The Influence of a Freshman iSTEAM Academy on Student Engagement and Educational Attitudes

David J. Shernoff
Rutgers University

Denise M. Bressler
East Carolina University

Isabella Massaro
Rutgers University

Suparna Sinha
Rutgers University

In this study, we attempted to combat the escalating problems of student disengagement and dropout at a partnering high school by piloting and evaluating a teacher professional development program to create a freshman "iSTEAM Academy" designed to radically transform the freshman experience. We found that students participating in the iSTEAM Academy were significantly more engaged, demonstrated more positive attitudes, and had greater aspirations to continue in STEM subjects than those in a more traditionally taught, comparison academy. Implications of the study for future practice included the importance of forums for transdisciplinary collaboration, a supportive administrative, and continued teacher professional development.

Keywords: STEAM, student engagement, high school, educational attitudes, university partnership

INTRODUCTION

Pervasive student disengagement persists as a significant problem in high schools, with upwards of one quarter of student populations found to be disaffected from school both nationally and internationally (Pino-James, Shernoff, Bressler, Larson, & Sinha, 2019; Shernoff 2013). A closely related problem is high school dropout; students cite disengagement as a predominant reason for dropping out, which can be seen as the final step in a gradual and cumulative cycle of withdrawal from school (Dupere, Leventhal, Dion, Crosnoe, Archambault & Janosz, 2015; Finn, 1989). Minority students and those in high-poverty, urban areas, report particularly high levels of academic disengagement (Balfanz, Herzog, & Mac Iver, 2007; Martin, Way, Bobis, & Anderson, 2015), and dropout can also be more frequent for minority youth (Gramlich, 2017).

Although there are many factors at multiple levels of students' ecological systems for pervasive disengagement, an especially influential and controllable one relates to a teacher-centered style of teaching emphasizing direct instruction and student memorization of disconnected facts (Shernoff, 2013). Such traditional modes of instruction have been found particularly disengaging by minority youth (National Research Council, 2012). Schools struggling with these issues, like the one that participated in the present study, need more effective approaches to engaging their predominantly minority student bodies, such as project-based learning to solve real world problems relevant to students' lives (Honey, Pearson, & Schweingruber, 2014; Quigley & Herro, 2019; Shernoff, Sinha, Bressler, & Ginsburg, 2017). Increasing a sense of belongingness is also very important among students of certain racial groups (Murphy & Zirkel, 2015). However, teacher preparation and the quality of teacher professional development are important variables for such approaches to "work" and yield the desired results. In this study, we attempted to combat the increasing issues of student disengagement and dropout at a partnering high school, particularly acute in the 9th grade.

The present study had three aims. The first was to build a new, 9th grade iSTEAM Academy (where "iSTEAM" stands for "integrated STEAM") for a partnering public high school on the East Coast of the US via a professional development and curricular development program for an interdisciplinary team of teachers in each of the STEAM subjects. The second aim was to evaluate the effectiveness of the program in terms of a) its influence on students' engagement, motivation, affect, attitudes towards STEM subjects, and future educational aspirations, and b) teachers' experiences and impressions of the program, including the impact of the academy on student participants. The third aim was to draw implications for the future viability and effectiveness of educational programs and professional development leveraging STEAM.

Reconceptualizing STEM Into STEAM

Strengthening the STEM workforce and increasing participation of underrepresented groups (e.g., women, minorities, and those underserved communities) has become an increasingly common goal (Asunda, 2014; National Science Board, 2014; Honey et al., 2014; Vasquez, Sneider, & Comer, 2013). It is suggested that in order to attract and retain a diverse STEM workforce, educational approaches need to be reconceptualized. One key reconceptualization of STEM is STEAM, where "A" represents the arts, including humanities (Quigley, Herro, & Jamil, 2017). Although research in this area is very young, early findings suggest that STEAM-based educational programs and curricula increase student motivation, engagement, and STEM disciplinary learning, as well as a wider diversity of students interested in pursuing careers drawing on science and mathematics (Masata, 2014). However, there is little conceptualization of STEAM beyond "adding the arts" to STEM, and limited research explaining how instructional approaches enact effective STEAM teaching (Quigley et al., 2017).

The strong focus on STEM has resulted, at least in part, out of a growing concern that American students need to be more competitive globally in STEM subjects, as measured by the Program for International Student Assessment (PISA) (Banchero, 2013; Jamil, Linder, & Stegelin, 2018; Katz, 2010). Proponents of STEAM, however, have looked beyond the issue of global competitiveness, seeing STEAM as a way to overcome a compartmentalized discipline approach to education (Guyotte, Sochacka, Costantino, Walther, & Kellam, 2014). STEAM is thus about collaboration. It is about weaving together subjects previously taught in isolation in a transdisciplinary endeavor leading to exciting and unexpected outcomes transcending traditional disciplinary education to address social practice (Guyotte et al., 2014).

Trending Toward STEAM

Boy (2013) observed that modern society has been redefined by increased complexity and connectivity. While the 20th century was based on linear engineering of complicated systems (e.g., the production of cars and airplanes), the 21st century has, "opened a new basis for holistic non-linear design of complex systems," and such systems "need to be investigated and tested as wholes, which requires a cross-disciplinary approach and new conceptual principles and tools…Consequently, schools cannot continue to teach only isolated disciplines based on simple reductionism" (p. 2). As creativity is one element required by the modern engineer in a world with rapidly changing problems and demands, Boy argues that it is time to prioritize creativity in the educational curricula. Creativity can thrive in modern classrooms as students engineer solutions to problems by considering human needs, think out-of-the-box, and break the barriers of traditional schooling. In doing so, there is a clear need to learn how to cooperate and coordinate more.

In this context, more and more districts and schools are teaching integrated STEAM each year (Bush & Cook, 2019). As research and literature on STEAM education is still relatively limited, however, a solid conceptualization of what STEAM is, and how to design and implement STEAM education has been lacking (Quigley, Herro, & Baker, 2019).

What Is STEAM?

STEAM is an acronym joining art with science, technology, engineering, and mathematics. As personified by creative achievers from Albert Einstein and Leonardo da Vinci to Pablo Picasso and Thomas Edison, scientists must have a vivid, intuitive imagination for new ideas, and artists must draw from principles governing the natural and physical universe. Educators and advocates alike, however, have struggled with how to do STEAM education (Quigley & Herro, 2019). As an ideal, the heart of STEAM is the striving for what Boix Mansilla, Miller, and Gardner (2000) called a *purposeful intertwining* in which "concepts and modes of thinking in one discipline enrich student understanding in another discipline" (p. 29). Inherent to this approach is reciprocity, or dialogue among disciplines, with the intent of developing an overarching synthesis. Like a watercolor painting in which colors bleed together and create new colors, the boundaries between disciplines emerge and new spaces between disciplines emerge.

As a paradigm, STEAM reflects a view of education emphasizing creative, transdisciplinary, real-world, and problem- or project-based teaching and learning (Henriksen, 2017). Jamil and colleagues (2018) conceptualize STEAM as a transdisciplinary learning process emerging as students solve real-life problems, the solution to which reaches across content areas. In this conceptualization, educators encourage students to see familiar things in a new light, combine things in nonobvious ways, to think independently and to create new things. Because most real-world problems do not have one right answer, opportunities are created for creative and divergent problem and risk-taking solving while meeting relevant challenges in new ways. Thus, STEAM can be an authentic approach to prepare children and adolescents in science, mathematics, engineering and technology in an inquiry-based and developmentally appropriate way.

The Promise of STEAM for Students and Teachers

The Hope for Students: Skills, Attitudes, and Engagement

STEAM has the potential to produce powerful, authentic learning opportunities that can help to engage students in STEM fields. STEAM is believed to provide benefits for students in a variety of areas, including the development of positive attitudes towards their education including STEM subjects, and increased motivation and engagement to learn. Interactional skills of communication and collaboration are naturally developed due to the emphasis on highly interactive instructional formats involving group work. Collaboration skills include inquiring, investigating, designing, and creating with others.

By allowing students to become curious and take control of their learning, STEAM projects are frequently reported to be fun, exciting, motivating, and engaging (Connor, Karmokar & Whittington, 2015; Henriksen, 2014; Jamil et al., 2018). Students demonstrate greater motivation and involvement when they can apply their knowledge to authentic and relevant real-life problems that require sustained engagement and collaboration (Barron & Darling-Hammond, 2008; Quigley & Herro, 2019). Studies also suggest that students develop more positive attitudes about learning and their education when involved in real-life problem solving. For example, their learning is deeper, knowledge retention is longer, and they develop a greater disposition for life-long learning through problem-based learning opportunities than through traditional approaches (Connor et al., 2015). Students have been observed to become interested and engaged enough to request a more in depth and detailed analysis or discussion of the topic during

STEAM projects (Connor et al., 2015). Thus, there is quickly becoming a consensus that STEAM is a potent way to increase interest and motivation (Quigley et al., 2017).

The Hope for Teachers and Importance of Professional Development

Especially because STEAM challenges teachers to conceptualization of what is being taught and how, teachers are the key implementors of the new teaching approach associated with STEAM activities. Success and failure are largely dependent on teachers' uptake of new pedagogies (Jamil et al., 2018). The opportunity for teachers to learn and grow in terms of their skills, attitudes and engagement is therefore as great as it is for students. To be successful, however, teachers need to be supported through professional development (PD). Given the range of understandings about STEAM, teachers consistently express the need for more PD in order to implement it in their classrooms (Jamil et al., 2018).

Challenges of STEAM

Although there are a variety of potential benefits of STEAM teaching and learning, there are also a number of challenges for teachers and students alike. First, a common set of challenges pertains to issues of time management, policies, and assessments (Quigley & Herro, 2019). A common perception of teachers is that time spent on hands-on STEAM projects takes time away from covering content (Jamil et al., 2018). For this reason, some teachers may have difficulty letting go of covering content and the perceived imperative for students to understand facts. Second, there are challenges related to planning STEAM units. This includes accessing resources and learning new content, sometimes in unfamiliar disciplines (Quigley & Herro, 2019). Third, there can be challenges around discipline integration, including gaining the expertise to address and integrate multiple disciplines. For many teachers, integrating mathematics can be especially challenging. Fourth, there are challenges of student understanding (Quigley & Herro, 2019). For example, there may be a small percentage of students who do not want to explore multiple concepts inherent to transdisciplinary learning (Connor et al., 2015). Teachers might also find it challenging to track student conceptual understanding as a STEAM unit unfolds due to the emphasis on inquiry and creation (Quigley & Herro, 2019). In this study, we sought to investigate the benefits as well as challenges of STEAM as perceived by teachers.

Research Questions

We investigated the following research questions:

1. Did students in the iSTEAM Academy experience greater engagement in learning, more positive affect, and more intrinsic motivation than students in the traditional academy?
2. Were there differences between academies in student engagement in all school subjects, or only some? Were there differences in terms of prevalence of instructional activities and social arrangements? Did instructional format and social arrangement moderate students' engagement in learning?
3. Did students in the iSTEAM Academy report greater gains in their desire to continue schooling from the beginning of the academy to the end of the academy than students in the traditional academy? Were their aspirations associated with the level of engaged learning, intrinsic motivation, and affect reported during classroom instruction. Was how much students liked STEAM subjects associated with their levels of engagement, motivation, and affect during instruction?
4. What were teachers' experience and impressions of the iSTEAM Academy, including strengths, challenges, and areas for improvement? What did they believe was the impact of the iSTEAM Academy on student participants?

METHODS

We employed a convergent parallel mixed methods approach to investigate the research questions and realize our study aims (Creswell & Plano Clark, 2018). We assessed iSTEAM students' engagement, motivation, affect, and educational aspirations in comparison to students in a schooling-as-usual academy ("Academy B") through repeated surveys. We also analyzed the experience of the teachers as they implemented the iSTEAM Academy through journals and interviews. Thus, the student surveys were analyzed quantitatively in a quasi-experimental design, while teacher experiences were analyzed qualitatively. Consistent with a convergent parallel mixed method approach, quantitative findings from the students' perspective were integrated with qualitative findings from the teachers' perspective to form implications and conclusions, a topic addressed in the discussion.

Participants

University-School Research Partnership

The participating high school graduates only two-thirds of its students, one of the lowest graduation rates in the country. Administrators from the school estimate that up to half of their students underperform academically. A university-school partnership was formed to address the tendency towards disengagement and dropout, particularly in the 9th grade. The partnership was formed among several university researchers and professional development specialists (i.e., article authors) and dedicated staff from the high school, especially the district science coordinator for high school grades. This bonafide partnership designed, coordinated and led the professional development and research project.

Recruitment of Teachers (N = 6)

Participating teachers included three teachers of mathematics (algebra), one teacher of English, one teacher of physics, and one teacher of world history / social studies. The physics teacher was male and the remaining teachers were female.

Recruitment of Students (N = 248)

The partnering school stated that students were selected for the iSTEAM Academy at random. We note that this is not the same as a random assignment procedure executed by the researchers. We lack 100% confidence that assignment to the iSTEAM group was not influenced by outside factors (e.g., a student's performance, behavior, interests, or parents). Thus, we consider the design quasi-experimental with respect to control group comparisons. The good possibility of random assignment or mostly random assignment provides an additional degree of confidence in causal inferences, but one falling short of the gold standard achieved by experimental designs.

Approximately 60% of the student sample identified as male, and 40% as female. Approximately 91% identified as Hispanic/Latino, 10% as Black/African American, 7% as White/Caucasian, 2% as Indian, 2% as Hawaiian, and 1% as Asian. Percentages exceeded 100% because some students identified as both Hispanic and another ethnicity. Approximately 75% indicated that Spanish was their first language, and 25% indicated English was their first language. When asked the highest level of education achieved by their mother, approximately 51% indicated that their mother had not completed high school. Thirty-two percent indicated that their mother's highest level of educational achievement was high school graduation, while 9% indicated college attendance, and 8% indicated college graduation.

Table 1 shows a comparison of demographic composition between students in the iSTEAM Academy (n = 98) and a traditional academy ("Academy B"; n = 150) used for comparison. The table shows that the proportion of students who were in the iSTEAM Academy vs. Academy B with respect to gender, race/ethnicity, first language, and maternal education was similar. There were no significant differences in proportionality with one exception: Only 3% of iSTEAM students identified as black compared to 14% of students in Academy B.

TABLE 1
STUDENT DEMOGRAPHICS BY ISTEAM ACADEMY AND ACADEMY B WITH TEST FOR SIGNIFICANT DIFFERENCES

	iSTEAM Academy (n = 98)	Academy B (n = 150)	Total (n = 248)	χ^2 / F-test
Female	38 (44%)	55 (38%)	93 (40%	.75
Male	49 (56%)	90 (62%)	139 (60%)	
Total	87 (100%)	145 (100%)	232 (100%)	
Hispanic/Latino	83 (94%)	129 (89%)	212 (91%)	1.91
Black	3 (3%)	20 (14%)	23 (10%)	6.59*
White	6 (7%)	10 (7%)	16 (7%)	.00
Hawaiian	3 (3%)	2 (1%)	5 (2%)	1.00
Indian	1 (1%)	3 (2%)	4 (2%)	.30
Asian	1 (1%)	1 (1%)	2 (1%)	.12
Total	88 (100%)	144 (100%)	232 (100%)	
Spanish is first language	66 (77%)	101 (72%)	167 (74%)	.59
English is first language	20 (26%)	37 (23%)	57 (25%	.56
Total	86 (100%)	140 (100%)	226 (100%)	
Mother did not finish HS	53 (59%)	35 (43%)	88 (51%)	.93
Mother graduated HS	18 (20%)	37 (45%)	55 (32%)	
Mother went to college	10 (11%)	6 (7%)	16 (9%)	
Mother graduated college	9 (10%)	4 (5%)	13 (8%)	
Total	90	82	172	

Note. Both race/ethnicity and first language categories are not mutually exclusive. Percentages in race/ethnicity columns sum to greater to 100% because some students identified as Hispanic and another ethnicity. The vast majority, but not all, participants who responded indicated that their first language was either Spanish or English.

Procedure

The goal of iSTEAM project was to support teachers in problem-based disciplinary integration through collaborative planning in an interdisciplinary team. In line with suggestions of previous research on teacher PD for conversion to STEAM (Quigley & Herro, 2019), all participating teachers gave and received help from each other in a PD summer institute and continuing Professional Learning Communities (PLCs) designed mainly for this purpose throughout the year. The project was implemented from August, 2017 until June, 2018. It consisted of an intensive, four-day summer institute focusing on iSTEAM teacher PD, and ongoing monthly PLC meetings throughout the 2017-2018 academic year.

iSTEAM Professional Development Summer Institute

At the four-day summer institute, the project partnership team worked with an interdisciplinary group of teachers at the school to create a freshman *iSTEAM Academy*. The summer institute was highly teacher-led. Its goal was to develop an integrated curricular and instructional approach to the freshman educational experience that would significantly engage participants in the academy compared to the traditional 9th grade experience; and that approach was to be based on integrated STEAM learning activities. The iSTEAM Academy was intended to be a radical departure from the traditional freshman experience. To plan the academy, university staff met with volunteering ninth grade teachers selected to represent multiple content areas (Math, Physics, Language Arts, History). Together, they strove to design new, project-based curricula integrating multiple disciplines that would be highly engaging for students and anchor sustained motivation to persevere academically. We encouraged teachers to make radical changes in designing teaching solutions to student disengagement.

The first day of the summer academy began with the immersion of teacher participants in an interdisciplinary, problem-based learning activity requiring creative thinking and cooperative teamwork. The activity was an engineering design challenge known as "Exploring Buoyancy." In this challenge, participants use their understanding of buoyancy, density, and pressure to design and build ocean exploring devices (The Tech Museum of Innovation, 2016). There were three goals for this first-hand experience with a project-based activity. First, participants were asked to solve a problem with limited directions on how to solve it. Second, participants experienced the need for cooperative teamwork and prerequisite knowledge (e.g., the concept of density). Third, they experienced original and creative thinking as well as frustration with the iterative, trial-and-error design process. These goals were explained in a debriefing that followed the activity.

Teacher participants spent the rest of the morning drawing and sharing out connections among the subject content areas. They also discussed the goals for the summer academy and larger project, as well as the foundation for an iSTEAM approach – especially as a vehicle for potentially improving student engagement – in the research literature. In the afternoon of the first day, teachers identified curricular themes throughout the academic year that could serve as in inspiration for an interdisciplinary STEAM project, writing and posting topics and themes on sticky notes in order to see patterns or clusters. This was followed by brainstorming possible themes for the iSTEAM Academy.

On the second day of the institute, teachers connected possible ideas for iSTEAM projects to their disciplinary standards, which helped them to orient to the standards of content areas that they did not teach. In the afternoon of the second day, teachers began to map out potential iSTEAM projects and timelines for them in the context of Project-Based Learning principles as emphasized by the facilitators (e.g., Buck Institute for Education, 2017). In the morning of the third day of the institute, teacher participants engaged in reflection and consideration of appropriate assessments. In the second half of the third day and on the fourth day, teachers mainly planned iSTEAM units in collaborative groups.

Teachers were thus given maximum autonomy and empowered to collaboratively create integrated iSTEAM curricula. They brainstormed topics that could encompass all STEAM subject areas and serve as a theme for the school year. As the professional development summer institute continued into the final days, the teachers decided on developing a multidisciplinary theme: *Mission to Mars*. In the fall, each teacher incorporated the theme into their classroom activities and tried to coordinate with other teachers wherever possible. For example, the English class developed a unit around reading Andy Weir's novel, *The Martian*. The physics class developed a rocket lab incorporating relevant mathematics. The social studies class developed a unit studying a potential colony on Mars. Teachers were given an opportunity to collaboratively discuss the iSTEAM Academy in monthly Professional Learning Communities (PLCs).

Professional Development Communities (PLCs)

Monthly PLC meetings provided ongoing professional development and support during implementation. Throughout the school year, project staff (from both the university and the school) met with the teachers at monthly PLC meetings to work through issues, brainstorm solutions, and to facilitate changes to classroom practice. Teachers had the opportunity to share their ongoing experience with teaching in the iSTEAM Academy and to receive feedback from fellow iSTEAM teachers and PD staff. The group discussed practical difficulties and successes with their curriculum design, and challenged each other's ideas and implementation strategies. The school facilitator (science supervisor) provided insights and feedback on pedagogical strategies, helped to evaluate student projects, served as a sounding board for new iterations of curricular units and projects, and addressed specific challenges associated with each lesson.

In the beginning of the iSTEAM Academy, there were many challenges. For instance, students were concerned about the work-load and grades. However, the mood improved substantially as the iSTEAM Academy developed some consistency and momentum. As the fall semester progressed, students began to feel positively about their participation in iSTEAM and sought to symbolize their group identity by making iSTEAM T-shirts and creating an iSTEAM Snap channel. More game-like units were developed such as a scavenger hunt in mathematics class and an entrepreneurial game in social studies, while students created and listened to podcasts in English/Language Arts. All classes displayed work related to the *Mission to Mars* theme outside of their classrooms, bolstering a sense of community identity. The physics class shared videos of their rocket launches. In the last week, all iSTEAM Academy students painted a 3-dimensional mural in a communal pod area.

Teachers conversed readily during the PLCs and appeared to develop a bond through mutual participation. They enjoyed and appreciate the opportunity share and support each other in a sustained way throughout the year, and shared their widely-held belief that a dedicated forum for continued co-planning was very valuable.

Procedure and Data Collection

The study of student experience was administered to all students in the iSTEAM Academy and Academy B, and included: a) a student background survey; b) a pre-post academy survey on students' educational attitudes and aspirations; and c) repeated administration of the Experience Sampling Method (ESM) measuring students' engagement, motivation, and affect in several iSTEAM lessons. All surveys were administered by teachers via Qualtrics surveys accessed from classroom computers after providing teachers with sufficient training. The study of teacher experience was administered only to iSTEAM Academy teachers by members of the research team (i.e., coauthors), and included: a) interviews with iSTEAM Academy teachers, and b) journals kept by iSTEAM Academy teachers.

Student Background Survey

Items soliciting student demographic information including gender, race/ethnicity, first language, and mother's highest level of education (as a proxy for socioeconomic status) were asked of student respondents during the pre-academy survey.

Pre-Post Academy Survey

A survey administered prior to and after the iSTEAM Academy and Academy B asked student participants the extent to which they liked and planned to pursue study in the STEAM subject. Since addressing the significant dropout problem at the participating school was a primary goal of the project, a key item on the pre-post survey asked the extent to which student participants intended to continue their education (i.e., through high school, college, and beyond).

The Experience Sampling Method (ESM)

The Experience Sampling Method (ESM) records the activity, perceptions, and cognitive and emotional states of persons while interacting in their natural environment. It has been found to be a valid and reliable instrument for measuring the quality of subjective experiences (Hektner, Schmidt, & Csikszentmihalyi, 2007; Zirkel, Garcia, & Murphy, 2015). The ESM was administered at least once in each of the iSTEAM and comparison classes by an experienced researcher. Administrations rotated among classes of each of the subjects approximately six weeks apart, for a total of five ESM administrations. Thus, participating students had an opportunity to respond to a maximum of five ESM surveys. As a modification of traditional ESM which is administered at random times, the survey was administered to each student in the class at the end of the selected class periods in order to minimize disruption. Students were provided access to a classroom computer in order to complete the survey prepared on Qualtrics. In completing the survey, students reported the date and time of completion, completed four items about the nature of the main activity completed during the lesson, 19 items about their engagement and perception of the activity, and 11 items about their emotions and affect during the activity. The survey took approximately four to five minutes to complete. A total of 524 ESM surveys were collected.

iSTEAM Teacher Interviews

In order to balance out forced-choice surveys to be analyzed quantitatively, teacher interviews were broad and open-ended. We wanted teacher participants to flexibly share as much information about their experience with the iSTEAM Academy as possible. The main goal of the interviews was to elicit the advantages and challenges of the iSTEAM Academy, the benefits for students, and suggestions for the future such as needed supports. Interviews were recorded and transcribed by a member of the research team. During the interviews, participating teachers shared their thoughts on the various components of the academy, such as the summer institute and PLC meetings. We took a phenomenological approach to coding the interview data (Linder, 2011; Moustakas, 1994).

iSTEAM Teacher Journals

In addition to interviews, participating teachers were asked to complete journals that prompted questions such as, 'How did you plan to implement/design this lesson/unit?', 'Describe the activities you did this week/period?', and other questions about obstacles students faced and any changes in their levels of engagement.

Measures

Educational Attitudes and Aspirations

Four items solicited the extent to which respondents liked school, as well as science, art, and working with technology on five-point Likert-type response scales from "not at all" to "a great deal." A single item asked responding students, "How far do you plan to go in school?" Responses were coded as follows: might not graduate high school = 1, graduate high school = 2, some college = 3, graduate college = 4, college and more (maybe Masters, Ph.D., etc.) = 5. Four additional items asked how likely it was that respondents would pursue science, as well as engineering, art, and technology on a five-point scale from "extremely unlikely" to "extremely likely." No items asked about mathematics, as it was not hypothesized that the integrated STEAM projects would influence a greater affinity or aspiration to pursue mathematics as an isolated discipline. No composite scales were created from these items; they were analyzed individually.

Experience Sampling Variables

There were 34 items on the Experience Sampling survey. Five items measured students' perceptions of the main activity being performed at the time of the signal (e.g., instructional format, social partners, etc.). Eighteen items measured respondents' engagement and perceptions of the activity (e.g., "Was it important?" "interesting?" "challenging?" etc.), and 11 items measured participants' cognitive and emotional states (e.g., "How were you feeling? – "happy?" "creative?" "stressed?" etc.) on a five-point Likert scale ranging from not at all to very much.

Student Engagement, Motivation, and Affect

Student experiential dimensions were identified based on the factorial structure emerging from the ESM survey data (i.e., factors with Eigenvalues over 1 as revealed by Exploratory Factor Analysis, or EFA) conducted at the between-students level.[1] Identified factors were: Engaged Learning (11 items, e.g., concentration, perceived effort, perceived level of attention, perceived learning, ability to contribute ideas, perceived engagement; α = .92)[2], Positive Affect (eight items, e.g., feeling happy, creative, excited, successful; α = .91), Authentic Interest (five items, e.g., perceived importance, interest, and relevance; α = .79), and Negative Affect (three items: stressed, bored, and irritated; α = .67).[3] Two items were not included in any factor, and were therefore analyzed as stand-alone items: intrinsic motivation (i.e., "wish to be doing another activity – reversed) and perceived challenge.

Analytic Approach

Research question 1 bearing on the effect of the iSTEAM Academy on students' engaged learning and quality of classroom experience was analyzed with separate multilevel structural equation models (ML-SEM) in MPlus 7.2 for each of the classroom experience variables. Engaged Learning, Authentic

Interest, Positive Affect and Negative Affect factors were created as latent variables in the between-students part of a two-level model (with student ID as the cluster variable). Each latent variable was regressed separately on the iSTEAM Academy as the primary independent variable (i.e., iSTEAM Academy = 1, Academy B = 0). Due to the lack of proportional representation of black students in the iSTEAM Academy, race/ethnicity was controlled with covariates.

For research question two, separate two-way Analysis of Variance (ANOVA) analyses with Duncan's posthoc comparison tests were utilized to compare mean engaged learning and other classroom experience variables (composite of factor items) by the iSTEAM Academy "treatment" factor and one instructional factor such as school subject, instructional format, and social partner. The two-way ANOVA analyses allowed for post-hoc comparisons providing additional information for efficiently interpreting mean differences, as well as plots for illustration purposes, both generated in SPSS 25.0. Due to the inclusion of situational and instructional factors, data were analyzed at the ESM survey level. A comparison of mean engaged learning by the treatment factor and instructional factors was also computed with multilevel models in Mplus 7.2, and nearly identical results were obtained. These multilevel analyses were used for affirmation purposes only.[4]

For research question three, we conducted a One-way Analysis of Covariance (ANCOVA) with educational attitudes/aspirations post-scores as the dependent variable, iSTEAM treatment group as the fixed factor, and pre-score on the same educational attitude or aspiration outcome variable as a covariate. Analyses were conducted on the between-student level. As a cross check, analyses were also completed as T-tests on the educational attitudes/aspirations gain score (i.e., postscore – prescore) with iSTEAM treatment as the grouping variable, which yielded identical results. The ANCOVA method, however, allowed us to additionally control for race/ethnicity.

We also examined the bivariate correlation matrix including composite variables for engaged learning, motivation, and affect as well as educational attitudes and aspirations at the level of the ESM surveys in the iSTEAM Academy only. This allowed us to answer whether, in general, students' engagement, motivation and affect in the iSTEAM Academy were related to educational attitudes and aspirations across all ESM surveys completed. We were interested in this question at the level of each students' encounter with iSTEAM instruction, not as a between-student difference. That is, when students experienced lessons in which they were highly engaged in learning, were their educational attitudes and aspirations also high?[5]

For research question four, we first extracted units of meaning bearing on the questions of the teachers' experiences, challenges and perceptions of the iSTEAM Academy, and then clustered the units to determine themes for secondary analysis. We then analyzed frequencies and patterns in the themes. We also made a descriptive "global" appraisal of each interviewee (i.e., for each research question, which theme did each teacher emphasize the most?) to generate a coherent overarching conceptualization of individual participants. Coding was completed by a single coder. We therefore acknowledge our inability to assure intercoder reliability as a study limitation.

RESULTS

Differences in Engaged Learning and Classroom Experience by Academy

Table 2 shows fixed effects of iSTEAM academy on engaged learning and other dimensions of classroom experience in the context of separate multilevel structural equation models controlling for race/ethnicity in the between-students part of the model. Results show that students in the iSTEAM Academy, on average, reported significantly higher engaged learning ($B = .24$, $\beta = .18$, $p = .01$), positive affect ($B = .24$, $\beta = .13$, $p = .06$), meaningful interest ($B = .27$, $\beta = .25$, $p = .00$), and intrinsic motivation ($B = .62$, $\beta = .40$, $p = .00$), and significantly lower levels of negative affect ($B = -.45$, $\beta = -.29$, $p = .00$), and challenge ($B = -.33$, $\beta = -.30$, $p = .01$), than students in Academy B. iSTEAM Academy coefficient estimates show that the average difference ranged from .24 (Engaged Learning and Positive Affect) to .62 (intrinsic motivation – single item) on the 5-point scale. Standardized estimates show that effect sizes of the iSTEAM intervention on classroom experience ranged from .13 (Positive Affect) to .40 (intrinsic motivation – single item) of a standard deviation.

TABLE 2
FIXED EFFECTS OF ISTEAM ACADEMY ON ENGAGED LEARNING AND OTHER DIMENSIONS OF CLASSROOM EXPERIENCE

	iSTEAM Acad Estimate (β)	S.E.	Est./S.E.	Two-Tailed P-Value
Engaged Learning	0.24 (0.18)	0.09	2.69	0.01
Positive Affect	0.24 (0.13)	0.13	1.91	0.06
Negative Affect	-0.45 (-0.29)	0.14	-3.35	0.00
Meaningful Interest	0.27 (0.25)	0.09	3.23	0.00
Challenge	-0.33 (-.30)	0.12	-2.69	0.01
Intrinsic Motivation	0.62 (.40)	0.15	4.16	0.00

Note. Analyses completed at the between-student level of separate multilevel models controlling for race/ethnicity.

Effects of iSTEAM and School Subject, Instructional Format, and Social Partners

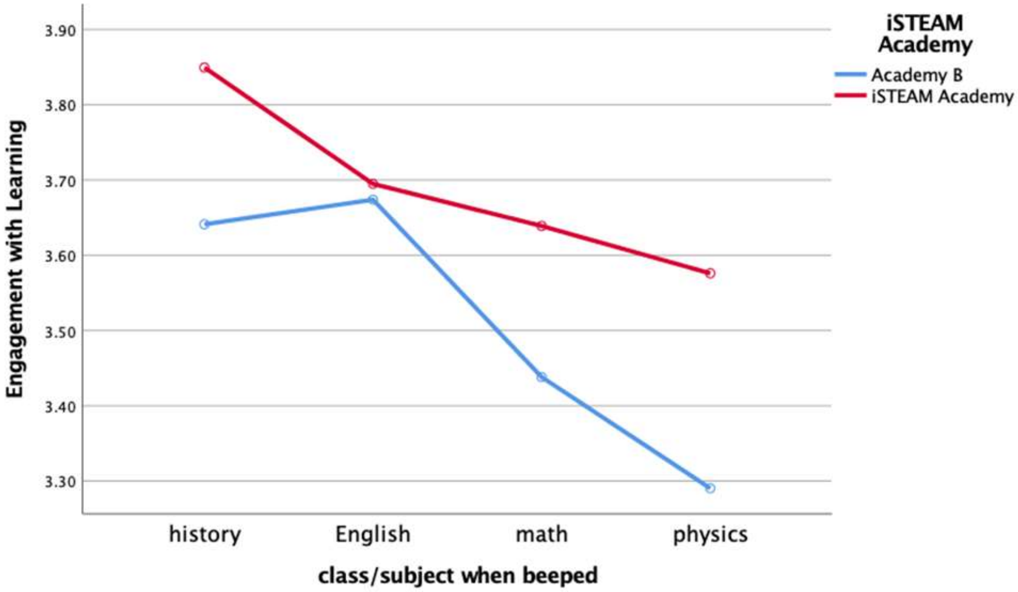
As shown in Table 3a, there was a significant main effect of the iSTEAM intervention ($F = 5.47, p < .05$) and school subject ($F = 3.86, p < .05$) on engaged learning after controlling for race/ethnicity, but the iSTEAM X subject interaction was not significant ($F = .60$, *n.s.*). Mean engaged learning in both academies by subject is provided in Table 3a and illustrated in Figure 1. Students reported higher engaged learning in the iSTEAM Academy in all four subjects. This difference is approximately .2 to .3 on the five-point scale in history, mathematics, and physics, while the difference in English class was negligible. With respect to the main effect of subject, a post-hoc Duncan's multiple range test revealed that engaged learning was in a higher statistical category in English and history class compared to physics class (the mean mathematics score was in both statistical categories). Although not tabled or illustrated, identical analyses with the other dimensions of experience as dependent variable yielded similar results (i.e., significant main effects but no interaction effect). One exception was that there the main effect of subject on negative affect was not significant. Another was that the iSTEAM X subject interaction had a positive effect on intrinsic motivation. Students reported much higher intrinsic motivation during history class in the iSTEAM intervention, approximately .87 of a point on the 5-point scale, but slightly higher intrinsic motivation in Academy B during English class.

TABLE 3A
MEANS, STANDARD DEVIATIONS, AND 2-WAY ANOVA RESULTS FOR THE EFFECT OF THE ISTEAM INTERVENTION AND SCHOOL SUBJECT ON ENGAGED LEARNING

Subject	iSTEAM Academy		Academy B		ANOVA *F*		
	M	*SD*	*M*	*SD*	iSTEAM	Subject	iS X Su
History	3.85	.58	3.64	.67	5.47*	3.86*	.60
English	3.69	.69	3.67	.89			
Math	3.64	.64	3.44	.64			
Physics	3.58	.82	3.29	.87			

Note. $*p < .05$, $**p > .01$. Analyses completed at the ESM survey level.

FIGURE 1
MEAN ENGAGED LEARNING IN EACH SCHOOL SUBJECT BY ACADEMY



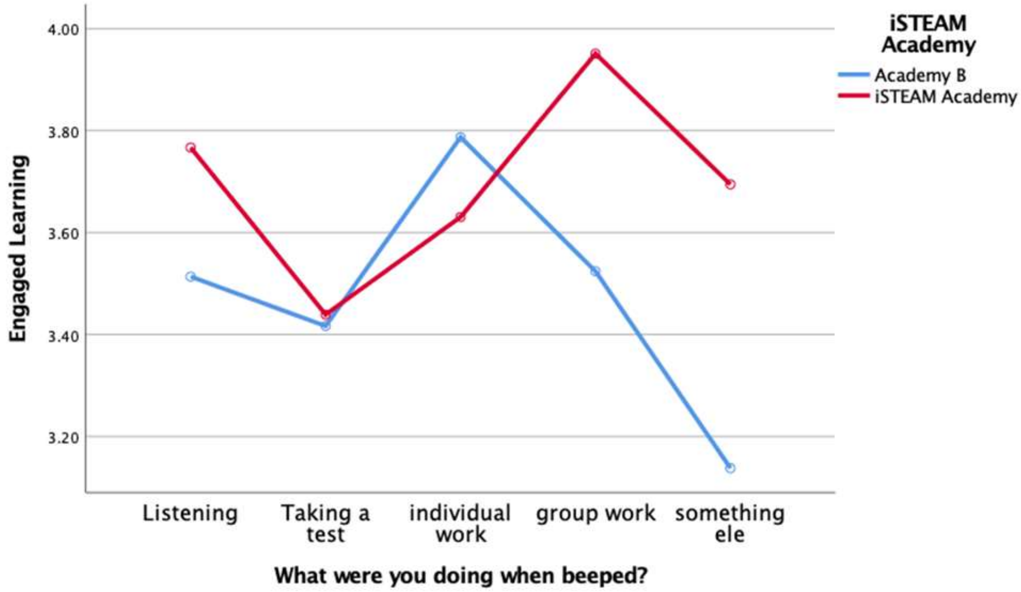
With respect to engaged learning in the instructional formats, Table 3b shows that the effect of the iSTEAM intervention (F = 6.85, p < .01), instructional format (F = 3.09, p < .05), and the iSTEAM X instructional format interaction (F = 2.48, p < .05) were all statistically significant. Mean engaged learning in both academies by instructional format is provided in Table 3b and illustrated in Figure 2. Students reported higher engaged learning in the iSTEAM Academy when listening, doing group work, and doing something else; higher engagement in Academy B during individual work; and about the same level of engagement when taking a test. Despite the significant main effect of instructional format, the comparisons of engaged learning by instructional format did not yield any significant differences. Similar results were found with positive affect and intrinsic motivation as the dependent variable, except that the main effect of instructional format on positive affect was not significant.

TABLE 3B
MEANS, STANDARD DEVIATIONS, AND 2-WAY ANOVA RESULTS FOR THE EFFECT OF THE ISTEAM INTERVENTION AND INSTRUCTIONAL FORMAT ON ENGAGED LEARNING

Activity	iSTEAM Academy		Academy B		ANOVA *F*		
	M	*SD*	*M*	*SD*	iSTEAM	Activity	iS X Act
Listening	3.77	.61	3.51	.70	6.85**	3.09*	2.48*
Test	3.43	.84	3.42	.70			
Ind. work	3.63	.74	3.79	.87			
Grp. work	3.95	.45	3.52	.76			
Something else	3.69	.61	3.14	.96			

Note. *p < .05, **p > .01. Analyses completed at the ESM survey level.

FIGURE 2
MEAN ENGAGED LEARNING IN EACH INSTRUCTIONAL FORMAT BY ACADEMY



As shown in Table 3c, a two-way ANOVA showed that the main effects of the iSTEAM intervention (F = 3.25, *n.s.*) and social partner (F = 1.76, *n.s.*) on engaged learning were not significant, and neither was the iSTEAM X social partner interaction (F = .30, *n.s.*). Mean engaged learning in both academies by social partner is also provided in Table 3c. Students reported higher engaged learning in the iSTEAM Academy with all social partners; the difference was approximately .2 on the five-point scale. The difference is much larger, over 1 point on the 5-point scale when with the teacher, but this difference is based on only one or two surveys in each academy. Although not tabled or illustrated, results were similar with the other dimensions of experience as dependent variable. The one exception was that the main effect of iSTEAM intervention on negative affect was significant.

TABLE 3C
MEANS, STANDARD DEVIATIONS, AND 2-WAY ANOVA RESULTS FOR THE EFFECT OF THE ISTEAM INTERVENTION AND SOCIAL PARTNERS ON ENGAGED LEARNING

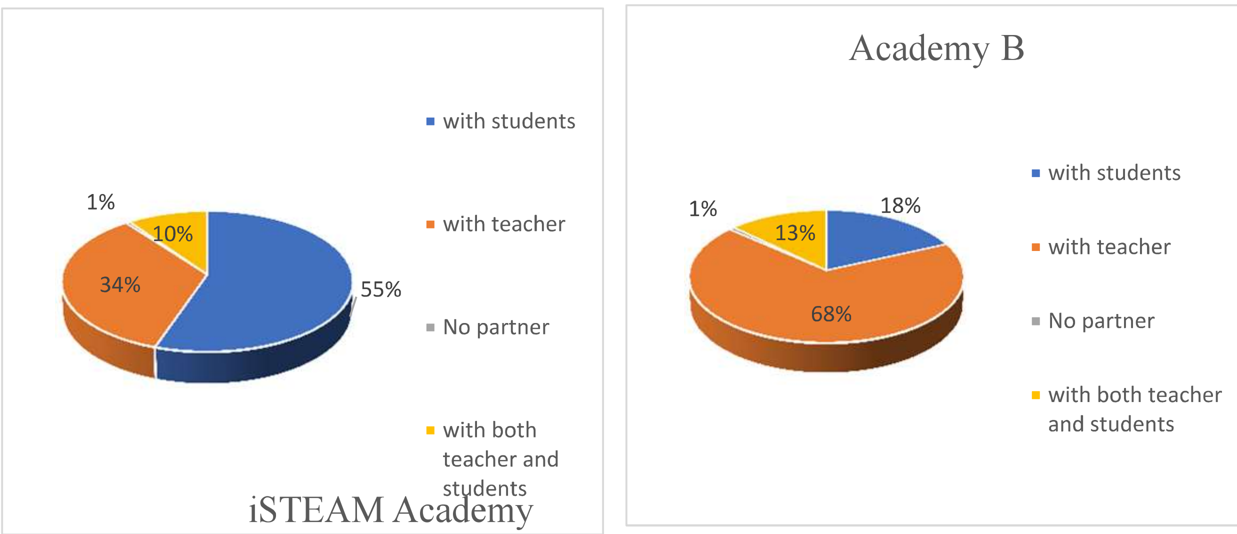
Social Partner	iSTEAM Academy		Academy B		ANOVA *F*		
	M	*SD*	*M*	*SD*	iSTEAM	Partner	iS X Pa
No partner	3.62	.77	3.42	.88	3.25	1.76	.40
w students	3.73	.61	3.37	.79			
w teacher	4.00	.58	2.87	.18			
w both student and teacher	3.87	.47	3.72	.63			

Note. *$p < .05$, **$p > .01$. Analyses completed at the ESM survey level.

A post-hoc analysis shows that there were also large differences in the percentage of time spent with different social partners between the iSTEAM and Academy B, as shown in Figure 3. Students in Academy B spent most of their time (68%), with the teacher and little time (18%) with students;

meanwhile, students in the iSTEAM Academy spent most of their time (55%) with students and less time (34%) with teachers.

FIGURE 3
PERCENTAGE OF TIME SPENT WITH SOCIAL PARTNERS BY ACADEMY



Gains in Aspirations to Continue Schooling From Pre-Survey to Post-Survey

Of primary interest to the study was the potential improvement in the desire to continue schooling as a result of the iSTEAM intervention. Table 4a provides means for this survey items at pre-survey and post-survey by Academy. In Academy B, mean scores declined from pre- to post-survey from 4.10 to 3.88; in the iSTEAM Academy, it increased from 4.00 to 4.19. This is also illustrated in Figure 4. Results of a One-Way ANCOVA with educational aspirations post-survey score as the dependent variable, the iSTEAM intervention as fixed factor, and educational aspirations pre-survey score as covariate is displayed in Table 4b. Race/ethnicity variables were also included as covariate controls. The main effect of the iSTEAM intervention was significant, $F(1) = 5.22$, $p < .05$, indicating that the change in educational aspirations among students in the iSTEAM intervention in comparison with the change in Academy B was significant. The effect size was small to medium ($\eta^2 = .07$). The comparative change in other educational attitudes and aspirations were not of equal interest, did not yield statistically significant results with identical ANCOVA models, and are not tabled or illustrated.

TABLE 4A
MEANS FOR EDUCATIONAL ASPIRATIONS AT PRE-SURVEY AND POST-SURVEY BY ACADEMY

	Pre-survey		Post-survey	
Source	*M*	*SD*	*M*	*SD*
iSTEAM Acad	4.00	1.11	4.19	1.02
Academy B	4.10	0.98	3.88	1.07

FIGURE 4
CHANGE IN MEAN SCORE IN EDUCATIONAL ASPIRATIONS FROM PRE-SURVEY TO POST-SURVEY BY ACADEMY

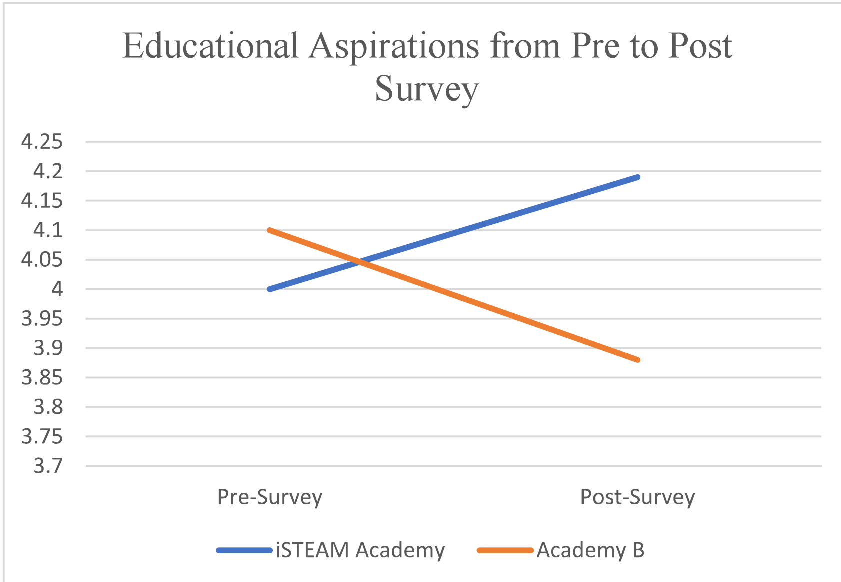


TABLE 4B
ONE-WAY ANCOVA RESULTS WITH EDUCATIONAL ASPIRATIONS AS DEPENDENT VARIABLE, ISTEAM ACADEMY AS FIXED FACTOR, AND PRE-SCORE AS COVARIATE

Source	*df*	*SS*	*MS*	*F*	η^2
Pre-survey	1	42.29	42.29	80.32***	.53
Hispanic	1	1.49	1.49	2.83	.04
Black	1	.52	.52	.99	.01
Indian	0	.74	.74	1.41	.02
iSTEAM Acad	1	2.75	2.75	5.22*	.07
Error	71	37.38	.53		
Total	77	1332.00			

Note. R^2 = .56. Adjusted R^2 = .52. *p < .05, ***p > .001. Analyses were completed on the between-student level.

The Association of Classroom Experience With Educational Attitudes and Aspirations

Table 5 displays a correlation matrix of classroom engagement, intrinsic motivation, positive affect, and negative affect variables with educational attitude and aspiration variables. Engaged Learning, Intrinsic Motivation, and Positive Affect all showed significant positive correlations with students liking of school in general, as well as science, art, and technology. The correlations were generally small, although the correlations with liking of school were moderate to small. Negative affect was significantly but negatively correlated to these same attitudes. Engaged Learning, Intrinsic Motivation, and Positive Affect were all significantly and positively correlated, and Negative Affect negatively correlated, with students' intention to continue schooling as well as to pursue science. Engaged Learning, Positive Affect, and Negative Affect were significantly correlated with students' intentions to pursue engineering in the expected direction, but intrinsic motivation was not significantly related. Only Positive Affect had a significant correlation with students' intention to pursue art, which was positive.

TABLE 5
BIVARIATE CORRELATIONS OF CLASSROOM EXPERIENCE VARIABLES WITH EDUCATIONAL ATTITUDES AND ASPIRATION VARIABLES

	Engaged Learning	Intrinsic Motivation	Positive Affect	Negative Affect
Like school	.30**	.40**	.31**	-.17**
Like science	.20**	.24**	.24**	-.23**
Like art	.17**	.14*	.13*	-.14*
Like technology	.16**	.13*	.19**	-.14*
School aspirations	.19**	.15**	.17*	-.15**
Science aspirations	.16**	.18**	.23**	-.15**
Engineering aspirations	.12*	.10	.20**	-.11*
Art aspirations	.02	.05	.13*	-.08

Note. *p < .05, **p > .01. Analyses completed at the ESM survey level.

Teachers Perceptions and Experiences From Interviews

Participating teachers' impressions of the strengths, challenges, improvements and impact on the students of the iSTEAM Academy are summarized in Table 6 and discussed below. Table 6 provides the answer most emphasized by the teacher of each subject, although teachers frequently discussed other responses as well.

TABLE 6
SUMMARY OF ANALYSIS FROM INTERVIEW DATA

	Algebra I	Algebra I	Algebra I	English	Physics	World History
Strengths	Working in the pod	PLC meetings	Working in the pod	Collaboration	Working in the pod	Increased attendance
Challenges	No flexibility in department	Students of varying levels in the same class	No flexibility in department	Lack of teacher participation	Keeping lessons interesting	Administration expectations
Improvements	New themes	N/A	New themes	More training	Use outside resources	N/A
Impact on Students	Family-like emotional supports	Engaged during group work	Family-like community	Hands-on learning	Academy environment increased engagement	Being part of a family

Strengths of the iSTEAM Academy

Teachers indicated enjoying the summer institute and being highly encouraged by it. They clearly appreciated the rare opportunity for extensive collaborative planning of integrated units. Teachers did not leave the institute with detailed lesson plans so much as a conceptualization and sense for the application of this interdisciplinary theme, *Mission to Mars*, as well as how it connected to the STEAM subjects and related to standards.

Teachers reported on a variety of advantages and many different strengths of the iSTEAM Academy. The main strength identified by all participating teachers was *collaboration*. Teachers enjoyed being able to work with other teachers, share ideas, and have other teachers on their team. Another strength that was identified was the inclusion of PLC meetings. These meetings allowed the teachers to come together, share their ideas, and get help from the researchers and school staff who ran the meetings. Three of the six teachers (50%) also noted that working in the pod was something that allowed the students to be maximally engaged and display enjoyment in the work. The pod was a community space that could be utilized by all of the participants in the academy for academy-wide activities such as a scavenger hunt.

Challenges for the iSTEAM Academy

The most consistently mentioned challenge during the interviews related to school administration. Five of the six teachers (83%) reported that the administration posed many obstacles and challenges to the successful functioning of the iSTEAM Academy. Administration was the greatest obstacle described for half of the participating teachers (i.e., three of six). According to one teacher, "We weren't allowed to be flexible and that hurt me in the long run because I was trying to work with other teachers and try to do different things. The frustration level really hit high going into the new calendar year because you want the program to work the right way and you want the kids to be engaged, but you kind of couldn't do it because the department (told us that we) couldn't do it." Teachers believed, for example, that administration and departments had rigid requirements that did not allow the mathematics teachers to collaborate effectively with the other subjects.

Another challenge that teachers reported related to inexperience with integrated curricula and the collaboration required to produce it. Several teachers stated that more experience or training collaborating on integrated curricula would have supported the project to be more effective and run more smoothly.

Impact of the iSTEAM Academy on Students

Analyses of interview data highlighted one area of impact discussed more than all others. Four of the six participating teachers (67%) reported that the students in the iSTEAM Academy felt like they were part of one big family. According to one teacher, "I feel like our students enjoyed school; I feel like they felt like they were part of something. Some of them said they wanted iSTEAM t-shirts, they felt like they were a family, they kept telling me the last two months that they're going to cry when freshman year's over because they're going to miss iSTEAM so much and they're going to come visit." This sentiment was one that was repeated many times across the interviews.

Overall, the teachers enjoyed participating in the academy and felt that students and teachers alike were able to benefit from the integrated style of learning and teaching. The students felt that they were part of something greater, and the teachers enjoyed being able to communicate with each other and integrate their subjects into a larger project or unit. When asked if they would be interested in doing something like the iSTEAM Academy again, one teacher responded, "Definitely, absolutely, I really enjoyed it…I would definitely like to work in this type of environment again."

Areas for Improvement

In several interviews, teachers shared their opinion that the theme, "Mission to Mars" was overused. The students had become bored with the theme by the end of the year. One suggestion made by several teachers was considering multiple different themes throughout the year. This would keep the students from becoming bored with a single theme and could encourage more engagement. A number of teachers also reported that they would have liked to have had more training. The summer institute and PLC meetings were clearly beneficial and appreciated; however, the teachers required more ongoing professional development and guidance in order to better understand integrated STEM and how to design and implement it.

Additional Feedback from Teacher Journals

Teachers' journal entries offered a different vantage point than the post-interview analyses. The teachers were asked to answer questions about their lesson plans, new activities they were considering, changes in student engagement, the challenges of implementing the lesson when they used a new instructional practice, and their feelings on trying a new lesson. Whereas teachers provided more digested reflections in the context of a dialogue with one of the researchers during the interviews, they provided private notes and observations on the day-to-day work of the iSTEAM Academy in their journal entries. We here summarize the most common answers to these questions.

When teachers were asked how they were going to implement this new lesson, 80% reported that collaboration with other teachers was their primary implementation support or strategy. Teachers also frequently reported was that they planned to do additional projects and use additional materials such as books or worksheets consistent with the "Mission to Mars" theme.

While the specific activities that the teachers used varied greatly based on the primary subject of the teacher, three of six (50%) reported doing more project-based activities than they had previously. A common activity that was used among the math teachers was incorporating more real-life word problems or scenarios that were centered around the theme. A variety of different video-based teaching methods were also used by many of the teachers. Watching videos related to class material helped maintain students' focus, and video-led notes were perceived as more engaging to the students than the teacher-led notes.

DISCUSSION

Effect of the iSTEAM Academy on Student Participants

Results from this study indicated that, overall, the iSTEAM Academy appeared to have a positive effect on students' engagement, attitudes towards STEAM subjects, and the desire to continue schooling. Results from the Experience Sampling Method captured after selected classes in each subject indicated that, compared to students in a schooling-as-usual academy (i.e., "Academy B"), students in the iSTEAM Academy experienced greater engaged learning as well as more meaningful interest, intrinsic motivation, and positive affect during instruction. Students in the iSTEAM Academy reported greater engagement than Academy B students particularly during group work and when listening to the instructor. Students in the iSTEAM Academy also reported spending more time with students (55% compared to 18% for Academy B students) and less time with the teacher (34% compared to 68% for Academy B students). These findings are consistent with the prevailing, young literature suggesting that when students become curious, take control of their learning, and work with their peers to solve real-world problems in STEAM projects, they report experiences that are fun, exciting, motivating, and engaging (Barron & Darling-Hammond, 2008; Connor et al., 2015; Henriksen, 2014; Jamil et al., 2018; Quigley & Herro, 2019; Quigley et al., 2017). This central finding was corroborated by participating teachers, who also observed an increased sense of family-like belonging and enjoyment among students as a frequently repeated theme across interviews.

Students' educational aspirations to continue schooling decreased from the beginning to the end of the project year in Academy B. This result appeared to be reflective of the pervasive disengagement of the student body in the freshman year, one of particular concern to the school because it frequently led to dropout. The present project was intended to address this problem. As hoped, educational aspirations increased from the beginning to the end of the project year for participants in the iSTEAM Academy in contrast to Academy B students. The change in scores from pretest to posttest for iSTEAM participants was significantly different than for Academy B students. Furthermore, students' educational aspirations as well as educational attitudes with respect to liking school and STEM subjects were significantly associated with their levels of engaged learning, intrinsic motivation, and positive affect during instruction.

Teacher Perceptions and Influencing Processes

The qualitative analyses of data collected from teachers both triangulated results regarding the influence of the program, and enriched our understanding of the processes and mechanisms by which consequences were achieved. Overall, the teachers in this project enjoyed participating in the iSTEAM Academy and felt that students and teachers alike benefitted from the integrated style of learning and teaching. They appreciated the rare opportunity to co-plan in a transdisciplinary way with fellow teachers around a common theme, as well as the opportunity to share ideas and obtain feedback in ongoing PLCs.

Thus, providing forums for interdisciplinary collaboration and continued feedback appears to be a critical aspect of implementing iSTEAM.

Teachers appeared to effectively engage students in learning by focusing on solving problems and creating solutions that frequently spanned multiple disciplines or benefitted from multiple perspectives. This was captured by the Mission to Mars theme and the variety of activities across disciplines resulting from it. The iSTEAM Academy focused on real-world problems requiring the 21st century skill of applying creativity to solve. This practice was consistent with those who have conceptualized STEAM in terms of student-centered, problem-based, or project-based approaches structured into an integrated curriculum (Connor et al., 2015).

The most frequently discussed mechanism allowing for success related to communication and collaboration – among teachers as they planned, among students as they worked, and among teachers working together with students. Collaboration in iSTEAM activities occurred readily when students investigated, designed, created, and inquired together in order to connect evidence with knowledge and experience. Thus, most of the iSTEAM activities involved group work. A greater reliance on technology compared to schooling-as-usual coincided with a student-led instructional style that differed sharply from a teacher-led style. Social relations were strengthened as students shared, critiqued, and mentored each other. Consistent with the observation of others (e.g., Henriksen, Mehta, & Mehta, 2019), collaboration was on full display as students shared their findings, experiences, and works produced.

Teacher Challenges, Professional Development, and Recommendations

Teachers frequently believe that time spent on hands-on STEAM projects takes time away from covering content, and therefore that they need to choose between engaging students and meeting standards (Jamil et al., 2018; Quigley & Herro, 2019). These common concerns were certainly reflected in the present project. Among the challenges most frequently mentioned by participating teachers were those pertaining to issues of time management, policies, and administrative support. A clear implication is that the cooperation, buy in, and support of administration can be a key factor in the success of STEAM units.

Another challenge that teachers reported related to their relative inexperience with integrated curricula. To be successful, teachers need to be supported through adequate professional development. Thus, another key implication of the study consistent with the recommendation of experts in STEAM (e.g., Quigley & Herro, 2019) is the critical need for continued PD and ongoing feedback to support effective collaborative planning, discipline integration, numerous design and implementation issues, and supporting students' problem-solving skills. These goals represent a fairly radical departure from traditional modes of teaching. Embedding PD opportunities in the school setting in order to adapt to the constraints and opportunities of the local environment is particularly recommended (Quigley & Herro, 2019). In order to transform practice, continuing professional development can be supported by PLCs or other opportunities for teachers to co-plan and collaborate with their teacher colleagues. Additional support structures including coaching and co-teaching can also support integrated STEM and STEAM units (Sinha, Shernoff, & Cuddihy, in press).

iSTEAM teachers journaled that they utilized more project-based, scenario-based, and video-based approaches than previously. At the same time, they also reported that there was a degree of boredom eventually associated with a single Mission to Mars theme. Use of real-real life scenarios and projects is a primary strategy for developing STEAM curricula emphasized by Quigley and Herro (2019). However, one area for improvement relates to the potential for transdisciplinarity in iSTEAM projects and activities. *Transdisciplinary* teaching and learning moves beyond work centered in specific disciplines, often involving a conversation or "space" between them to produce new perspectives. It also requires an understanding and integration of contexts to make disciplinary content more relevant. STEAM can be further characterized as a holistic approach to education utilizing a global perspective to address contemporary social issues, including those that are international in scale (Quigley et al., 2019). Ideally, iSTEAM units involves three components: a) a relevant, problem-based approach, b) disciplinary integration, and c) multiple ways to solve a problem. Future work in iSTEAM professional development may therefore strive for increasingly higher levels of transdisciplinarity to achieve higher levels of effectiveness.

LIMITATIONS AND CONCLUSIONS

The present study was not without its limitations. Although far from the only limitation, a primary one was the limited sample size with respect to teacher participants, and "case study" approach focusing on a single iSTEAM project. It will be important for future studies to increase sample size as well as diversity of projects to achieve greater generalizability of study results. A variety of other study limitations were acknowledged throughout this report. Despite its limitations, the study provided a sure step in the direction of suggesting that integrated STEAM curricula and instruction can effectively improve students' engagement and educational attitudes, and that teacher professional development and ongoing feedback emphasizing interdisciplinary planning and collaboration are essential supports for ensuring success.

ACKNOWLEDGEMENT

This research, conducted by the Rutgers Center for Mathematics, Science, and Computer Education, was supported by a Community-University Research Partnership Grant for New Brunswick made available by Rutgers University. All opinions, findings, and conclusions are those of the authors and do not necessarily reflect the views of Rutgers University.

ENDNOTES

1. EFA conducted at the within-student level yielded very similar measures, with a few exceptions.
2. As engagement has traditionally been measured by a scale of ESM items (e.g., concentration, interest, and enjoyment; Authors, 2013), few ESM studies have included an item that asked respondents simply and directly, "How engaged were you in the activity?" as we did in this study. We did so partly to learn the correlation between this item and the scaled measure of Engaged learning (with the item removed), which was .80. Thus, this single item measuring students' engagement may be considered an adequate proxy for the scaled measure in similar populations.
3. Although the internal consistency of Negative Affect was a shy of acceptable limits, we believe this was due to the low number of negative affective items since measures of negative affect in previous ESM studies with a greater number of items typically have had acceptable internal reliability. Therefore, we retained the measure in analyses and note the low alpha as a study limitation.
4. ANOVA results could not be computed in the within-students part of a two-level model in MPlus because the structural part of the model defining latent experiential variables would not converge. This was most likely due to lack of sufficient repeated data per student. On average, each student contributed less than two ESM surveys, with many students providing two or three surveys, but many others contributing only one or none. Only a smaller number of students contributed four, five, or six surveys. The lack of sufficient within-student data for within-student analyses in the multilevel context, leading to our inability to account for the dependency of each survey on student, is recognized as a limitation.
5. Although it may be preferable, in the multilevel context, to examine this relationship as a within-student model, the level-1 structural model defining the latent experiential variables would not converge in MPlus 7.2 due to insufficient within-student observations per student. Thus, the analyses were conducted at the ESM survey level.

REFERENCES

Asunda, P. A. (2014). A conceptual framework for STEM integration into the curriculum through career and technical education. *Journal of STEM Teacher Education*, *49*(1), 3-16. doi: doi.org/10.30707/JSTE49.1Asunda. Retrieved from https://ir.library.illinoisstate.edu/jste/vol49/iss1/4

Balfanz, R., Herzog, L., & Mac Iver, D. J. (2007). Preventing student disengagement and keeping students on the graduation path in urban middle-grades schools: Early identification and effective interventions. *Educational Psychologist*, *42*, 223-235. doi: 10.1080/00461520701621079

Banchero, S. (2013). U.S. high-school students slip in global rankings. *The Wall Street Journal*. Retrieved from http://www.wsj.com/articles/

Barron, B., & Darling-Hammond, L. (2008). Teaching for meaningful learning: A review of research on inquiry-based and cooperative learning. In R. Furger (Ed.), *Powerful learning: What we know about teaching for understanding* (pp. 11-70). San Francisco, CA: Jossey-Bass.

Boix Mansilla, V., Miller, W. C., & Gardner, H. (2000). On disciplinary lenses and interdisciplinary work. In S. Wineburg & P. Grossman (Eds.), *Interdisciplinary curriculum: Challenges of implementation* (pp. 17-38). New York: Teachers College Press.

Boy, G. A. (2013). *From STEM to STEAM: Toward a human-centred education*. Paper presented at the Proceedings of the 31st European Conference on Cognitive Ergonomics, Toulouse, France.

Buck Institute for Education [BIE]. (2017). *What is Project Based Learning (PBL)?* Retrieved from http://www.bie.org/about/what_pbl

Bush, S. B., & Cook, K. L. (2019). Structuring STEAM inquiries: Lessons learned from practice. In M. S. Khine & S. Areepattamannil (Eds.), *STEAM education: Theory and practice* (pp. 19-35). Cham, Switzerland: Springer International Publishing.

Connor, A., Karmokar, S., & Whittington, C. (2015). From STEM to STEAM: Strategies for enhancing engineering & technology education. *International Journal of Engineering Pedagogy*, *5*, 37-47. doi: https://dx.doi.org/10.3991/ijep.v5i2.445

Creswell, J., & Plano Clark, V. (2018). *Designing and conducting mixed methods research* (3rd ed.). Thousand Oaks, CA: Sage Publications.

Dupere, V., Leventhal, T., Dion, E., Crosnoe, R., Archambault, I., & Janosz, M. (2015). Stressors and turning points in high school and dropout: A stress process, life course framework. *Review of Educational Research*, *85*, 591-629. doi: 10.3102/0034654314559845

Finn, J. D. (1989). Withdrawing From school. *Review of Educational Research*, *59*(2), 117–142. doi: https://doi.org/10.3102/00346543059002117

Gramlich, J. (2017). *Hispanic dropout rate hits new low, college enrollment at new high*. Retrieved May 12, 2019, from http://www.pewresearch.org/fact-tank/2017/09/29/hispanic-dropout-rate-hits-new-low-college-enrollment-at-new-high/

Guyotte, K. W., Sochacka, N. W., Costantino, T. E., Walther, J., & Kellam, N. N. (2014). STEAM as social practice: Cultivating creativity in transdisciplinary spaces. *Art Education*, *67*, 12-19.

Hektner, J. M., Schmidt, J. A., & Csikszentmihalyi, M. (2007). *Experience sampling method: Measuring the quality of everyday life*. Thousand Oaks, CA: Sage.

Henriksen, D. (2014). Full STEAM ahead: Creativity in excellent stem teaching practices. *The STEAM Journal*, *1*, Article 15. doi: 10.5642/steam.20140102.15

Henriksen, D. (2017). Creating STEAM with design thinking: Beyond STEAM and arts integration. *The STEAM Journal*, *3*, Article 11. doi: 10.5642/steam.20170301.11

Henriksen, D., Mehta, R., & Mehta, S. (2019). Design thinking gives STEAM to teaching: A framework that breaks disciplinary boundaries. In M. S. Khine & S. Areepattamannil (Eds.), *Steam education: Theory and practice* (pp. 57-78). Cham, Switzerland: Springer.

Honey, M., Pearson, G., & Schweingruber, H. (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*. National Academies Press.

Jamil, F. M., Linder, S. M., & Stegelin, D. A. (2018). Early childhood teacher beliefs about STEAM education after a professional development conference. *Early Childhood Education Journal*, *46*, 409-417. doi: 10.1007/s10643-017-0875-5

Katz, L. (2010). STEM in the early years. *SEED Paper for Early Childhood Research and Practice*, *3*, 1-3.

Linder, S. M. (2011). The facilitator's role in elementary mathematics professional development. *Mathematics Teacher Education and Development*, *13*, 44–66.

Martin, A. J., Way, J., Bobis, J., & Anderson, J. (2015). Exploring the ups and downs of mathematics engagement in the middle years of school. *Journal of Early Adolescence*, *35*, 199-244. doi: 10.1177/0272431614529365

Masata, D. (2014). *Understanding the STEAM skills gap*. STEAM education news. Retrieved from http://www.educationandcareernews.com

Moustakas, C. (1994). *Phenomenological research methods*. Thousand Oaks, CA: SAGE Publications.

Murphy, M. C., & Zirkel, S. (2015). Race and belonging in school: How anticipated and experienced belonging affect choice, persistence, and performance. *Teachers College Record*, *117*, 1-40.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.

National Science Board. (2014). *Science and engineering indicators 2014: A broad base of quantitative information on the U.S. and international science and engineering enterprise*. Arlington, VA.: National Science Foundation. Retrieved from https://www.nsf.gov/statistics/seind14/

Pino-James, N., Shernoff, D. J., Bressler, D. M., Larson, S. C., & Sinha, S. (2019). Instructional interventions that support student engagement: An international perspective. In J. A. Fredricks, A. L. Rechly, & S. L. Christensen (Eds.), *Handbook of student engagement interventions: Working with disengaged youth* (pp. 103-119). Mahwah, NJ: Elsevier.

Quigley, C. F., & Herro, D. (2019). *An educator's guide to STEAM: Engaging students using real world problems*. Teachers College, Columbia University: Teachers College Press.

Quigley, C. F., Herro, D., & Baker, A. (2019). Moving toward transdisciplinary instruction: A longitudinal examination of STEAM teaching practices. In M. S. Khine & S. Areepattamannil (Eds.), *STEAM education: Theory and practice* (pp. 143-164). Cham, Switzerland: Springer International Publishing.

Quigley, C. F., Herro, D., & Jamil, F. M. (2017). Developing a conceptual model of STEAM teaching practices. *School Science and Mathematics*, *117*, 1-12. doi: https://doi.org/10.1111/ssm.12201

Shernoff, D. J. (2013). *Optimal learning environments to promote student engagement*. New York: Springer.

Shernoff, D. J., Sinha, S., Bressler, D. M., & Ginsburg, L. (2017). Assessing teacher education and professional development needs for the implementation of integrated approaches to stem education. *International Journal of STEM Education*, *4*, 1-16. doi:10.1186/s40594-017-0068-1

Sinha, S., Shernof, D. J., & Cuddihy, C. (in press). Collaboration in PK-12 integrative STEM instruction. In G. Rose, A. & K. Stith (Eds.), *Leading with stem education: Successful practice for school and district leaders*. Lanham, MD: Rowman & Littlefield.

The Tech Museum of Innovation. (2016). *Design challenge learning*. Retrieved from https://www.thetech.org/educators/design-challenge-learning

Vasquez, J., Sneider, C., & Comer, M. (2013). *STEM lesson essentials, grades 3–8: Integrating science, technology, engineering, and mathematics*. Portsmouth, NH: Heinemann.

Zirkel, S., Garcia, J. A., & Murphy, M. C. (2015). Experience-sampling research methods and their potential for education research. *Educational Researcher*, *44*, 7-16. doi: 10.3102/0013189x14566879