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Article

Conjecture Mapping an Integrated steM Camp to Support Middle School Students' STEM Identity and STEM Interest

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Abstract: This study reports on an integrated steM camp that aimed to improve middle school students' STEM identity, interest in STEM careers, and interest in environmental issues. Conjecture mapping was used as a tool to design the camp and to investigate if, how, and why the program features influenced the mediating processes and if, how, and why the mediating processes influenced the program outcomes. This study is grounded in design-based research and uses data from observations, interviews, surveys, facilitator reflections, and a group interview to answer the research questions. The findings revealed that most of the program features facilitated the intended mediating processes, which in turn influenced the intended outcomes. We also found that participants' interest in STEM careers, interest in environmental issues, and interest in STEM identity increased. The findings of this study and the revised conjecture map advance the field's understanding of how to improve middle school students' STEM-related outcomes through an integrated steM camp. The findings also speak to some of the challenges of this designed environment and provide recommendations to address those challenges.

Keywords: conjecture mapping; mathematics; informal STEM; camp; STEM identity; STEM interest; environmental issues

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1. Introduction

"Harnessing the power of these [STEM] disciplines and shaping and deploying them in ways that promote the wellbeing of all citizens and long-term stewardship of the natural world requires a well-informed population of critical thinkers that understands the STEM disciplines" (National Academies of Sciences, Engineering, and Medicine, 2024). According to researchers, mathematics is often the silent letter in the STEM disciplines when it comes to STEM education (Shaughnessy, 2013), especially in informal STEM learning (Blanchard et al., 2020). Thus, many of the positive impacts reported about informal STEM learning environments (e.g., Broder et al., 2023; De Lira et al., 2022; King & Pringle, 2019; Kudaisi, 2025; Reid-Griffin, 2019) tend to come from studies where the STEM focus is primarily on the other STEM disciplines (Blanchard et al., 2020). Thus, a gap in the research exists on the impacts of informal STEM learning environments that explicitly integrate mathematics (e.g., Aklman et al., 2019).

To attend to this gap in practice and in research, Stohlmann (2018) proposed integrated steM, where the capital m indicates an explicit focus on mathematics within STEM education. That is, within STEM education, mathematics is explicitly integrated with at least one of the other content areas. This explicit integration of mathematics is important because mathematics forms the foundation for other STEM disciplines (Ben-

Jacob, 2019). It is also important because it gives students additional opportunities to develop mathematical proficiency, which is needed to succeed in school mathematics and to be successful in STEM careers. Additionally, an explicit focus on mathematics within informal STEM learning is especially significant because such an out-of-school context allows students to engage in innovation development (National Academies of Sciences, Engineering, and Medicine, 2024).

Given that prior research on STEM camps provides evidence of positive impacts on students, the field would benefit from further research that examines the impacts of STEM camps that explicitly integrate mathematics, which we refer to henceforth as integrated steM camps. Research on how to facilitate learning in these environments in such a way that leads to positive outcomes for students would add to the existing literature on current strategies, methods, and curricula that support positive STEM outcomes for students. Not knowing this information threatens our ability to offer such programs.

Additionally, research is scant on how certain program elements and mediating processes influence outcomes. In fact, much of the research on STEM camps focuses on outcomes such as STEM interest (e.g., Schroeder et al., 2024), STEM career knowledge (e.g., Hirsch et al., 2017), STEM career interest (e.g., Tekbiyik et al., 2022), STEM identity (e.g., Roberts & Hughes, 2019), STEM efficacy (e.g., Weist & Crawford-Ferre, 2023), and motivation (Lindt & Gupta, 2020). However, few studies focus on how those outcomes were achieved. Consequently, in many of these studies, we only know what the outcome was, not how the outcome was achieved. Thus, the field would benefit from studies that make clear connections between achieved outcomes and how those outcomes were achieved (e.g., mediating processes). Furthermore, the field would benefit from research that describes program features that contribute to the mediating processes that support the intended outcomes of the interventions.

In the current study, we address gaps in prior research by designing and investigating the impact of an integrated steM camp on middle school students' STEM identity, interest in environmental issues, and interest in STEM careers. We focused on STEM interest because of the research that shows that STEM identity influences student persistence in career choice (Stewart, 2022; Stewart et al., 2023). We focused on STEM interest because of the research that shows that students who become interested in STEM by 8th grade are more likely to choose a STEM career (Tai et al., 2006) and research that shows that interest is a greater predictor of students' decision to choose a STEM career path (Maltese & Tai, 2011). In addition to investigating outcomes, we make connections between program features of the integrated steM camp and the mediating processes they elicit, which in turn may support the intended program outcomes.

1.1. Theoretical Framework: Conjecture Mapping

We used conjecture mapping as a guiding framework to design, implement, and investigate the theoretical basis of the integrated steM camp, allowing us to accept, reject, or refine our initial hypotheses (Boelens et al., 2020; McKenney & Reeves, 2019; Sandoval, 2014). Conjecture mapping is "a technique for mapping conjectures through a learning environment design, distinguishing conjectures about how the design should function from theoretical conjectures that explain how that function produces intended outcomes" (Sandoval, 2014, p. 18). Conjecture mapping is also a research tool that supports researchers in explicating a design that they plan to implement (Sandoval, 2014). Researchers create initial conjecture maps at the beginning of their study before implementation. After collecting data throughout the study, they make data-driven decisions to develop the next conjecture map. This refinement allows researchers to adjust and meet desired outcomes for their next cycle of intervention. It is important to note that the arrows in the "conjecture map specify a relation open to empirical refinement"

(Sandoval, 2014, p. 27). A conjecture map consists of four parts: a high-level conjecture, embodiment, mediating process, and outcomes (see Figure 1). The high-level conjectures provide a hypothesis or initial idea of learning through a specific context. Embodiment represents the program elements that focus on the learning environment and involve tangible aspects of the context. These program elements can include tools and materials used, task structures, participant structures, and discursive practices. The mediating process is the observable actions that result from participants engaging with the embodied program elements. These mediating processes can include observable interactions (OI), artifacts (A), and other context influences. Outcomes are the desired results researchers aim to achieve from the learning environment. These outcomes could be learning outcomes, interest outcomes, or other desired outcomes. Conjecture maps provide insight into hypothesized connections between embodiment, mediating processes, and outcomes, which are expressed as design conjectures (DC) and theoretical conjectures (TC). Design conjectures outline the meditating processes that the program features may elicit (Sandoval, 2014). Theoretical conjectures outline the mediating processes that we hope will influence program outcomes (Sandoval, 2014).

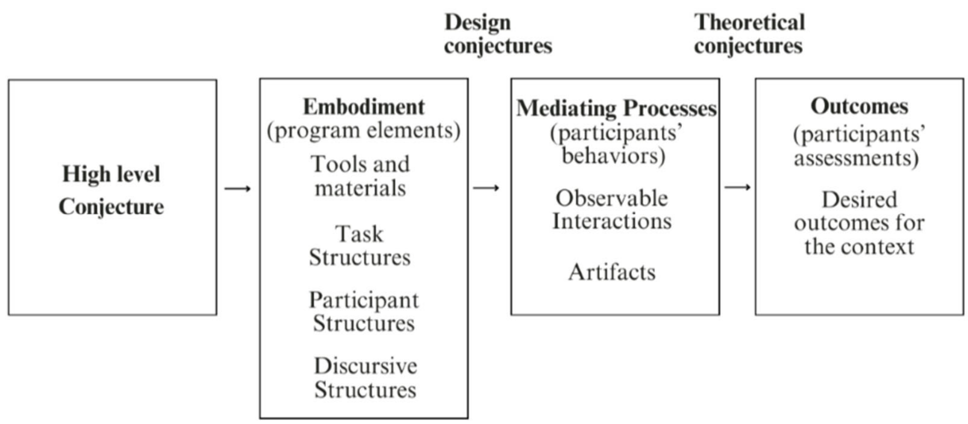

Figure 1. Conjecture mapping process adapted from Sandoval (2014).

Altogether, tools and materials under the program elements (embodiment) will elicit observable interactions (mediating processes) for participants during the summer integrated steM camp, which we hope would positively influence program outcomes. We used conjecture mapping as the theoretical basis for the design, implementation, and investigation of the integrated steM camp under investigation in the current study. In the next section, we will describe each component of our initial conjecture map that was designed for the integrated steM camp.

We used conjecture mapping to explore how the design of an integrated steM camp increased middle school students' STEM identity, interest in STEM careers, and interest in environmental issues (Sandoval, 2014). Figure 2 presents the initial conjecture map developed by the first author. The goal of the current study is to identify the program elements of an integrated STEM camp that would yield the mediating processes that are needed to support the intended outcomes of the program. The first step in the development of the conjecture map for the current study was to construct the high-level conjecture. After constructing this high-level conjecture, research was conducted on what program elements would support the intended outcomes of the program. After relying on the research literature to inform the program elements that could potentially lead to the student outcomes, a decision was made about the observable interactions that we hoped to see as a result of participants engaging with the program elements, which would in turn support the achievement of the intended outcomes of the program.

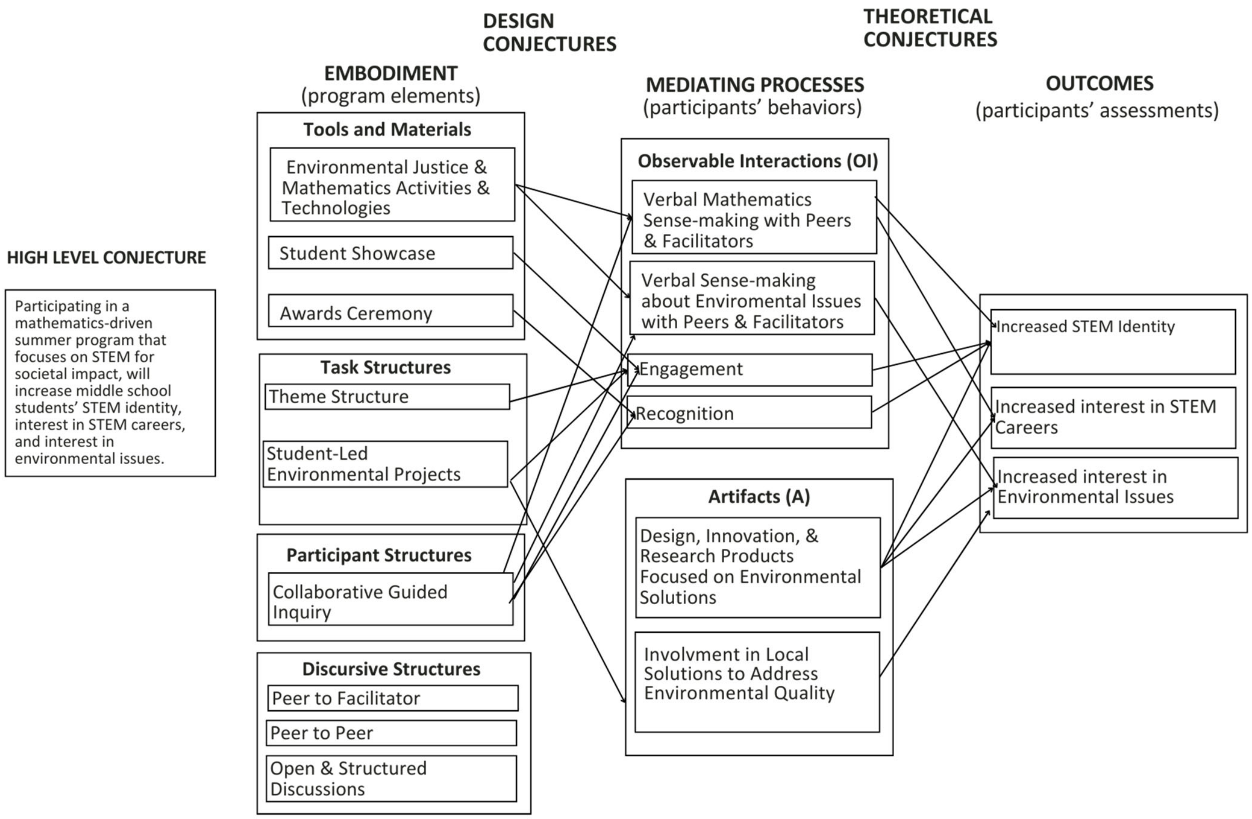

Figure 2. Initial conjecture map.

1.1.1. High-Level Conjecture

The high-level conjecture for this project is as follows: participating in an integrated steM camp that focuses on STEM for societal impact will increase middle school students' STEM identity, interest in STEM careers, and interest in environmental issues. The embodied program elements of the steM camp include the following: (1) tools and materials (environmental justice activities that have mathematics and technology embedded in them, a student showcase, and an award ceremony); (2) task structures (theme-structured camp, standards-aligned curriculum materials for mathematics and environmental science, and student-led environmental projects); (3) participant structures (collaborative guided inquiry); and (4) discursive structures (collaborative opportunities for peer-to-facilitator, peer-to-peer, and open and structured discussions) (Sandoval, 2014). These program elements, their mediating processes, and the intended outcomes will be described in further detail in the sections that follow. We describe these by first describing the mediating process, why it is important, and its resulting theoretical conjecture. Next, we describe the program elements that elicit the mediating process, why they are important, and its resulting design conjecture.

1.1.2. Mediating Processes: Observable Interactions

Mediating process 1 is *verbal mathematics sense-making with peers and facilitators* (see Figure 2). This mediating process is an observable interaction in which students verbally engage in mathematical sense-making with their peers and facilitators. The conversations, including language and vocabulary, between the participants in a group setting while performing an experiment, research, or participating in the creation of an artifact constitute verbal mathematics sense-making with peers and facilitators. Verbal mathematics sense-making is important because it provides insight into students' mathematical thinking and supports educators in facilitating further mathematical discourse. This is in part why the National Council of Teachers of Mathematics (2014) encourages mathematics educators to elicit and use evidence of student thinking and to facilitate meaningful mathematical discourse. Additionally, this mediating process also provides opportunities for participants to develop connections with mathematical skills and integrated steM activities. As such, based on the mediating processes, *theoretical conjecture 1 (TC-OI-1)* is as follows: if students participate in verbal mathematics sense-making with peers and facilitators, then there will be an increase in STEM identity and an increased interest in STEM careers.

Verbal mathematics sense-making with peers and facilitators can be facilitated by three program elements: environmental justice activities that have embedded mathematics and technology content, standards-aligned mathematics, and collaborative guided inquiry. Environmental justice activities that have mathematics and technology embedded in them are activities developed by the facilitators for students to participate in exploring a common goal. This program element was integrated into the program design based on Gray et al.'s (2020) findings that STEM camp participants were more engaged with STEM lessons that showed them how they could help others or that taught them how their actions could "protect the lives of humans, animals, or plants" (p. 6). Providing aligned standards with the mathematics activitieshelps to ensure that students are engaging with the appropriate grade level mathematics as described by the local standards, the Texas Essential Knowledge and Skills standards (Texas Education Agency, 2012). Thirdly, collaborative guided inquiry is an opportunity for students to work with their peers on the various activities of the camp with the assistance of a facilitator. Collaborative inquiry is important because it is a 21st-century skill (Geisinger, 2016; Pérez, 2018). It is also important for collaborative inquiry to be guided so that students have support when they need it. In this way, we allow for productive struggle (Warshauer, 2015). We believe that by having this guidance, students will have opportunities to have success with the content, which will support them in recognizing themselves as learners and doers of mathematics (Aguirre et al., 2013) and STEM more broadly, which in turn will increase their STEM identity. Based on the program elements, *design conjecture 1 (DC-OI-1)* is as follows: if environmental justice activities have embedded mathematics and technology content, standards-aligned mathematics, and collaborative guided inquiry are used, then students will engage in verbal mathematics sense-making with peers and facilitators.

Mediating process 2 is *verbal sense-making about environmental issues with peers and facilitators*. This mediating process is the observable interactions of the participants that use language and sense-making regarding environmental issues with their peers and with facilitators. The conversations, including language and vocabulary, between the participants in a group setting while performing an experiment, research, or participating in the creation of an artifact constitute verbal sense-making with peers and facilitators. This mediating process provides opportunities for participants to explore their positionality regarding environmental issues. Based on the mediating processes, *theoretical conjecture 2 (TC-OI-2)* is as follows: if students participate in verbal sense-making with peers and facilitators regarding environmental issues, then there will be an increased interest in environmental issues.

Verbal sense-making about environmental issues with peers and facilitators can be facilitated by three program elements: environmental justice activities that have embedded mathematics and technology content, standards-aligned environmental science, and collaborative guided inquiry. The environmental justice activities that have embedded mathematics and technology content are described in the previous section. The standards-aligned environmental science content that students engaged with is light pollution. In Texas, middle school students learn about pollution (Texas Education

Agency, 2021). Providing aligned standards with the environmental science activities helps to ensure that students are engaging with the appropriate grade level environmental science as described by the local standards, the Texas Essential Knowledge and Skills standards. Thirdly, as mentioned earlier, collaborative guided inquiry is the opportunity for students to work with their peers on the various activities of the camp with the assistance of a facilitator. For example, the final facilitator-led collaborative inquiry project of the camp was an open-ended design project. The open-ended design project element of the program was designed based on Tyler et al.'s (2019) findings about the positive impacts of an "open-ended design project[s]" and its positive results for getting students interested in STEM (p. 21). For this project, students engaged in Python coding and used physical materials to engineer a light post that points at the right angle, such that it limits light pollution's effect on birds. Based on the program elements, *design conjecture 2 (DC-OI-2)* is as follows: if environmental justice activities have embedded mathematics and technology content, standards-aligned mathematics, and collaborative guided inquiry are used, then students will engage in verbal sense-making with peers and facilitators regarding environmental issues.

Mediating process 3 is *engagement*. We conceptualize engagement as a behavioral aspect because it is what we can see. As such, we use Allen et al.'s (2019) definition of engagement as "behavioral (e.g., participating or involving oneself in STEM activities or projects)" (p. 6). Engagement in STEM is closely related to STEM identity development (Cribbs et al., 2015). We measured engagement by noting if students were participating in the various activities of the camp. For example, we observed that most of the students were engaging in the Texas Instruments coding activity. Based on the mediating processes, *theoretical conjecture 3 (TC-OI-3)* is as follows: if students are engaged, then there will be an increase in STEM identity and an increase in interest in STEM careers.

Engagement can be influenced by having a student showcase, collaborative guided inquiry, student-led environmental projects, and a theme structure. As collaborative guided inquiry was described earlier, we will describe the student showcase, the student-led environmental projects, the theme structure, and the importance of each.

The student showcase was designed to engage students such that they knew that they would be presenting their research to their family members, teachers, community members, and other relevant stakeholders (e.g., government officials) at a showcase. The student showcase took place at the university instead of the middle school where most of the camp took place. We explained to the students that they would be the "experts" at their presentation to bolster their STEM identity and get them to recognize themselves as doers and learners of mathematics (Aguirre et al., 2013) and STEM more broadly and to be recognized by others. We also thought that students being deeply engaged in their projects that related to real-world phenomena would make them more interested in a STEM career. More specifically, because the projects were connected to real-world phenomena, we thought that this type of experience would get students more interested in a STEM career. In doing so, we hoped that their STEM identity would increase and that they would get more interested in STEM careers.

The student-led environmental projects were projects that allowed for the autonomy of the students to choose an issue that they wanted to focus on. Each member of the team was responsible for researching and speaking during the presentations of their projects. However, at the start, each member was assigned a role in the group (e.g., reporter, recorder, researcher, and designer in some cases). This was to ensure that each member was playing an active role during the project development portion. We asked students to examine a problem that exists because of the electric lights in their home, school, community, the state, and any other place that affects them. Though it was a student-led project, students were expected to use what they learned and engaged with in the camp to develop their projects. However, they were also encouraged to explore beyond what they learned in the camp.

Regarding the theme structure, the camp was designed based on the theme of light using a popular term that youth use. The camp was titled camp LIT. This theme structure was used based on research that identifies the use of themes as an important program structuring element (Lee et al., 2018) and research that indicates that the use of themes gets students interested in STEM (Tyler et al., 2019). Based on the program elements, *design conjecture 3 (DC-OI-3)* is as follows: if collaborative guided inquiry, student-led environmental projects, theme structure, and a student showcase are enacted, then students will be engaged.

Mediating process 4 is *recognition*. As mentioned earlier, recognition of oneself and recognition by others as doers and learners of mathematics and STEM more broadly play an important role in increasing students' STEM identity (Cribbs & Utley, 2023). According to Allen et al. (2019), recognition "refers to how youth view themselves in relation to STEM as well as how they feel they are viewed by others (i.e., their parents, teachers, or friends) in relation to STEM" (p. 7). In the current study, we measured recognition through observations whereby we looked for instances of how the participants recognized themselves and if and how they were recognized by their peers and facilitators in relation to STEM ability. Based on the mediating processes, *theoretical conjecture 4 (TC-OI-4)* is as follows: if students are recognized, then there will be an increase in STEM identity and an increase in interest in STEM careers.

For our initial conjecture map and design of the program, we wanted to be intentional about recognizing students in the program. As such, we were intentional about recognizing students as they participated in group activities during the collaborative guided inquiry time. During this time, facilitators had opportunities to recognize and encourage the students in STEM, and students also had the opportunity to recognize and encourage each other. We also designed the program so that students would participate in an award ceremony where the participants would be recognized for their work. This program element is based on research that suggests that recognition positively contributes to students' mathematical identity development (Cribbs & Utley, 2023), which is applied broadly to STEM. Based on the program elements, *design conjecture 4 (DC-OI-4)* is as follows: if collaborative inquiry and an award ceremony are used, then students will be recognized.

1.1.3. Mediating Processes: Artifacts

Mediating process 5 is *design*, *innovation*, *and research products focused on environmental solutions.* We designed the program to elicit design, innovation, and research products that focused on environmental solutions. This component of the camp was included based on research that suggests that "stand alone" projects play an important role in getting students interested in STEM (Tyler et al., 2019). These projects were research or design projects related to light pollution (e.g., light quality) but also related to their interest (e.g., light quality in their neighborhood). The project options for this program include student research projects or innovation projects. A research project involves asking a research question and looking for an answer. An innovation project involves students creating a product that solves a problem in the environment. For these projects, the role of the facilitator was to support the students through the process. This support looked like facilitators encouraging student engagement and answering questions. Based on the mediating processes, *theoretical conjecture 5 (TC-A-1)* is as follows: if students engage with the design, innovation, and research products focused on environmental solutions, then there will be an increase in STEM identity, increased interest in STEM careers, and increased interest in environmental issues. The design, innovation, and research products that focused on environmental solutions in the initial conjecture map can be influenced by offering student-led environmental projects as an activity in the camp, as discussed earlier. Based on this program element, *design conjecture 5 (DC-A-1)* is as follows: if student-led environmental projects are offered, then design, innovation, and research products are created.

Mediating process 6 is involvement in local solutions to address environmental quality. We designed the program to elicit this artifact, which would get participants more interested in STEM careers because of the connection of STEM content to the real world and the potential to be able to make an impact in their community (Gallay et al., 2021). This was based on research that indicated that engaging students in projects that involved students in providing solutions to local problems was an effective process for getting students interested in STEM (Gallay et al., 2021). Based on the mediating processes, *theoretical conjecture* 6 (TC-A-2) is as follows: if students engage with involvement in local solutions to address environmental quality, then there will be increased interest in environmental issues. The involvement in local solutions to address environmental quality can be influenced by offering student-led projects that focus on environmental issues, as described earlier. Based on this program element, *design conjecture 6 (DC-A-2)* is as follows: if student-led environmental projects are offered, then there is involvement in local solutions to address environmental quality.

1.2. Summary

The outlined theoretical framework presented six conjectures that explained the relationship between the program elements of the summer STEM camp and the mediating processes. There are also six theoretical conjectures developed based on the relationship between the mediating processes and the outcomes. Figure 2 demonstrates the initial conjecture map of the integrated steM camp. The map shows how the program elements are related to the mediating processes and the outcomes developed. The primary focus of the study is the desired outcomes, as the aims of the summer STEM camp are to increase STEM identity, interest in STEM careers, and increase interest in environmental issues. By focusing on the mediating processes throughout the summer STEM camp, we can connect the outcomes to the most effective mediating processes. Even though each conjecture is analyzed and discussed as separate focal points, we acknowledge that some conjectures influence each other interchangeably.

1.3. The Present Study

The camp being studied was the first design cycle of a research project that focuses on the development of positive STEM outcomes for a diverse group of middle school students. More specifically, the goal of the camp was to improve participants' STEM identity, interest in STEM careers, and interest in environmental issues. The development of the STEM camp was led by the first author but was co-constructed by a team of university professors with social studies and STEM backgrounds, a research assistant (second author of the paper), one middle school mathematics teacher, and one middle school science teacher. The summer camp development was informed by each of the designers' expertise in their respective areas. The area of expertise of author 1 is in informal learning environments, STEM education, STEM for societal impact, and background experience with underrepresented middle school students. The expertise of the second author was background experience with underrepresented middle school students.

The larger project uses design-based research to engage in an iterative cycle of design, testing, evaluating, and reflecting (Scott et al., 2020). The first author (researcher) and the second author (research assistant) collaborated to evaluate the first cycle of the program. The primary aim of the research in the present study is to test the design conjectures and the theoretical conjectures of the integrated steM camp. The aim of testing these conjectures is to determine if they need further clarification and refinement. Our research questions are as follows: (a) To what extent are the mediating processes achieved, and how do the features of the informal integrated steM camp contribute to this? and (b) How do the mediating processes appear to contribute to the outcomes of the program?

2. Materials and Methods

2.1. Research Design

This study is grounded in design-based research (DBR) with conjecture mapping (as described above) (Sandoval, 2014). DBR has a two-fold commitment: practical improvement and theoretical refinement (Sandoval, 2014). Additionally, DBR aims to "engineer innovative educational environments" that take place in real-life contexts (Barab & Squire, 2016, p. 4). DBR is typically used to study how the designed learning environment achieves the outcomes they were designed for. Within this approach, researchers engage in a cyclical iterative process of designing, testing, evaluating, and reflecting (Scott et al., 2020). The design phases consist of designing an environment informed by problems of practice, context, existing theories, and frameworks (Scott et al., 2020). The problem of practice that this program addresses is the need to develop informal STEM programs with mathematics educators involved, the need to develop students' STEM outcomes, and the need to provide more curriculum models for informal STEM programs (e.g., Blanchard et al., 2020; Conway et al., 2022; Sahin, 2015). The designed environment is expressed in the conjecture map discussed above. Once the design is complete, it is then tested with the participants that it was designed for (Scott et al., 2020). This is the implementation phase and is discussed to some extent in the Results section. During the evaluation phase, the research team will evaluate if the intended student outcomes were met (Sandoval, 2014). The intended outcome of this design is that middle school students' STEM identity, STEM career interest, and interest in environmental issues will increase. After evaluating the impacts of the program, we wanted to know why and how the intended outcomes were achieved. This takes place within the evaluate and reflect phase. This analysis takes place by analyzing the conjecture map. The result of this analysis is reported in the Results section of this study.

2.2. Research Context—The Summer Camp

Camp LIT exists as a research practice partnership between the university and the middle school. The camp was situated in the Southwest United States in a rural-fringe area outside a major metroplex. The camp took place over 9 days. During days one through three of the camp, students engaged in STEM lessons and activities that explored light and light pollution (see Table 1). They investigated the effects of light pollution on the environment through inquiry-based research. On day four, students attended a college tour at the local university. On day six, students programed LED lights and built, refined, and presented models of light fixtures designed to prevent light pollution in specific scenarios. On days seven and eight, groups of students investigated a light pollution issue that was interesting to them and co-developed presentations. Participants were provided with a basic outline of what their projects should include (i.e., background information on the electric light, a problem, and a proposed solution) as support to guide their model creation process. Participants ended the day practicing their presentations by presenting to their peers and facilitators. On the final day of the camp, students presented their final models to a panel of university professors, students, and their families. On that same day, students attended a field trip to the planetarium, where they learned about the sun.

Table 1. Outline of camp activities.

Week	Day	Focus of the STEM Activity
1	Tuesday	Campers used common household materials to create light. Campers use their knowledge of averages to make comparisons of light production times and duration between groups.
	Wednesday	Campers were presented with typical and alternative histories of the innovation of electric light. Campers use their understanding of mathematics to make sense of historical documents.
	Thursday	Campers investigated the meaning of light pollution and its impact on plants, animals, and humans. Campers also used their understanding of mathematics to investigate the most energy-efficient lights to reduce air pollution. Campers also engaged in a mathematics warm-up where they performed calculations for percents, decimals, and fractions.
	Friday	Campers went on a college tour to a local university.
2	Monday	Campers used Texas Instruments graphing calculators to use Python coding to program lights to turn off and on when someone is within a certain distance.
	Tuesday	Campers built physical models that represented a solution to light pollution.
	Wednesday	In groups, campers investigated a light pollution issue that was interesting to them. Campers were encouraged to use mathematics where they felt it was relevant.
	Thursday	Campers practiced presenting their projects to each other.
	Friday	Campers presented their work to the larger community and attended a field trip to a planetarium where they learned about the sun as a source of light.

2.3. Participants

The study included 13 rising 6th- through 9th-graders, aged 11–13 in grades 7–9. Eight participants identified as male and five as female. Among the youth, 53.8% identified as Black, 15.4% as two or more races, 15.4% as White, 7.7% as Hispanic/Latino, and 7.7% as Asian. A professor from the university with mathematics teaching experience led the program as the lead facilitator. A graduate student from the university, who was also a staff member at the middle school, served as the research assistant. Two additional research assistants who were graduate students served as research assistants in the camp. Two additional facilitators, a mathematics teacher, and a science teacher, assisted the lead facilitator. Two professors from the university also served as guest facilitators. Participation in the research aspect of the STEM camp was voluntary.

2.4. Ethics

Before conducting this study, we obtained internal review board approval from the University of North Texas (approval number: IRB-23-334), research approval from the school district, and research approval from the school principal. In addition to receiving approval from the appropriate institutions and institution personnel, we also obtained written informed assent from all the children who participated in the study and written informed consent from all the parents of the children who participated in the study. We invited participants to participate in the study by hanging up flyers around the school. We also recruited among the students who showed up to participate in the camp. It was not a condition of the camp that students had to participate in research to participate in the camp. As such, not all students who participated in the camp participated in the research. Participants who chose to participate were given consent and assent forms for their parents to sign. All participants were given pseudonyms for confidentiality.

2.5. Data Sources

The data collected for this study include observational field notes, participant artifacts, a pre-survey, a post-questionnaire, a retrospective pre/post-survey, a post-questionnaire, and an end-of-camp group interview. The observational field notes were taken each day of the camp. Observers were instructed to follow an observational protocol that asked them to document the general activities of the camp, campers' verbal mathematics sense-making with their peers and facilitators, campers' verbal sense-making about environmental issues (in this case, light pollution) with peers and facilitators and the ways in which students were engaged.

Participant artifacts included pictures of their work and copies of their final presentations. Participants sat at two different times to complete the pre-camp survey and a post-camp questionnaire. The pre-survey asked participants to respond to three Likert scale items regarding their interest in environmental issues, their interest in light pollution, and their interest in STEM careers (see Table 2). In addition to the questions on the pre-survey, the post-survey also asked to complete items related to their STEM identity and to open-ended questions that asked them if and how the program supported their interest in STEM careers and environmental issues. The STEM identity questions were a retrospective pre/post-survey measured participants' understanding of self as a person who can do STEM and be in STEM, as well as how they perceive they are viewed by others (Allen et al., 2019; Noam et al., 2020). The STEM identity survey was developed by Noam et al. (2020), who offered a retrospective survey design and a traditional pre-post design. They explained that one of the advantages of using the retrospective survey design is that it protects against response shift bias. That is, participants' understanding of what is being measured changes over time, potentially making the traditional pre-post less valid. Permission to use the STEM identity scale was gained through PEAR. This measure draws on other published surveys that measure science and mathematics identity (e.g., Aschbacher et al., 2014; Cribbs et al., 2015). The pre-test portion of the survey asked participants to rate questions related to STEM identity before participating in the survey. The post-test portion of the survey asked participants to rate STEM identity after participating in the program.

Table 2. Study measures.

Scale	Definition	Format	Sample Item/Item	Scale Endpoints	# of Items
STEM Identity	Understanding of oneself as a person who can do STEM and be in STEM.	Retrospective Pre/post-test	"I think of myself as a STEM person."	4-point scale strongly disagree (1) to strongly agree (4)	7
Environmental Interest	Interest in environmental science.	Pre-survey/ Post-survey	"I am interested in environmental issues".	5-point scale strongly disagree (1) to Strongly agree (5)	1
STEM Career Interest	Interest in pursuing a STEM career.	Pre-survey/ Post-survey	"I am interested in pursuing a STEM career".	5-point scale strongly disagree (1) to strongly agree (5)	1

The end-of-camp group interview was conducted after the end-of-camp surveys. We asked participants to respond to the following prompt: As a result of the camp, we wanted you to become more interested in STEM. Did you do so, and if so, why? This was the same question that we had them respond to on the questionnaire before engaging in the group interview. We used all the data sources to test the design and theoretical conjectures.

2.6. Data Analysis

The quantitative data were analyzed using descriptive statistics and significance tests (Sign test). Field notes from the observations were analyzed through directive deductive content analysis (Miles et al., 2014). More specifically, we read through the observational notes, looking for instances of the mediating processes and intended outcomes discussed earlier. The artifacts were analyzed to determine the extent to which they incorporated environmental issues and focused on local solutions to environmental issues. Responses to the open-ended questions and the group interview were analyzed in inductive coding (Miles et al., 2014). More specifically, we read through the responses and looked for reasons that students indicated that they became more interested in STEM careers and environmental issues. We then used the results of this analysis to further analyze our initial conjecture map. To analyze our conjecture map, we used Boelens et al.'s (2020) classification system (see Table 3). We analyzed each mediating process to the extent to which it is, sometimes, or not achieved. Secondly, we analyzed the theoretical conjecture to the extent to which it is plausible (e.g., plausible, not plausible, plausible but limited data, and insufficient data to comment on plausibility). Lastly, the design conjectures were analyzed to the extent to which they are supported (e.g., supported, not supported, or supported but with limited data).

Table 3. Analysis process.

Analysis Component	Classification
Mediating Process	Achieved Not Achieved Sometimes Achieved
Theoretical Conjecture	Plausible Not Plausible Plausible but Limited Data Insufficient Data to Comment on Plausibility
Design Conjecture	Supported Not Supported Supported but with Limited Data

3. Results

We organize our findings into six sections. These six sections align with the mediating processes in our conjecture maps. For each mediating process, we provide the extent to which (1) the mediating process is achieved and what it looked like within the context of the camp, (2) if the corresponding theoretical conjecture is plausible, and (3) if the corresponding design conjecture is supported (see Table 4). Organizing our results in this way answers our research questions, which are as follows: (a) To what extent are the mediating processes achieved, and how do the features of the informal integrated steM camp contribute to this? and (b) How do the mediating processes appear to contribute to the outcomes of the program?

Table 4. Outcomes of the design and theoretical conjectures.

	Design Conjecture **Supported, Not Supported, Supported with Limited Data**	**Theoretical Conjecture** **Plausible, Not Plausible, Plausible but Limited Data, or Insufficient Data to Comment on Plausibility**
1	The use of environmental justice and mathematics activities and technologies, standards aligned, and collaborative guided inquiry will solicit students' verbal mathematics sense-making with peers and facilitators.	If students participate in verbal mathematics sense-making with peers and facilitators, then there will be an increase in STEM identity and an increased interest in STEM careers. **Outcome: Plausible**

	Outcome: Supported	
2	The use of environmental justice and mathematics activities and technologies, standards aligned, and collaborative guided inquiry will aid students in creating verbal mathematics sense-making with peers and facilitators regarding environmental issues. **Outcome: Supported**	If students participate in verbal sense-making with peers and facilitators regarding environmental issues, then there will be an increased interest in environmental issues. **Outcome: Plausible**
3	The use of collaborative guided inquiry, student-led environmental projects, theme structure, and an awards ceremony will engage students. **Outcome: Supported**	If students are engaged, then there will be an increase in STEM identity and an increase in interest in STEM careers. **Outcome: Plausible**
4	An award ceremony will provide recognition to student participants. **Outcome: Supported**	If students are recognized, then there will be an increase in STEM identity and an increase in the interest in STEM careers. **Outcome: Insufficient Data to Comment on Plausibility**
5	When student-led environmental projects are presented in the program, design, innovation, and research products are created. **Outcome: Supported**	If students engage with the design, innovation, and research products focused on environmental solutions, then there will be an increase in STEM identity, increased interest in STEM careers, and increased interest in environmental issues. **Outcome: Insufficient Data to Comment on Plausibility**
6	The sixth and final program element conjecture is that when student-led environmental projects are presented, there is involvement in local solutions to address environmental quality. **Outcome: Not Supported**	If students engage with the involvement in local solutions to address environmental quality, then there is increased interest in environmental issues. **Outcome: Insufficient Data to Comment on Plausibility**

3.1. Mediating Processes: Observable Interactions

3.1.1. Verbal Mathematics Sense-Making with Peers and Facilitators

Verbal mathematics sense-making with peers and facilitators was a successful mediating process. The students participated in a Python Coding activity where they applied their understanding of distance and inequalities to co-create a code that would detect if a person was within a certain distance of the calculator. If a person was within a certain distance of the calculator, the program would turn a light on, and if they were not, it would turn the light off. This activity was designed to mimic a motion detector that senses when someone is present and executes the command of turning on a light.

Verbal mathematics sense-making was enacted when students had to find out what the distance would be from the ultrasonic rangers that were connected to the calculator. To find the number, students were asked to place their hands in front of the ultrasonic ranger and then to move backward until the ranger stopped detecting. Each group was asked how far they were able to go before the ultrasonic ranger stopped detecting the distance. Students began to share different numbers until the class reached the conclusion that the furthest distance that the ultrasonic ranger could detect was 10. The facilitator then guided the class in a discussion about the type of inequality that would need to be written that would represent the distance being greater than 10. After much discussion, we collectively developed the inequality $d \geq 10$, with d representing distance. We discussed that ifthe number is greater than or equal to 10, that means that the person is “out” of the room and that the light should be off. We also discussed that if the number is less than 10, then the person is “in” the room and that the light should be on. The facilitator explained how the students would create that code in the calculator, which resulted in what is displayed in Figure 3. Thus, through this activity, students were able to engage in verbal sense-making about mathematics, specifically distance and inequalities.

Figure 3. Texas Instruments Python coding for detecting distance.

Another instance of the successful mediating process was an activity where students used common household materials to produce light. Each group ran a trial and then reported how long it took them to produce the light in seconds. One group reported that it took them 11 s, and the other group reported that it took them 12 s. The groups were then instructed to calculate the average. Eustace commented that "the avg is when you add up a bunch of numbers and divide by how many numbers you have. It tells you like the most common." Hailey responded by asking, "what are we finding the average of?" Dr. Kudaisi, the facilitator, responded with "the average time". Eustace responded and said, "11.11111… oh! Is it?" and then wrote it down. He later changed his answer to 11.5 after discussing with his group mates how to perform the calculation (see Figure 4). During the same activity, students began to make connections between the way that they were creating the light and the amount of time the light stayed on. For example, Gage commented that they wanted to "make sure it's straight because the bending of the electrical current could mess with the light", explaining that "a cube might work". Gage also noticed that their trial lasted "for 10 more seconds", speculating that it could have been because they "used more pressure and doubled the lead." Thus, this activity proved successful in getting students to engage in verbal mathematics sense-making.

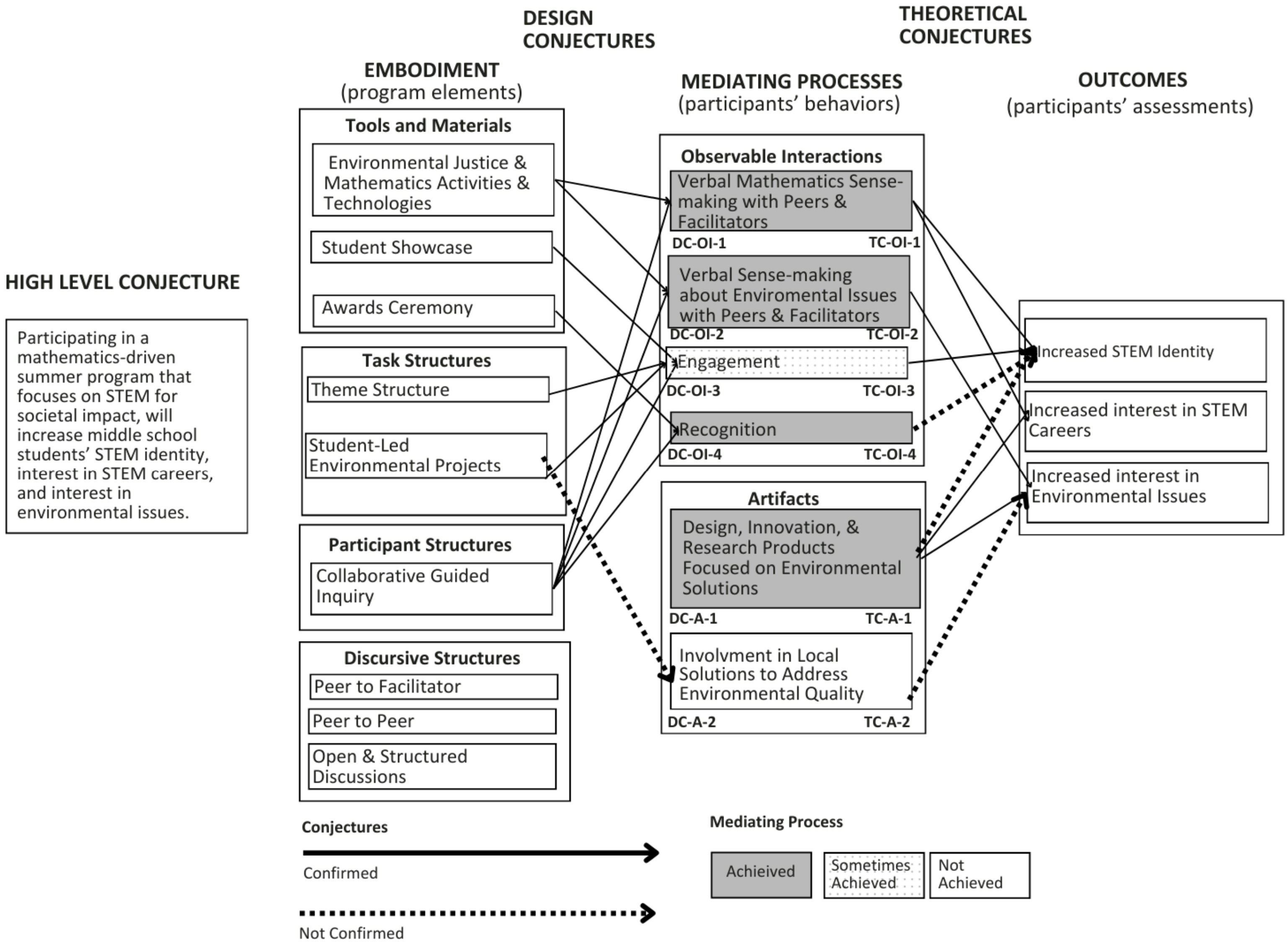

Figure 4. Revised conjecture map.

Students at the end of the camp participated in a semi-structured interview and were asked if the camp increased their interest in a STEM career. Darren, a rising 7th-grader, shared his new interest in a STEM career: "Yes because I got more interested in coding and technology." Adrian, a rising 8th-grader, shared that the camp supported his interest in a STEM career by saying, "It did due to the early math warmups and coding." A pre-post survey administered by the research team also showed an increase in STEM career interest (see Table 5). The pre-survey (n = 13) exhibited a mean of 2.75 (SD = 1.22). However, when the post-survey was administered (n = 13), the average mean was 3.58 (SD = 1.16). While we did detect an increase in means from pre to post (+0.83), the results of a Sign test revealed that the increase was not statistically significant (z = 1.51, p = 0.06).

Table 5. Quantitative results.

	N	Pre-Survey	Post-Survey	Mean Change	Significance Test	
Outcomes		**Mean (SD)**	**Mean (SD)**	**+/−**	**z**	***p***
STEM Identity	12	2.58 (0.73)	3.04 (0.67)	+0.46	2.48	0.04 *
Interest in Environmental Issues	13	3.25 (1.36)	3.67 (0.98)	+0.42	0.50	0.31
Interest in STEM Careers	13	2.75 (1.22)	3.58 (1.16)	+0.83	1.51	0.06

Note: * Significant at 0.05 level.

The results suggest this *theoretical conjecture* to be *plausible*: if students participate in verbal mathematics sense-making with peers and facilitators, then there will be an increase in STEM identity and an increased interest in STEM careers. Many students referenced joy, excitement, and fun in their interview responses when engaging in activities that required verbal mathematics sense-making. Cedric, a rising 8th-grader, shared, "This program helped support my mathematics by getting me excited for math." When asked about what they liked about the camp, many of the responses involved the Python coding activity with the Texas Instruments calculator. The research team and camp facilitators did acknowledge that a more in-depth lesson on how to use the calculator initially would have benefited the coding lesson. This may prevent students from becoming frustrated and discouraged.

Three aspects of the summer camp were developed to support students with their verbal mathematics sense-making with peers and facilitators: environmental justice and mathematics activities and technologies, aligned standards, and collaborative guided inquiry. At the beginning of one of the days of the camp, students participated in a mathematics warm-up. The students shared the warm-up activity that helped them get excited for the day. Wade, a rising 7th-grader, shared, "[the camp] help[ed] me with math skills," in reference to his math identity and his participation in the activities of the camp.

The aligned standards promoted mathematics sense-making. A few of the camp members were reluctant about the math aspect of the camp, sharing their negative experiences with mathematics in their traditional classroom setting. Gaige, a rising 7th-grader, on the first day of the camp, shared with one of the facilitators: "I suck at math. I barely passed this year." However, by utilizing a non-traditional learning environment through an integrated steM camp, Gaige was involved with mathematics skills at his appropriate grade level.

Collaborative guided inquiry prompted the students to engage in mathematics sense-making. Throughout their light-bulb experiment, students had to collaborate on roles and duties. By tracking data of time and materials used, small groups of students guided their inquiry together. However, when students were off-track due to excitement or when power structures were involved in their group, the facilitators were able to prompt students back into the inquiry. This came from redirected prompts, asking questions about their data, offering reluctant members of the group a different role, or even a chance to repeat a step of the experiment for participation. All these observations provide support for the design conjecture: if environmental justice activities have embedded mathematics and technology content, standards-aligned mathematics, and collaborative guided inquiry (especially using questioning), then students will engage in verbal mathematics sense-making with peers and facilitators.

3.1.2. Verbal Sense-Making About Environmental Issues with Peers and Facilitators

Verbal sense-making about environmental issues with peers and facilitators was successfully achieved. In an inquiry-based guided activity, students in small groups researched the impacts of light pollution on humans, plants, and animals. The three groups of students had specific roles throughout the guided inquiry, which prompted their sense-making about light pollution. The facilitators guided the students through their roles, allowing students to develop autonomy. Jane, a rising 8th-grader, played the role as a researcher in her group as she was required to find data and facts regarding light pollution on plants. As she was interpreting the text, a facilitator guided her:

> Facilitator: "Jane, what did you find?"
>
> Jane: "Without adequate light, carbohydrates cannot be…wait. No, that's not really it."
>
> Facilitator: "It's okay if you don't understand it."
>
> Jane: "Artificial light can endanger plants."
>
> Facilitator: "Oh! That's a good one!"
>
> Jane: "It can endanger plants and then affect animals."

The encouragement and assistance from the facilitators influenced the active verbal sense-making about environmental issues during the guided inquiry.

The lead instructor of the camp led an activity titled Five Principles of Responsible Lighting adapted from the Dark Sky (2024). Students as a whole group observed pictures of artificial lighting used in different settings. Specifically, an image of a house utilizing outdoor artificial lighting allowed the students to utilize their verbal sense-making about environmental issues as they connected their own housing and artificial lighting with the picture. One image had artificial lights bordering around the house. Students immediately acknowledged the unnecessary use of artificial lighting and criticized its sustainability. Shane shared how it is not efficient for the extra lights and was curious about the other ones, but sarcastically questioned, "You making a lighthouse or something?" Jane acknowledged that her home does have lights on outside at night, creating a connection of sustainability: "We have our lights on at night, but when the last person goes to bed at night, we turn off all the lights." Exploring the principles of responsible lighting through images where the students can relate developed strong connections between their own lives and the content.

A pre-post survey administered by the research team also showed an increase in interest in environmental issues. The pre-survey (n = 13) exhibited a mean of 3.25 (SD =1.36). However, when the post-survey was administered (n = 13), the average mean was 3.67 (SD = 0.98). This is a mean change of +0.42. This showed an increase in interest in environmental issues from the camp participants. However, the results of a Sign test revealed that the increases were not statistically significant (z = 0.50, p = 0.31). Nevertheless, the results show this theoretical conjecture to be plausible: if students participate in verbal sense-making with peers and facilitators regarding environmental issues, then there will be an increased interest in environmental issues. In a semi-structured interview, Adrian shared, "I never knew about how much light pollution affect our daily lives", as he agreed that the summer camp supported him in developing an interest in environmental issues.

Three aspects of the summer camp were developed to support students with their verbal sense-making with peers and facilitators regarding environmental issues: environmental justice and mathematics activities and technologies, aligned standards, and collaborative guided inquiry. Students participated in an environmental justice activity where technology has played an active role in light pollution and its effect on animals and the environment. The lead facilitator showed a short video of sea turtles relying on light from the moon for their direction to sea water. However, we see in the video how light pollution from buildings and other artificial systems can mislead sea turtles and cause harm to them and the ecosystem. Students shared responses with each other and with the facilitator of their observations, the impacts of artificial light pollution, and the overall outcomes. Students then shared potential solutions on how the sea turtles and their ecosystem can be impacted in a positive way.

The use of aligned environmental science s standards in the summer camp promoted verbal sense-making of environmental issues. The light pollution and environmental science activities aligned with the middle school science standards. For example, one of the 8th-grade TEKs read: "use scientific evidence to describe how human activities, including the release of greenhouse gases, deforestation, and urbanization, can influence climate." The activities of the camp aligned with this standard because of the focus on how human activities influence the climate. Integrating this standard allowed for students who previously experienced this standard to apply it in the steM camp, and it allowed for the others to make headway into the science curriculum.

The overall summative project of the summer STEM camp was a collaborative guided inquiry. Small groups of students were encouraged to create light models to improve light pollution in a given scenario. Using the knowledge gained from the summer program, students developed these models to be the solution to the given problem. Groups were assigned animals, plants, and humans. Their self-created models were solutions to prevent or reduce light pollution. As students developed their models, verbal sense-making of environmental issues was at play continuously. In the creation of their model, the lead facilitator guided the conversations with the small groups regarding warm and cool colors with LED lighting. The facilitator asked about the status of their model, and they shared about the choices of their lighting: "We said warmer colors are better, not necessarily because they use more energy, but because of the way that they look so they don't hurt our eyes." All these observations provide support for the design conjecture: if environmental justice activities have embedded mathematics and technology content, standards-aligned mathematics, and collaborative guided inquiry, then students will engage in verbal sense-making with peers and facilitators regarding environmental issues.

3.1.3. Engagement

Engagement was sometimes achieved depending on the activity and group power structures. Students were given numerous opportunities to be engaged in the summer steM camp. This was first observed on the first day when students were placed in small groups for a light-bulb experiment. Somes students were engaged by exhibiting joy in their participation or through their peer-to-peer conversations. However, some students were not engaged due to the power structures established in the group. Gage and Wade took over the supplies and led the experiment, leaving Samantha and Jane only to observe. Jane agreed to be the timekeeper but realized quickly that her job was not needed until later. The boys led the experiment, leaving the girls left out. The girls were disengaged.

The camp facilitators had to intervene with this power structure and allow Jane and Samantha to be active in the experiment. As Gage and Wade agreed to allow the girls to lead the next trial of the experiment, the girls became engaged. The smile on Samantha's face lit up as she observed the lightbulb turn on from their construction.

At the end of the camp, this was observed when students participated in a field trip to a nearby university where they visited a planetarium. The university provided a documentary on the solar system, specifically focusing on the sun and light. Students were engaged in the planetarium as they were asking questions constantly throughout the experience to advance their knowledge. Students shared with the camp facilitators through semi-structured interviews about their STEM career interests. Cedric shared that the camp helped him "develop an interest in STEM because the camp was fun." Adrian shared his engagement as he "loved the hands-on learning the camp did multiple times." Angelica, however, had a deeper engagement as she understood the impact of STEM on society. When asked about a possible career in STEM, she shared, "This made me interested in a STEM career because it showed me how humans can be beneficial." This inclusion of STEM's impact on society, the environment, and humans supported the development of an interest in pursuing a STEM career. The results suggest that theoretical conjecture is plausible: if students are engaged, then there is an increase in STEM identity and an increase in interest in STEM careers.

Three aspects of the summer camp were developed to support engagement: a student showcase, theme structure, and collaborative guided inquiry. At the conclusion of the camp, students were recognized for their participation.

The student showcase was designed to engage students such that they knew that they would be presenting their research to their family members, teachers, community members, and other relevant stakeholders (i.e., government officials). As such, the student showcase functioned as a time to recognize them for their participation. It took place at the university instead of the middle school, where most of the camp took place. The beginning of the student showcase was an opportunity for each group to present their models and presentations to the audience members. We explained to the students that they would be the "experts" at their presentation to bolster their STEM identity and get them engaged as doers and learners of mathematics (Aguirre et al., 2013) and STEM more broadly and to be engaged by others. In this way, we hope that their STEM identity will increase. As such, our theoretical conjecture was as follows: if students are engaged, then there will be an increase in STEM identity and an increase in interest in STEM careers.

Students first learned about the summer steM camp through a launch party hosted at their campus. The after-school event was open to all interested students. The lead facilitator introduced the summer camp and then shared the theme structure: Camp LIT. The LIT focused on the past-tense verb of light. The lead facilitator then provided materials to the students, such as a flashlight. The terms light pollution and environment were introduced to the students. This hands-on approach immediately immersed the students in the engaging aspect of the camp. Every activity in the camp was sequenced around light, including its purpose, effects, pollution, and the problems presented.

A significant moment during the camp for engagement was the introduction of the Texas Instruments Coding Calculator. Students explored the fact that innovators utilize similar skill sets of coding in their projects. As soon as students received a calculator in their hands, the room became silent. The facilitators shared that all you could hear was the buttons on the calculators as the students explored the device. Shane immediately stated, "Oh this looks very interesting!" as soon as one was placed on his desk. Students as a class had to explore the foundations of coding as a class to write a program that would perform a conditional output. That is, if a person is within a certain distance, then the light turns on. This collaborative guided inquiry immensely provided engagement for the students. Four students in the semi-structured interview specifically mentioned coding in their responses. Angelica shared, "the activity was fun. Like building the light bulbs and stuff." The projects embedded coding, and the collaborative inquiry supported engagement because it provided gratification. The results suggest the design conjecture to be plausible: if collaborative guided inquiry, student-led environmental projects, theme structure, and an awards ceremony are enacted, then students will be engaged.

3.1.4. Recognition

Recognition was successfully achieved. Students were recognized throughout the camp for their work completed, learning, and participation in the daily activities. In our study, students were recognized for both math-doers and steM-doers, and for active participation in the camp with the various activities. Recognition was honored through tangible rewards and through intangible rewards. Gage was recognized throughout the camp numerous times for his active participation in research projects, math warm-ups, and group activities. His recognition was influenced as he continued to improve his projects. However, even after being recognized at the award ceremony, Gage still professed a negative STEM identity, writing, "The program cannot fix my relationship because I hate math." The theoretical conjecture is plausible but with limited data: if students are recognized, then there will be an increase in STEM identity and STEM career interest.

Collaborative guided inquiry was integrated into the camp as a design feature designed to foster recognition through the steM camp. During a mathematics activity, Blue recognized himself as a doer of STEM when he utilized the graphing calculator in the mathematics activity: "I have it!" Blue pointed out 0.5 on his calculator. His self-determination for learning was recognized by the facilitators. At this moment, there was an increase in STEM identity, as there was reluctance and hesitation from Blue during the mathematics activity. However, from his own recognition of being a STEM-doer and from the verbal recognition from the facilitators, his STEM identity increased at that moment. Another example of collaborative guided inquiry was small group experiments. During the light-bulb experiment, Shane was reluctant to participate in the experiment with his group. The lead facilitator asked Shane if he would like to try, but he said that he was afraid something would explode. The lead facilitator encouraged Shane to try next. As he did, the lead broke, and Shane cried, "No!" The lead facilitator recognized Shane's discouragement but acknowledged his ability to be a STEM-doer by sharing, "It's okay, just try again!" Shane attempted the experiment immediately for a second try. This recognition here from the lead facilitator increased Shane's STEM identity as he did not identify as a STEM-doer from the beginning due to his disengagement from the experiment. However, after recognizing his presence in the group, encouraging his participation, and recognizing his ability to accomplish the guided inquiry, Shane became encouraged to complete the tasks. Shane shared the same disengagement later in another guided inquiry when his graphic calculator was showing an error message. His heavy breathing and frustration were recognized by one of the facilitators: "Calm down, Shane. Breathe." The lead facilitator approached Shane and said, "So. We talked about computational thinking skills and that challenges are gonna' come, and that's okay. So, you're experiencing what- engineers experience! And they just keep going." Shane attempted the graphic calculator a second time after the recognition from the lead facilitator and then screamed "YES!" when the LED light turned on from the coding.

The award ceremony as a program designed to foster recognition was successfully achieved. Every student in the summer camp was recognized for their efforts and participation. This program element is based on research that suggests that recognition positively contributes to students' mathematical identity development (Cribbs & Utley, 2023), which is applied broadly to STEM. As each student's name was called individually to receive their certificate of achievement and medal, one of the camp facilitators added a unique statement to recognize an accomplishment. For example, when Samantha was called, the facilitator added, "for coming out of her shell." When Shane was called, the facilitator added, "for working hard." However, the lead facilitator interjected and recognized Shane for his perfect attendance at the camp. The students, parents, and university observers applauded and acknowledged this accomplishment. One of the camp facilitators concluded the presentation by offering her own anecdote of how the program affected her as an educator, providing recognition to the students for their efforts. Our results indicate support for our design conjecture: if collaborative inquiry and an award ceremony is used, then students will be recognized.

3.2. Mediating Processes: Artifacts

3.2.1. Design, Innovation, and Research Products Focused on Environmental Solutions

Design, innovation, and research products focused on environmental solutions were achieved. As mentioned previously, students in small groups were expected to conduct research on light pollution. They were asked to design and develop a model that would be the solution to the problem scenario they were interested in pursuing (i.e., light pollution on humans, plants, or animals). As students developed their models, utilizing various materials and LED lights, the goal was to focus on presenting the solution and verbally explaining their product. Eustice and Cedric worked together and presented the effects of light pollution on humans. They first began their presentation by defining artificial light and providing examples. They briefly shared the effects of light pollution on humans they researched. This was the scenario they were interested in pursuing, and they shared it with the audience. They transitioned their presentation to the history of artificial light before they introduced their solution. This was their opportunity to showcase their literature research on when artificial light was created and how it was developed. As they shared their problem statement, a solution was presented to the audience. Eustace and Cedric described their new LED light model, including how it was constructed, its functions, and how it will solve their problem. Eustace shared with the audience that their model will help control the type of lighting used in a device for humans and make the function of the light useful. The emphasis from Eustace and Cedric was on controlling artificial lighting to create awareness among humans. The presentation led to a question-and-answer opportunity for audience members to ask the presenters. One audience member asked, "What color makes it less harmful?" The group answered, "warmer lights are a more natural color, and white lights attract more bugs", when explaining the different types of colors in artificial lights. The last question asked to the group was as follows: "Why focus on impacts of humans and not plants and animals?" Cedric responded, "Because we are humans, and we wanted to see the impact of these things on us." Eustace then added that we all own cell phones, which contribute to light pollution, and utilize artificial lighting, which allows a personal connection to the research. As such, the results provide support for our design conjecture that if student-led environmental projects are offered, then design, innovation, and research products are created.

Design, innovation, and research products focused on environmental solutions were achieved. Adrian shared in the semi-structured interview that coding influenced his interest in a STEM career: "It did even further my ambitions of a STEM career due to the coding aspects." The projects throughout the camp embedded coding, which engaged Adrian throughout the design and innovation aspects of creating his LED light model. Angelica shared in her interview that she was interested in a STEM career because the design projects were embedded in STEM for social impact. She experienced the synthesis of STEM's influence on society during the camp. The participants during the semi-structured interviews expressed their reasons for an interest in a STEM career but also shared their interest in environmental issues. Darren was asked if he became more interested in environmental issues, and he shared, "Kinda because I didn't know or care about light pollution and now, I care a bit". The design projects throughout the camp had light pollution embedded in them. When Darren was asked what he liked about the camp, he mentioned the design, innovation, and research projects that focused on environmental issues specifically.

There was insufficient data to comment on the plausibility of the increase in STEM identity. When referring to the semi-structured interviews, there were no instances of STEM identity to be measured. However, we measured STEM identity in the survey. The pre-survey (n = 12) exhibited a mean of 2.58 (SD = 0.73). However, when the post-survey was administered (n = 12), the average mean was 3.04 (SD = 0.67). This is a mean change of +0.46. This showed an increase in STEM identity among the camp participants. A Sign test revealed that this increase was statistically significant (z = 2.48, p = 0.04). Even though we know that students' STEM identity increased significantly after participating in the camp, we do not know what caused those increases. As such, we have insufficient data to comment on the plausibility of the design, innovation, and research products positively influencing STEM identity specifically. However, for the other two outcomes of increased interest in STEM careers and increased interest in environmental issues, the results showed that our theoretical conjecture is plausible.

3.2.2. Involvement in Local Solutions to Address Environmental Quality

Involvement in local solutions to address environmental quality was not achieved. As mentioned earlier, we hoped that offering student-led projects would lead to involvement in local solutions to address environmental quality. However, the camp design did not support this mediating process. Consequently, because this mediating process was not enacted, we have insufficient data to comment on the plausibility of our theoretical conjecture that if students are involved in local solutions to address environmental quality, then they will have increased interest in environmental issues.

Only one of the four presentations focused on a local issue. The other presentations focused on broader issues, which include the impact of electric light on the mental state of humans, the living conditions of owls, the living conditions of turtles, and the medical impact on humans. However, it is important to note that one of the student-led projects did focus on a local issue that was aimed at addressing a local problem related to environmental quality. Angelica's group project focused on light pollution in Paris, Texas. This qualifies as a local issue because it is an issue in the state where they reside. Given what we found regarding involvement in local solutions to address environmental quality, our findings provide no support for our design conjecture that if student-led environmental projects are offered, then there is involvement in local solutions to address environmental quality.

4. Discussion

4.1. Reflections on Findings

This study focused on the embodiment of an integrated steM camp aimed at increasing middle school students' STEM identity, interest in STEM careers, and interest in environmental issues. Using guidance from Boelens et al. (2020), we used conjecture mapping to investigate (1) if the mediating processes were achieved, how, and why, (2) the extent to which our theoretical conjectures are plausible, and (3) the extent to which our design conjectures are supported by our findings. More specifically, we wanted to know if and how the program elements influenced the mediating processes and if and how mediating processes influenced the outcomes of the program. Our findings revealed that most of the program features facilitated the intended mediating processes, which in turn influenced the intended outcomes. While we found some positive findings, we also found that two of the mediating processes, involvement in local solutions to address environmental quality, needed to be improved, which is reflected in our revised conjecture map in Figure 4. In the next section, we will discuss alternative designs for the mediating processes that need more improvement.

4.2. Mediating Process

We found that the mediating process of engagement was achieved sometimes. This was due to the power structures we observed in one of the groups that contained two boys and two girls. The two boys were very engaged, so much so that the facilitators had to intervene to allow the girls to participate in the hands-on portion of the activity. This finding is like Griffin et al.'s (2015) research that indicates that mixed-gender collaborations often shower power imbalances favoring boys. Amemiya and Bian (2024) suggest that educating children about the structural causes of gender gaps in STEM can increase their recognition of societal barriers. We argue that having this discussion before group activities might also improve the gender dynamics of the group. Research by Cyr et al. (2024) also suggests that interventions can improve boys' perceptions of girls' STEM abilities. Such interventions are significant because of the associated risk. Vela et al. (2019) found that girls' confidence decreased after participating in a mixed-gender group. Based on work by Leopold and Smith (2019), implementing reflective group work activities may support collaborative learning. Additionally, we recommend that future designers of STEM camps continue to engage students in co-ed learning due to research that indicates that mixed-gender groups can lead to better learning outcomes for girls and promote higher-order thinking (Cen et al., 2014; Ma et al., 2022).

We also found that student-led projects did not facilitate involvement in local solutions for environmental quality. This was in part due to the quick turnaround time that would be needed to invite city officials to student presentations. More specifically, because the student-led projects were unique to the students' interests, it was hard to predict the direction that participants would take their projects. Not knowing this information ahead of time made it difficult to predict who to invite. For example, Hailey's group presented about the impact of electric light on the mental health of individuals, writing that continuous access to electric light can "take a toll" on people's "mental state". They further explained that it "makes people feel tired, they can't function as they would normally do". We did not anticipate this would be a topic. However, if we knew in advance that this would happen, we would have considered who to invite to the student showcase to hear this information. An alternative design for a future iteration is to allow students to do a topic that interests them as one component of the learning experience and do something more specific to the local context for the final projects. In this way, students get to do a project that interests them and a project that addresses the needs of the immediate community. Knowing the immediate needs of the community ahead of time will support the decision of what local community members and officials to invitein advance. Even though this mediating process was not achieved, we view it as a worthwhile endeavor because it can support students in making practical contributions to their community through STEM projects (e.g., Mildenhall & Cowie, 2021).

4.3. Limitations

The sample size in this study was small but was useful for conducting an in-depth analysis of an integrated steM camp with middle school students. While having more participants would have strengthened the results of the study, we still believe that it is beneficial to have the account that we provide. It is useful for designers who hope to or are already working with this population (middle school students from racially and economically diverse backgrounds) within informal STEM learning environments. We also believe that this study is useful for teachers and schools wanting to take a more integrated approach to STEM. Stohlmann (2019) provides three different ways that STEM integration can take place within the confines of the traditional classroom model. The current study is an adapted version of one of three of Stohlmann's (2019) suggestions. Likewise, STEM educators could adapt this model for integration in their classroom contexts. Though these benefits exist, we still acknowledge that this study had a small sample size. To make our study stronger, despite the small sample size, we used data from multiple sources, including observations, interviews, surveys, facilitator reflections, and a group interview. By triangulating our data, we hoped to reduce bias and provide a more nuanced view of our results.

4.4. Future Research

Further research could also explore the impact of an integrated steM camp on students' mathematics outcomes specifically. This is important because mathematics plays an important role in science, technology, and engineering. Additionally, mathematics serves as both a gateway and gatekeeper to mathematics-dependent majors (Aguirre et al., 2013). As such, it is essential that targeted interventions be designed and implemented with students with the goal of increasing mathematics outcomes such as mathematics competence, mathematics performance, mathematics perception, and mathematics self-efficacy (e.g., Weist & Crawford-Ferre, 2023).

Another area for further research is developing a program where we observe significant differences. Based on the quantitative findings, there was an increase in every measure based on pre- and post-test means. However, upon further testing, using a Sign test, the only increased outcome that was statistically significantly different was STEM identity. Further research could explore ways to support statistically significant differences in STEM career interest and interest in environmental issues. Additionally, limitations in the type of test used (e.g., pre-post method versus retrospective pre-post method) exist. While both have their challenges associated with their use, retrospective measures may better support participants in comparing their experiences because participants may have a clearer understanding of what they are responding to.

4.5. Implications

Stohlmann (2018) called for an integrated approach to STEM education where the M in STEM is emphasized. Likewise, Shaughnessy (2013) argued that mathematics educators needed to make the M in STEM more explicit. Blanchard et al. (2020) called for mathematics educators to get involved in informal STEM learning because of the overrepresentation of science educators, indicating that much of the informal STEM programming tends to be science driven. In this work, we took up this call and designed an integrated steM intervention within an informal STEM learning context. Our results provide evidence that an integrated steM camp can lead to positive outcomes for racially and economically diverse middle school students. This is significant because few studies report on the impact of integrated steM camps (e.g., Lindt & Gupta, 2020; Milton et al., 2023; Wiest, 2008; Weist & Crawford-Ferre, 2023). Another implication of this study is that it is an explicit map of how others wanting to take up the call can get involved in informal STEM learning through an integrated steM camp. Other mathematics educators can consider how they might adapt this model to fit their own context.

Another implication of this study is that it led to increases in middle school students' interest in STEM careers. This group of students represented the following races: Black, 15.4% as two or more races, 15.4% as White, 7.7% as Hispanic/Latino, and 7.7% as Asian. This is significant because of the call to get more underrepresented groups involved in STEM to support the competitiveness of the country (Casey, 2012) and individuals. Additionally, getting middle school students interested is significant because, according to research, students are more likely to pursue STEM careers if they develop an interest by eighth grade (Tai et al., 2006).

5. Conclusions

We conducted this study to investigate how to improve middle school students' STEM-related outcomes through an informal STEM learning intervention, namely an integrated steM camp. More specifically, a group of educators from various STEM and social studies backgrounds designed the integrated steM camp for students at a middle school with a diverse student population. Our study showed that the types of activities influenced participants' verbal sense-making because they were interested in content being engaged with and were able to connect to it in their own lives. Additionally, offering student-led environmental projects supported the development of design, innovation, and research products focused on environmental solutions because students had choices about what they chose to pursue. This autonomy of choice supported student engagement as well. Finally, collaborative guided inquiry supported participants' verbal sense-making and engagement because the facilitator was actively present, asking questions and guiding students through a hands-on activity. These findings, the overall findings of the study, and the revised conjecture map advance the field's understanding of how to improve middle school students' STEM-related outcomes through an integrated steM camp, speak to some of the challenges of this designed environment, and provide recommendations to address those challenges. Additionally, the findings can be used as a foundation for developing other integrated steM camps that have the aim of supporting middle school student outcomes.

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