment (Cropp et al., 2022). For the current study, Mrs. Morgan clarified expectations by explaining that she did not want students looking something up on the Internet to post. Instead, posts should be connected to students' *naturally occurring experiences* of noticing science connections. Such experience could include natural online experiences. Thus, if students naturally came across content-relevant stories or images while online, they could post these, but Mrs. Morgan instructed them not just search for something to post for the assignment.

Other modifications involved the integration of additional TTES design principles, and the use of some of these principles was expanded in year 2. One such principle was *modeling transformative experience* (Pugh, 2020). Specifically, Mrs. Morgan posted her own Seeing Science pictures at the start of each unit along with a caption as a model of her own transformative experiences and how to do the activity. For example, she posted a picture of her garden with the caption:

> I started my seedlings! Mini bell peppers, regular bell peppers, jalapeño, cherry tomatoes, and Romatomatoes. Not only have humans articially selected plants for domestication (evolution), but these seeds will undergo cellular respiration and when they sprout they will do photosynthesis! Two units in one post right here!

At the start of the evolution unit, she displayed this post to the class and elaborated on her experience of seeing the world through the lens of evolution. This modeling of posts and re-seeing was the same in years 1 and 2.

A second design principle applied from the TTES model was *helping students identify re-seeing opportunities* (Pugh, 2020). In year 1 of the current study, Mrs. Morgan led the students in a discussion of opportunities for seeing the world through the lens of particular content. For example, for an evolution unit, Mrs. Morgan asked students to think of everyday opportunities they might have to make connections to

Table 3 Seeing science design principles and modifications to prior implementation

Design principle/modification	Year 1	Year 2
Scaffold re-seeing and make use of boundary-crossing objects	Same as prior implementation (Students asked to share pictures with captions of re-seeing experiences)	Same as prior implementation
Clarification of expectations	Focus on naturally occurring experiences as opposed to posting memes and pictures from the internet	Same as Year 1
Modeling transformative experiences	Teacher posted own pictures with caption at unit start with elaboration of experience	Same as Year 1
Identifying re-seeing opportunities	Teacher led discussion of re-seeing opportunities	More extensive discussion supplemented by prepared examples and a follow-up handout of re-seeing opportunities
Prompting scientific thinking, perceiving, and valuing in and out of school	Same as prior implementation (sporadic in-class discussions of Seeing Science posts)	Regular interval (~two-weeks) Seeing Science discussions involving sharing of posts and deliberate scaffolding of scientific perceiving and valuing
Crafting content as ideas	Same as prior implementation (no deliberate crafting)	Introduced content with statements focused on inspiring content-related anticipation
Technology platform	Same as prior implementation (GroupMe)	Google Classroom

evolution and perhaps take a picture. Students mentioned examples such as viewing wildlife or paying attention to relevant stories on the Internet or social media. Mrs. Morgan shared further examples such as re-seeing their pets, coming across roadkill, and noticing invasive species of trees. In year 2, Mrs. Morgan expanded and formalized this strategy of helping students identify re-seeing opportunities. She again led a discussion of re-seeing opportunities, but pushed the students to identify more opportunities and came prepared with a detailed list of opportunities that she developed in collaboration with us. She kept a record of the opportunities discussed and then created a handout with re-seeing opportunities. For example, one re-seeing opportunity read,

> Books, Movies, TV, Videogames—So many action dramas involve genetics. Some are focused on mutations or genetic anomalies (*X-Men*, *Godzilla*, *Stranger Things*, *The Incredibles*, *Age of Adeline*). Others address genetic engineering or cloning (*Jurassic Park*, *Rampage*, *Star Wars*, *Spider-Man*, *Planet of the Apes*, *The Giver*, *Uglies*, *Horizon Zero Dawn*). When you read or watch these, re-see the events in terms of what you now know about genetics. What is real science and what is science fiction?

A TTES design principle that was expanded upon in the current study was *prompting scientific thinking, perceiving, and valuing inside and outside of school* (Pugh, 2020). This principle involves scaffolding students' effort to see the world through the lens of course content by doing such things as orienting students toward taking a science perspective, pushing their thinking and perceiving, prompting further engagement in everyday life, and validating students, interests while addressing their anxieties. The class discussions of the Seeing Science posts provided an opportunity for the teacher to engage in these scaffolding strategies. This was done somewhat sporadically in year 1, similar to the prior implementation (Cropp et al., 2022). Such discussions were expanded on in year 2 and formalized as Seeing Science discussions. Specifically, in year 2, Mrs. Morgan conducted Seeing Science discussions about every two weeks during the project implementation. They typically were done at the start of class as part of a warm-up and took about 15 min. In these discussions, she asked the students to review the Seeing Science posts from the prior 2-week period and select one post they found interesting. Students took turns stating which post they found interesting and Mrs. Morgan would find and display it on a screen in the class. Students shared why they found the post interesting, and the author of the post often contributed additional information. During these discussions, Mrs. Morgan would help the students focus on taking a scientific perspective and push them to think more deeply about the scientific connection represented by the post. Mrs. Morgan also validated students' interests by expressing enthusiasm about the posts and science connections. At the end of such discussions, she encouraged the students to do further re-seeing in their everyday lives. We provide an example of a Seeing Science discussion in the results.

Finally, a TTES design principle added in year 2 was *crafting content as ideas* (Pugh, 2020). This principle generally focuses on inspiring content-relevant anticipation; that is, getting students to anticipate thinking about and acting on the content in everyday life. Specifically, Mrs. Morgan added statements designed to awaken anticipation when first introducing the unit and the Seeing Science project for that unit, such as the following:

> I want you to have a journey with the idea of evolution. This shouldn't be something you just learn about in class. Evolution and natural selection should be a lens that you can use to see the world. You are never going to look at the world the same. Hair color, wild animals, your pets, trees, disease. All these things you will see through the lens of evolution and you will see a fascinating world that only be revealed by knowledge of evolution. Take the journey and bring your camera along. I want to see the pictures.

In additions to these TTES design principle modifications, a technology change was made in year 2. In year 1, Mrs. Morgan used the GroupMe app for the Seeing Science project as in the prior implementation. However, she found it cumbersome to get students signed up for a GroupMe account and to track participation. In year 2, she switched to using the Google Classroom feed as the platform for the Seeing Science project as this would not require students to make new accounts and she found it easier to track participation in Google Classroom.

Data Collection

Seeing Science posts were archived and retained for later analysis. In addition, we observed and recorded six teaching sessions in which the Seeing Science activity was introduced and Seeing Science discussions conducted. We conducted semi-structured interviews with Mrs. Morgan (lasting 30–40 min) at the start and end of each year and semi-structured individual interviews with 17 students (lasting between 15 and 30 min) at the conclusion of the project each year.

Analysis

Individual posts were manually copied from the Google Classroom feed into an Excel spreadsheet. All participants were assigned IDs to maintain confidentiality. Nonparticipants were removed from the data. After each individual post was copied to the spreadsheet, the data were randomized.

The first 20 posts were coded independently for depth, type, and format by two independent raters. Scores on the first 20 posts demonstrated strong agreement across all categories, and coders proceeded to code the rest of the data. However, after coding all posts, the agreement for depth was relatively low. Consequently, the raters revised and clarified the coding scheme, and the data were recoded. The second round of coding exhibited improved agreement. Inter-rater reliability was 88% for depth, 100% for type, and 97% for format. All disagreements were resolved through discussion, and final codes were agreed upon.

A second major analysis was conducted to obtain a deeper understanding of transformative engagement from classroom observations and student interviews. Observations and interviews were analyzed using a case study approach (Bogdan & Biklen, 2007). Seven observations of the Seeing Science activity were conducted. Each video observation was transcribed using Otter.ai (AISense Inc., 2020). Transcripts were manually cleaned to adjust grammar and spelling, and further checked for consistency with video recordings. Student interviews were conducted after the conclusion of the Seeing Science project. Individual interviews took place in-person in year 1 and virtually using the Zoom communication platform (Zoom Video Communications Inc., 2016) in year 2. Each of the five student interviews was recorded and transcribed using Otter.ai. After the initial recording was complete, the interviews were manually checked for grammar, spelling, and accuracy with the audio recordings. Quotes from observations and interviews were extracted from the transcripts to illustrate students' experiences with the Seeing Science activity.

Results and Discussion

We first present the results of the Seeing Science post-coding and discuss the relation between these results and the modifications made to the project. Next, we present the results for the more holistic qualitative analysis of students' experience with the project, with the goal of understanding how the project influenced (or not) connections between the in-school and out-of-school experience.

Results for the Seeing Science Posts

We first coded the Seeing Science posts in terms of depth to understand the level of students' engagement and investigate whether revisions to the Seeing Science activity facilitated deep engagement. Figure 1 illustrates the coding scheme for depth. Levels of depth included (1) non-relevant, (2) simple response, (3) content-relevant, non-serious, (4) content-relevant, non-substantive, (5) content-relevant, substantive, and (6) content-relevant, deeply substantive. Non-relevant posts were ones unrelated to the purpose of the project. Simple response posts were text responses to another student's post and involved minimal commentary, typically just a single word (e.g., "exactly") or phrase (e.g., "fair enough"). Content-relevant, non-serious posts were those in which students referenced course content but seemed to do so in a silly or non-serious manner. Content-relevant, non-substantive posts conveyed a valid but low-level connection to the course content. That is, students referenced course content but referred to very basic, even elementary-level ideas or just stated vocabulary without elaboration. On the other hand, content-relevant, substantive posts conveyed a deeper connection to the course content. Students referenced more advanced ideas and did so with more elaboration or explanation.

Finally, content-relevant, deeply substantive posts were those in which students provided a scientifically rich and elaborated caption. In addition, these posts clearly referenced a natural re-seeing episode. That is, the students clearly described an example of a time they perceived an object, issue, or event through the lens of course in their everyday lives outside of class.

Table 4 presents the coding results for Depth. Participation was extremely low in year 1 in the regular classes and not much can be made of these results. In year 2, participation increased in the regular classes, but was still low. All posts made from the regular class in year 2 were content-relevant, but over half were non-substantive (58.5%). In the pre-AP classes in year 1, nearly half (48.3%) of the posts were non-relevant, simple responses to other students' posts, or non-serious. In the pre-AP classes in year 2, all posts were content-relevant and nearly half were deeply substantive (48.9%). A Mann–Whitney nonparametric test confirmed that the differences between year 1 and year 2 in the pre-AP classes were statistically significant, $U(N_{\text{year1}} = 87, N_{\text{year2}} = 45) = 843.5$, $p < 0.000$. However, there were more total posts in year 1 in the pre-AP classes, driven by the number of low-level posts. When these were removed from the analysis, we still found a greater depth of posts in year 2, $U(N_{\text{year1}} = 45, N_{\text{year2}} = 43) = 743.5$, $p = 0.046$ (see Table 5).

When first implemented, the Seeing Science project was disappointing in that students almost exclusively made posts that were non-relevant or non-substantive (Cropp et al., 2022). As described in the methods, we began working with a new teacher (the prior teacher moved out of the district) and added additional structure and teaching for transformative experience design principles (Pugh et al., 2017a). In year 1, over a third of posts (36.7%) in the pre-AP classes were content-relevant and substantive or deeply substantive. This result was promising, however, a majority of posts were still non-relevant or non-substantive.

In addition, participation in the regular classes was so low that coding of the posts was not meaningful. Accordingly, we worked with Mrs. Morgan to further revise the

Coding Scheme for Seeing Science Posts with Examples

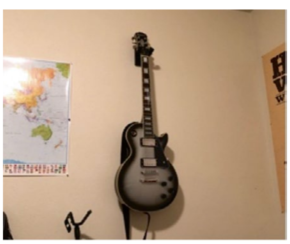
A. Non-Relevant Post.
Example: "… what have I started."

B. Simple Response to a Content-Relevant Post.
Example: "Exactly" [response to: "…wild dogs were let loose in Australia, and became the breed dingo."]

C. Content-Relevant, Non-Serious Post.
Example:

Caption: Gingerbread men don't have the same DNA or RNA as we humans do.

D. Content-Relevant, Non-Substantive.
Example:



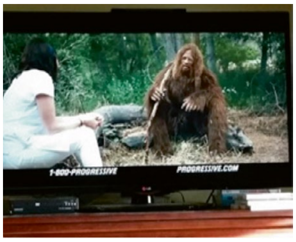
Caption: This is my silverburst les paul and it relates to what we're doing because the guitar is made out of wood which is living and therefore has dna in it.

E. Content-Relevant, Substantive Post.
Example:

Caption: It's time to connect science to music! So, I take a lot of music classes, choir and orchestra. In orchestra, Mr. [Thomas] was talking about how bar lines came into existence. Music used to only be a few lines long, so bar lines weren't needed. Once music became pages long, it was too hard to look at it all together. This, is an evolution of music writing and how it has changed. This reminds me of biology because we're talking about evolution and how species change over long periods of time.

Fig. 1 Coding Scheme for Seeing Science Posts with Examples

F. Content-Relevant, Deeply Substantive Post.
Example:



Caption: So I was watching TV, and this Progressive commercial came on that had Bigfoot in it. I had never thought of it before, but since I literally see science everywhere now, I realized that Bigfoot would probably be related to us in some way. I was thinking, if Bigfoot is real, how closely related would he be to us, and what is our common ancestor? I started also thinking about traits we would have in common, like the fact that we walk on two feet, and that for the most part his body structure looks like ours, but bigger and hairier. Something I wonder is about its face shape because it's not too similar to ours or other primates. Edit: I literally just found a picture of a primate family tree with the Sasquatch! [This picture was posted but we did include it due to copyright issues]

Fig. 1 (continued)

project and its implementation as described in the methods. These revisions made a clear impact in the pre-AP classes as the proportion of content-relevant substantive or deeply substantive posts rose to 77.8% with nearly half of all posts being deeply substantive. However, there were almost twice as many posts in year 1 despite more students participating in year 2, with students making a lot of non-relevant, simple response, or content-relevant non-serious posts in year 1 that were virtually absent in year 2. So, was the depth of posting in year 1 just washed out by the additional number of low-level posts these students provided? To test this, we removed the low-level posts from the analysis and found that students in year 2 still made a substantially more content-relevant, deeply substantive post and substantially less content-relevant, non-substantive posts (Table 5).

In addition to depth, we also coded Seeing Science posts in terms of the type and format of the post. The goal here was to further understand students' engagement as well as investigate how revisions to the Seeing Science project influenced participation in the activity. In terms of the type of post, we coded posts as being either original posts or responses to classmates' posts in order to understand how the dynamics of posting changed (if at all) from year 1 to year 2 (see Table 4). In the regular classes in year 1, participation was low and not much can be made of the results. In the pre-AP classes, the majority (62.1%) of year 1 posts were responses to classmates' posts and 37.9% were original posts. Response posts could be silly comments (e.g., "Yee haw," or "LOL"), simple affirmations (e.g., "I agree"), or more substantive comments on what another student posted (e.g., "Different species can evolve to different needs in completely different areas of the wild"). In contrast, there were no responses to classmates' posts in year 2 for both pre-AP and regular biology classes, meaning all of the posts (45 in pre-AP and 58 in regular) were original posts about students' own experience. A Chi-Square test confirmed that the differences in year 1 and year 2 in the pre-AP classes were statistically significant, X^2 $(1, N=132)=47.268$, $p<0.001$. We did not conduct a statistic analysis for the regular classes because of the low number of participants in year 1.

We also coded posts according to six post formats: (1) text only, (2) emoji (emoji only or text and emoji), (3) meme, (4) picture from the internet, (5) video from the internet, and (6) own picture or video (see Table 4). Posts with memes, pictures or videos from the internet, and students' own pictures or videos may have also included text or emojis. Again, not much should be made of the year 1 results in the regular classes due to the low participation rate. In year 1 in the pre-AP classes, a large proportion of posts (60.9%) were text-only and a relatively small portion (14.9%) involved students posting their own picture or video. In year 2, a smaller but still large proportion of posts in the pre-AP classes (46.7%) were text-only and more posts (31.1%) were students' own pictures or video. Posts in the regular classes in year 2 were mostly text-only (79.2%) and a small percentage (18.9%) were students' own pictures or videos. In year 2, there were no emoji's, memes, or Internet video posts, although

Table 4 Seeing science posts coded by depth, type, and format

	Pre-AP		Regular	
	Year 1 *n* (%)	Year 2 *n* (%)	Year 1 *n* (%)	Year 2 *n* (%)
Depth				
Non-relevant	22 (25.3%)	0 (0.0%)	1 (20.0%)	0 (0.0%)
Simple response	10 (11.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Content-relevant, non-serious	10 (11.5%)	2 (4.4%)	1 (20.0%)	9 (17.0%)
Content-relevant, non-substantive	13 (14.9%)	8 (17.8%)	0 (0.0%)	31 (58.5%)
Content-relevant, substantive	19 (21.8%)	13 (28.9%)	1 (20.0%)	13 (24.5%)
Content-relevant, deeply substantive	13 (14.9%)	22 (48.9%)	2 (40.0%)	0 (0.0%)
Type				
Original post	33 (37.9%)	45 (100%)	5 (100%)	53 (100%)
Response to a classmate post	54 (62.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Format				
Text only	53 (60.9%)	21 (46.7%)	0 (0.0%)	42 (79.2%)
Emoji	7 (8.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Meme	4 (4.6%)	0 (0.0%)	2 (40.0%)	0 (0.0%)
Internet picture	5 (5.7%)	10 (22.2%)	0 (0.0%)	1 (1.9%)
Internet video	5 (5.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Own picture/video	13 (14.9%)	14 (31.1%)	3 (60.0%)	10 (18.9%)
Total	87 (100%)	45 (100%)	5 (100%)	53 (100%)

students did post pictures from the Internet (22.2% in pre-AP and 1.9% in the regular classes). A Chi-Square test confirmed that the format differences between year 1 and year 2 in the pre-AP classes were statistically significant X^2 (5, $N = 132$) $= 20.226$, $p < 0.001$.

Overall, in year 2, students demonstrated considerably greater depth in their Seeing Science posts and were more likely to post their own pictures or videos than in year 1. In addition, simple responses to other posts and the posting of emojis, memes, and Internet videos were not present in year 2. These findings mainly apply to the pre-AP students as participation in the regular biology classes was very low in year 1. Compared to the initial implementation of the Seeing Science project (Cropp et al., 2022), students in the current study engaged more deeply with the project and more in line with our intentions, particularly in year 2.

In the methods, we described revisions made to the Seeing Science project in years 1 and 2 and these revisions as a whole are probable contributors to the changes observed. The study design does not allow us to link specific revisions to specific changes with certainty. Nevertheless, we feel it will be beneficial to reflect on potential linkages. First, we believe it is likely that *clarifying expectations* for the project and *modeling* Seeing Science posts contributed to the increase in content-relevant posts and original pictures and videos along with the reduction in memes and silly posts. It seems that through the clarification of expectations and modeling, students had a better sense of how to participate in line with the project intent, resulting in deeper-level and a larger number of posts.

Second, we believe the increase in depth, particularly in year 2, was likely related to efforts to *prompt scientific thinking, perceiving, and valuing inside and outside of school*. As described in the methods, Mrs. Morgan employed this design principle during Seeing Science discussions and these discussions were formalized and expanded in year 2. As illustrated later in the results, these discussions served as an opportunity to push students' thinking outside of their typical mindset and get them to make deeper connections, which established a norm for more impactful Seeing Science posts.

Third, we suspect the *crafting content as ideas* strategy helped foster greater participation in year 2. That is, efforts by Mrs. Morgan to inspire anticipation about acting on the content likely encouraged students to participate in the Seeing Science project and may have also contributed to more substantive content-relevant posts by encouraging thinking beyond just their experiences. Finally, the reduction in low-level post from year 1 to year 2 may partially reflect the change in posting platform from GroupMe to Google Classroom. The former affords more of social media type

Table 5 Depth of seeing science posts for pre-AP classes controlling for extra low-level posts in year 1

	Pre-AP	
	Year 1 *n* (%)	Year 2 *n* (%)
Content-relevant, non-substantive	13 (28.9%)	8 (18.6%)
Content-relevant, substantive	19 (42.2%)	13 (30.2%)
Content-relevant, deeply substantive	13 (28.9%)	22 (51.2%)
Total	45 (100%)	43 (100%)

interactions (e.g., posting emojis or memes, responding to others) than Google Classroom. In addition, students may have been more likely to respond to their peers on GroupMe than on Google Classroom because GroupMe is geared more towards promoting social conversation.

Qualitative Analysis of Students' Experience with the Seeing Science Project

The purpose of the qualitative analysis was to understand how the project helped students make and deepen connections between school content and everyday experience (if at all). We start with a case study of Madison's (pseudonym) experience, drawing on data from posts, class discussion, and an interview. Some of this data was presented in a prior publication and is cited accordingly. This case study illustrates how the project encouraged Madison to make connections in her everyday life and how her connections helped the class further explore the content and its relevance. The case study begins with an excerpt from a Seeing Science class discussion in which another student commented on Madison's post (names have been changed):

> "Okay," responded Hiro. "I was looking at Madison's [see Figure 1, example F] and she was talking about Bigfoot and how Bigfoot is real—that there might be a common ancestor between him and us since we're what he's supposed to look like and I thought that was really cool to…look into creatures that might not be real and look at how they would fit into…evolution and where they would go in cladograms and…I thought that was fun."…
> "Absolutely, yeah," responded [Mrs. Morgan]. "So what was this called again? You said it, Hiro."
> "Cladogram," answered Hiro.
> "Cladogram. Abso-freakin-lutely. The family tree, and it's interesting that they decided to put it here by the great apes. Interesting." (Pugh, 2020, p. 68)

This vignette illustrates how Madison made a connection between science content and her everyday experience of watching a commercial. The Seeing Science project primed her to make such a connection. In an interview, she clarified that the Seeing Science project,

> was actually really fun and it helped me see or take the classroom into my personal life…I feel like I usually see things after I learned things, when I'm just out and about. But since I had to it, like, really, really pay attention to them, I found myself getting more… How do I phrase it? I found myself thinking more. How can I relate this to what I'm doing in my classroom? And then how can I share this with my peers to help them understand that too?

Madison's caption to her Bigfoot post further illustrates that the project primed her to seek out connections as she wrote, "I had never thought of it before, but since I literally see science everywhere now…" It seems her enjoyment of the assignment, desire to complete the assignment, and wish to share her connections with classmates all combined to lead her to pay attention to science connections in her everyday life and see science everywhere.

Madison was able to capture a picture of the commercial and, as confirmed in a later interview, the experience spurred her to do research resulting in finding a cladogram with Bigfoot: "I actually did some research on it and, like, found the image that linked it to orangutans and stuff and I just thought that was really funny." Her post then became a concrete artifact the class used to develop connections between unit content and everyday experience. Mrs. Morgan prompted the students with questions and the further discussion included consideration of whether humans could mate with Bigfoot, what defines a species, Ligers, and how geographic isolation could have led to speciation:

> "Would we be able to mate with Bigfoot?" [asked Mrs. Morgan]
> "No, I don't think we would," responded Hiro.
> "Why wouldn't we be able to mate with them?"
> "I think it would be just too far back, too many changes. But you know, I don't know."
> Lupe jumped in: "I think that our babies wouldn't be able to have babies. Like mules. Like horses and donkeys can have babies but most mules, if not all mules, are sterile. Like ligers are bred in captivity. Ligers are lions and tigers that have had a baby and like 99% of the time they are sterile."
> "True that," responded [Mrs. Morgan]. "Remember that by definition of a species, you [can] mate and have fertile offspring. I had another question about this. Oh, where do these things live right here?" She pointed to the apes on cladogram.
> "Africa and Asia?" responded Lupe tentatively.
> "Yeah! And this guy . . ." [Mrs. Morgan] pointed to Bigfoot. ". . . we think of Bigfoot as being North American or a Canadian type of thing. What's that called when they become separated? Maybe there was the land bridge type of thing. Maybe it, like, caught a log and ran away, and was able to become a new species. What's that called?"
> "Are we going with things like gene interest or like speciation?" asked Margo.
> "I'm thinking of speciation. What kind of isolation is that? Cuz these guys are on different continents."
> "Geographic?" asked Margo.
> "Yeah geographic isolation. Abso-freakin-lutely." (Pugh, 2020, p. 68-69)

Madison's experience highlights engagement in transformative experience (Pugh, 2011). She engaged in motivated use by applying school content in her everyday life. To a degree, this application was for an assignment, but her comment stating "I literally see science everywhere now" indicates she was going beyond the assignment and engaging in genuine motivated use of content. She also demonstrated school-prompted interest (Bergin, 1996), which is an aspect of motivated use, by researching the cladogram. In addition, Madison experienced expansion of perception in that she was able to re-see everyday objects and events through the lens of school content. Finally, she developed experiential value as indicated by her comment that it was "really fun…[to] take the classroom into my personal life." Moreover, her experience, mediated through the Seeing Science posts and discussion, helped the class establish meaning and relevance with the content. Meaningful Seeing Science classroom discussions, such as this one focused on Madison's post, were a more regular occurrence in year 2 and contributed to classroom culture in which connecting science to everyday experience was valued.

Similar to Madison, other students were primed by the Seeing Science project to make rich connections between their school learning and everyday experience. The following Seeing Science post describes a student engaging in motivated use and expansion of perception by applying genetics to guacamole and chips and re-seeing this familiar snack through the lens of a genetics unit:

> Reasons why mRNA is guacamole and DNA is chips: 1. The nitrogen bases on mRNA literally spell out "GUAC." 2. Chips get the spotlight because guacamole is just dirty butter (my opinion) and isn't as awesome and chips have many reasons for being there (guacamole, salsa, etc.) just like DNA has many different functions. 3. When you put guacomole (sic) into a container, it takes the opposite shape, just like how mRNA takes the opposite shape of DNA in transcription because it has to match compatible pairs of nitrogen bases with the nitrogen bases on DNA.

Another student was able to re-see bug spray through the lens of proteins (expansion of perception) and researched the mechanics of bug spray in preparation for a trip abroad (motivated use):

> I am going to Belize over spring break, so I am going to have to get better bug spray. I was interested and looked up how bug spray works. Basically, people smell like carbon dioxide and insects like mosquitos have evolved to track that scent (a mutation that became an advantage). By using odorant binding proteins (OBPs) like deet, we can mask our smell. These AgamOBPs compete with the mosquito's OBPs to be able to bind with the attractive odorants and cause the mosquitos to completely miss your scent. Proteins are great and sometimes humans can't produce certain proteins that would have an evolutionary advantage, so they have to find them elsewhere. If someone were able to produce these proteins, they would have quite an advantage over other humans, especially when it comes to things like diseases spread by insects.

Both of these posts provide evidence of students engaging in transformative experiences during the Seeing Science project. Their depth illustrates that students were authentically engaging with science content outside of school. In Madison's example, students' transformative experiences outside of class stimulated discussion in the classroom, further emphasizing the power of these connections. However, as detailed in the first section of results, the quality of posts varied. Some posts may be interpreted as students simply doing what they were assigned rather than truly undergoing transformative experiences. Thus, it seems the Seeing Science project provided the opportunity for deep connections, but only some students fully embraced this opportunity (with more students embracing the opportunity in year two).

Post-intervention interviews yielded further examples of how the Seeing Science project supported engagement with school content in everyday life for some students. We had planned to compare interviews between year 1 and year 2, but the COVID-19 pandemic and switch to online learning toward the end of year 2 resulted in only five interviews in year 2. Out of those five interviews, four students indicated that the Seeing Science project helped them apply school content to their everyday lives. For example, one student explained how the project influenced her to make connections to biology and talk about these connections with her friends,

> Some of my friends…we'd like see something that connected with bio, and we just start talking about it and, usually, when I talk about classes with my friends, it's like, 'Hey, did you get this homework done? Can I, like, see it?'…But this was actually like connecting to the class and had nothing to do with, like getting an assignment.

When asked about the Seeing Science project, another student explained, "I thought it was really cool to see like all of the science, outside of class, and that it really literally is everywhere…So, it forced me to think like scientifically outside of class. Yeah, like, what am I seeing outside of class that I can connect to class?".

The experiences of these students illustrate how Seeing Science prompted and deepened connections between school science content and everyday experience. However, one student from year 2 did not share these same experiences. This student enjoyed the activity, but mostly because it was fun to read classmates' silly responses; "The best part was kind of just reading everyone else's [posts] and laughing at how silly they were." This student was entertained but did not express any re-seeing experiences. Due to the limited number of interviews, these data should not be interpreted as representative of the full sample. Rather, they illustrate ways in which the project functioned to support transformative experiences for some students and ways in which it functioned as mere entertainment for other students.

General Discussion

Transformative experience theory (e.g., Pugh, 2011, 2020) seeks to understand the nature of transformative experiences, that is, experiences in which students use school content to see and experience the world in meaningful, new ways. A product of this theory is the Teaching for Transformative Experiences in Science (TTES) instructional model. The current study investigated the potential of pairing boundary-crossing mobile technology and social media with components of the TTES model. Specifically, we collaborated with a high school biology teacher to design the Seeing Science project, a project in which students were asked to take pictures when they noticed connections to biology course content in their everyday lives and post these pictures to a collaborative platform along with a caption explaining the connections.

Results of the current study suggest that the Seeing Science project can support students in connecting their in-school learning to their out-of-school experience and help them undergo transformative experiences. In fact, these connections can be quite rich and can serve as artifacts at the center of engaging class discussions as illustrated in the case study of Madison. This finding aligns with those of Herrick et al. (2022) who used photography to foster transformative experiences among fifth-grade students learning climate concepts. They explained that photography allowed students to bring their "outside moment of [transformative experience] back into the classroom to re-see it in scaffolded ways with their teacher and peers" (p. 108). However, we also found that participation and engagement varied. In line with design-based research (Anderson & Shattuck, 2012), the results provide insight into the functioning of the project in context, yield practical application principles, and contribute to the theory of transformative experience, including the role of mobile technology and social media in the fostering of transformative experiences.

One general principle that can be derived from the current study is that the Seeing Science project functions better when supported by other TTES strategies. Indeed, gauging by the level, depth, and type of participation in year 1, it seems supportive TTES strategies are necessary for the project to function, particularly in the regular biology classes. We underestimated the degree to which students would naturally engage with the activity. We assumed students would naturally and frequently engage in taking and posting their own pictures because mobile technology and social media are so prevalent in students' lives. That is, we assumed these technologies would naturally bridge students' everyday and school experiences in line with prior theory (Baş & Sarıgöz, 2018; Goodwin, 2012; Zheng et al., 2016). However, it seems this is asking too much of the technology. While such technology has the *potential* to function as a bridge, students largely treat their in-school lives separately from their out-of-school lives. To get the technologies to function as a bridge, the students need clear expectations, models of how to engage, help identifying re-seeing opportunities, framing of content that inspires anticipation, and prompting in terms of their scientific thinking and perceiving. Thus, instead of considering the Seeing Science project as a stand-alone TTES strategy that fosters transformative experiences, it is best understood as a strategy that aligns with other TTES strategies and contributes to a holistic approach to teaching for a transformative experience. This finding supports prior research finding that TTES strategies need to be utilized holistically and in an integrated manner (Pugh et al., 2010b, Pugh et al., 2017a).

Another general principle is that the technology platforms used for the Seeing Science project might influence the nature of participation. When a social media platform (GroupMe) was used, participation was more frequent but involved many posts typical of social media: simple reactions, silly comments, emojis, and so on. When Google Classroom was used as the platform, posts were more content-rich and in line with the project intent. However, posts were less frequent and all responses to other student posts disappeared. Thus, different platforms carry different affordances and constraints (Pimmer & Tulenko, 2016; Sammel, 2014; Stewart, 2015; Xue & Churchill, 2019), which may result in different engagment. A social media platform may possibly afford greater collaboration and sense of community at the expense of deeper, content-focused participation, whereas we found the opposite to be true when students used Google Classroom.

One context-specific finding is that the Seeing Science project functioned better in the pre-AP biology classes than in the regular biology classes. This is not surprising. Nevertheless, the finding highlights the fact that further design-based research is needed to understand how frequency and quality of participation can be increased in regular biology classes.

Theoretical Implications

John Dewey theorized that as aspects of society become formalized, they also become separated from everyday experience. As art became formalized and products attained classic status, they became more isolated in museums or concert halls and separate from everyday experience (Dewey, 1980). Likewise, as education became formalized, it became isolated in the classroom and cutoff from everyday experience (Dewey, 1938). Much theoretical work has focused on restoring the connection between school learning and everyday experience. Constructivist perspectives (e.g., Smith et al., 1993) have investigated how teachers can draw on students' schemas constructed from their experiencing of the world. Culturally responsive pedagogy (e.g., Ladson-Billings, 1995) models have explored ways of connecting school learning to students' cultural experience. One insight from this research is that bridging in-school and out-of-school experience has powerful learning benefits but is hard to achieve and requires deliberate scaffolding. Prior research on transformative experience theory found that, even in the context of "good" science instruction, only around 10% of students naturally undergo transformative experiences (e.g., Pugh, 2002; Pugh et al., 2010a, b, 2017b). To increase this percentage, deliberate scaffolding of experience and targeted instructional strategies are needed (e.g., Girod et al., 2003; Heddy & Sinatra, 2013; Pugh et al., 2017b). The current study supports and builds on these findings. As described above, participation and the level of transformative engagement were relatively low in year one when scaffolding was more limited. We assumed that students would readily engage with mobile technology and such technology would naturally bridge in-school and out-of-school experience due to its boundary-crossing nature. However, we found this not to be the case. Thus, we conclude that mobile technology and collaboration technology (e.g., GroupMe, Google Classroom) are relevant to transformative experience theory. However, it needs to be understood that these technologies can support undergoing the transformative experience, but on their own, they are unlikely to bridge the gap between school learning and everyday experience.

Practical Implications

The practical implications flow directly from the theoretical implications. The current research suggests teachers can help students bridge the gap between school and everyday experience; that is, teachers can help make learning transformative. This is important because such transformative experiences foster deep levels of learning and help students identify with science and develop an interest in particular content (Pugh, 2020). Moreover, to borrow an argument from Dewey (1938), such experiences are critical to the core purpose of education, which is to enrich and expand everyday experience. Based on the current research, we offer three recommendations for fostering transformative experiences. First, we encourage teachers to use technology in ways similar to the Seeing Science project to support transformative experiences. That is, we encourage teachers to use technologies which allow students to capture moments of re-seeing in their everyday lives and share these moments with fellow students. We also encourage teachers to use the student experiences shared via technology as anchors for grounding content learning in the student experience. Second, we encourage teachers to provide clear expectations and models for technology use. Students have in-school and out-of-school identities and norms, including technology use norms. Getting students to use technology in everyday life in ways that align with school purposes is a challenge. Thus, establishing expectations and norms is important and likely to be a process that extends over multiple implementations. Third, we encourage teachers to implement the technology in collaboration with teaching for transformative experiences in science (TTES) strategies. Because transformative experiences are difficult to foster, teachers can't rely on the technology itself to bridge the gap between school and everyday experience. Implementations of the Seeing Science project are likely to be disappointing if not supported by a broader transformative experience pedagogy.

Limitations and Future Directions

Because there were multiple modifications between year 1 and year 2, we cannot pinpoint exactly which changes were responsible for the transformations observed in the quality of participation or if these transformations resulted from a holistic combination of changes. Future research could seek to tease out which of these factors contributed the most to the change in participation.

Additional factors may also have played a role in the transformations observed between years 1 and 2. One possible influential factor was the COVID pandemic forcing everything to move online in year 2, possibly impacting student interactions and posts. Future research could use an experimental or quasi-experimental approach to confirm the effects of the Seeing Science project on particular outcomes.

The current study investigated the functioning of the Seeing Science project within a particular content area. Future design-based research is needed to understand its functioning in different contexts and develop its effectiveness in different content areas. Some important factors to explore would include the impact of student age, different teachers, and/or different ways of implementing the Seeing Science project as either more formative or summative elements of assessment. As mentioned previously, future design-based research is also needed to support the effectiveness of the project in regular biology classrooms.

Future research could also explore the development of an app to support the Seeing Science project. As mentioned previously, both GroupMe and Google Classroom had certain affordances and constraints. A custom app could address constraints and embed additional affordances. For example, re-seeing opportunity prompts could be sent through the app and response templates could be developed to help students post in line with project goals.

Finally, the Seeing Science project is one way to foster students' transformative experiences with science content, but is by no means the only way to encourage connections between in-school learning and out-of-school experience. Furthermore, we took for granted the value of Western, scientific ways of seeing the world. In accordance with Law's (2015) argument, we respect different perspectives on science and meaning making. We acknowledge that the Western, scientific perspective is not without its problems. Future research could explore ways the Seeing Science project could encompass broader re-seeing perspectives such as indigenous and non-Western perspectives.

Conclusion

Integrating in-school learning with out-of-school experience is critical to developing meaningful, deep-level learning (National Research Council, 2000) and actualizing the potential of education to enrich everyday life (Dewey, 1938). The Seeing Science project is a promising intervention for achieving this purpose when paired with other Teaching for Transformative Experiences in Science (TTES) strategies. That is, it can support students in undergoing transformative experiences by priming them to look for and notice connections to science content in their everyday lives, helping them re-see aspects of their everyday world through the lens of science content, and creating a classroom culture in which science connections are shared and valued. However, engagement with the Seeing Science project varied and participation was more limited in regular biology classes. Additional research is needed to understand how the project can be implemented with greater effectiveness is regular classes, where the need for fostering transformative learning is likely greater.

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Data Availability The data that support the findings of this study are available on request from the corresponding author, Kevin Pugh. The data are not publicly available due to their containing information that could compromise the privacy of research participants.

Declarations

Ethical Approval Approval to conduct the research was received from the relevant university institutional review board, and ethical guidelines were followed in conducting this research. Informed consent was obtained from all participants.

Conflict of Interest The authors declare no competing interests.

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