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Using Self-Determination Theory to Explain How Community-Based Learning Fosters Student Interest and Identity in Integrated STEM Education

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Abstract

Real-world problems serve as authentic learning contexts for students to integrate science, technology, engineering, and mathematics (STEM) knowledge, enhancing their interest and fostering their identity in STEM. Primary school students' unfamiliarity with real-world problems can be addressed through community engagement; however, research in this area is insufficient. This study used self-determination theory (SDT) to examine and explain the effect of community engagement on student STEM interest and identity development. The mixed-methods sequential explanatory design was adopted, and two experimental groups were set up: community engagement (CE; $N=72$) and non-community engagement (NCE; $N=69$). The CE group reported significantly higher needs satisfaction levels with autonomy, competence, and relatedness and greater STEM interest and identity. The CE group also expressed that the autonomy encouraged them to learn beyond the classroom and helped them engage with the community; that they were able to build better products through iterations and feedback from users; and that they experienced meaningful learning by creating useful products for others. These findings support the pedagogical value of community engagement projects to foster autonomous motivation. This study explicates how young students' STEM interest and identity could be fostered using SDT contextualized as a community-based STEM engagement project. Through this study, educators worldwide are provided with practical suggestions on using the tested approach.

Keywords Design-based projects · STEM · Interest · Identity · Community engagement · Self-determination theory

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Introduction

Food shortage, climate change, and pollution are complex real-world problems. Such problems have led to a growing demand for integrated science, technology, engineering, and mathematics (STEM) education in K-12. Integrated STEM education can be accomplished by exploring the in-depth connections among the various STEM domains (Honey et al., 2014; Stohlmann et al., 2012). Interest and identity are the major learning outcomes of integrated STEM education and help predict student future study and career preferences; hence, further research on STEM interest and identity is warranted to encourage more students to join the STEM workforce. The development of STEM is encouraged by instructional approaches that initiate different types of integrative activities. Generally, project-based learning by investigating and engaging with complex real-world problems is known to promote greater integrated education (i.e., inter-disciplinary and trans-disciplinary education; Markula & Aksela, 2022). Compared with discipline-related problems, real-world problems are more relevant to students and are more likely to motivate their engagement in solution finding (Stohlmann et al., 2012). Confined by the usual learning that happens in K-12, some real-world problems (e.g., designing driverless cars and making growing plants hydroponically) are too advanced and less accessible for young children (e.g., primary/elementary school students), as these problems lack relevant authentic and physical experiences. Therefore, such problems are good for inquiry-based but not design-based project learning. Contextualizing real-world problems in local community settings may help students better understand these problems (Nykiforuk et al., 2021).

A group of interacting students living/studying in a common location is considered a local community (Rennie et al., 2018). Students feel more familiar with and can recognize community-based problems. They want to act in such situations or do things that benefit the community, also known as "social good" (Chai et al., 2021). Some studies have assessed how interest and identity in STEM learning facilitate social good (Barton et al., 2017; Godec et al., 2022; King & Pringle, 2019). Moreover, it remains unclear how the association between the community and primary schools engages students in integrated STEM learning.

Incorporating the community's ideas when solving real-world problems could help students feel more connected to relevant problems, resulting in greater motivation and engagement (Cooper, 2007; Mooney & Edwards, 2001; Rennie et al., 2018; Wiseman et al., 2020), which could be explained by the "need satisfaction" component of self-determination theory (SDT; Ryan & Deci, 2017, 2020). SDT proposes that all learners have three basic needs: autonomy, competence, and relatedness (Ryan & Deci, 2020). Satisfying all of these motivates students to engage in integrated learning, resulting in better outcomes. Accordingly, this study used SDT to explain how community engagement fosters STEM interest and identity among primary school students undergoing integrated STEM learning in Hong Kong. In Hong Kong, the first curriculum document related to STEM education was published in 2015 to encourage integrated learning. Most schools are situated in a populated area (around one or more communities). The communities are accessible to students and teachers. The study findings contribute to the literature by presenting detailed evidence on the roles of community engagement in integrated STEM learning among primary school students and emphasizing the importance of need satisfaction in design-based STEM learning.

Literature Review

Design-Based Projects in Integrated STEM Learning

Integrated STEM learning combines some or all four STEM disciplines into a joint learning experience (Honey et al., 2014); each STEM discipline offers overlapping, shared knowledge and skills. Such instructional approaches are more student-centered, less fragmented, and more relevant and stimulating (Furner & Kumar, 2007; Honey et al., 2014; Stohlmann et al., 2012). Integrated learning can foster higher-order thinking skills and more learning positive attitudes toward STEM subjects (Stohlmann et al., 2012). Through integrated learning, students can become problem solvers, innovators, and logical thinkers (Han & Kelley, 2022; Kopcha et al., 2017) and develop strong STEM interest and identity; thus, it is crucial to understand how integrated STEM learning can be designed and implemented.

Design-based projects are commonly applied to integrated STEM learning. These projects involve real-world problems and hands-on learning that require multiple ideas and solutions (English, 2019). Dealing with real-world problems provides rich opportunities for integrated learning (English, 2019; Kangas et al., 2013). These problems may be more tangible and meaningful to students because they are applicable to the lives of students and the community. Moreover, these problems provide an opportunity for applying the skills and knowledge learned in classrooms and encourage students to be aware of their ideas and choices and to understand how they fit into a larger social environment (Quigley et al., 2017). The complexity and unpredictability of these problems can stimulate problem-solving and collaborative skills. In most cases, no perfect solution is available, which pushes students to think and argue about different solutions.

Design-based projects can be implemented through five iterative phases: (i) empathize: develop a good understanding of the users' needs through research; (ii) define: frame and scope the problem and identify its goals and boundaries; (iii) ideate: generate a range of ideas for planning in contrast to focusing on developing one idea; (iv) prototype: agree on the best idea and transform it into a prototype/product; and (v) test: get user feedback to identify improvements (Chiu, 2021a, 2021b, 2022; English, 2019). These iterative activities require students to engage in long-term learning. The students' commitment may be tested throughout the project. Some students may not take each of the phases seriously, neglect some phases, or overthink on problems or rush to quickly complete their projects (Chiu, 2021a, 2021b, 2022). Accordingly, strategies to enhance and maintain student motivation should be considered when designing integrated STEM projects. Student motivation could be enhanced by incorporating community engagement with the school curriculum (Trott, 2019).

Community Engagement for STEM Education

Community-based learning is an intentional pedagogical strategy used by teachers to integrate student learning with community engagement (Cooper, 2007; Mooney & Edwards, 2001); this establishes a link between what is taught in classrooms and the students' surrounding communities. Moreover, community-based learning connects the cyclical, collaborative, and reflective processes of teaching and learning that are rooted in authenticity and social good (Wiseman et al., 2020) and is an opportunity for students to use their personal observation- and social interaction-based ideas to design and find solutions for real-world problems. The deduced solutions may benefit the students' communities. Such learning approaches tend to be meaningful and are directly applicable to students' daily lives, inherently motivating student engagement. For example, Barton and colleagues (2017) reported that a makerspace for STEM education provides a critical, connected, and collective environment that supports African-American and Latino youths' sustained and mutual engagement; these youths then develop a stronger STEM identity. King and Pringle (2019) revealed that community-based learning makes STEM education more inclusive and reported that Black girls (i) had their interests in STEM ignited, (ii) agentically engaged in STEM activities, and (iii) had better formal STEM learning experiences. Tan and Barton (2018) found that engaging communities in STEM learning supported the intersectionality of African-American female school students' identities (i.e., being a better STEM student and enthusiastic youth maker for underprivileged social groups). These studies focused on the benefits of community-based learning in STEM, particularly for the underrepresented or disadvantaged. However, most of those studies were conducted among the Western population and older students (such as those who completed higher education). In comparison, studies on the Eastern population and younger children are limited. Hence, using SDT, a motivational theory, the present study used a different perspective to explain how community-based learning fosters STEM learning outcomes among primary school students in Hong Kong.

SDT and Community Engagement for STEM Interest and Identity

SDT explicates how three human basic needs—autonomy, competence, and relatedness—affect motivational orientation within a social context (Ryan & Deci, 2017, 2020). Autonomy is making choices and decisions based on one's own values and beliefs (free will); competence is feeling confident in one's ability to complete tasks and being able to achieve goals and tackle challenges; and relatedness is feeling connected to and supported and cared by others and organizations. SDT is widely used to explain student motivation and well-being in educational contexts (Ha & Roehrig, 2022; Reeve & Halusic, 2009). Learning environments that support individual experiences of autonomy, competence, and relatedness can foster autonomous motivation, which is a high-quality energy source of engagement (Chiu, 2022) and ensures long-term problem solving.

According to SDT, connecting communities using STEM design-based projects is more likely to motivate primary school students. Community-based learning may be perceived as an SDT-based need support strategy. The community around young students' neighborhoods may present many meaningful problems that could enhance the students' learning owing to their familiarity and relevance with the problem rather than with regional or global issues (Barton et al., 2017; King & Pringle, 2019). Incorporating community-based learning may be one of the effective pedagogic strategies for integrated STEM learning (Zizka et al., 2021). Teachers can engage their students in solving neighborhood problems (i.e., communities around their schools or houses). The students can then identify the problems by collecting field data, collaborate with users to propose solutions, and receive feedback on their solutions. This makes the problems more personal and familiar and helps students develop empathy for others' life experiences and points of view (relatedness in SDT). Moreover, it inspires the students to be more creative about the problems (Mildenhall & Cowie, 2021) and allows them to ask more specific and appropriate questions to gain a deeper understanding of the problems (i.e., competence in SDT). This makes the students feel that they have more control in the problem-solving process and accept responsibility for their solutions (i.e., autonomy in SDT). The needs satisfaction leads to higher engagement in STEM education (Chiu, 2021a, b), resulting in stronger interest and identity towards STEM.

Interest is a relatively enduring preference for certain topics and activities (Schiefele, 1991). It includes two major components: value-related that refer to the personal significance of a topic or subject, e.g., perceiving importance, and feeling-related refers to the feelings about a topic, or object, e.g., feeling joy and fun (Schiefele, 1991). Interest gets stronger over time from curiosity (Renninger & Hidi, 2011). It affects students' attention to a STEM learning or wanting to be involved with and to discover more about a subject. Students with stronger interests feel more capable (competence) and better self-regulate their behaviors (autonomy and relatedness) in persevering with challenging tasks (Hidi & Ainley, 2008). Student interest is strongly associated with identity. Students who are interested in STEM activities will enjoy STEM subjects, which may lead to stronger STEM identity (Verhoeven et al., 2019). Identity development in STEM education refer to identity as "how individuals know and name themselves, who one is or wants to be, as well as to how one is recognized by others" (Goos & Bennison, 2019; Kim et al., 2018). Students' STEM identities are socially constructed with others and developed through internalization of their learning experiences (Hill et al., 2010; Vincent-Ruz & Schunn, 2018). This is supported by needs satisfaction in SDT.

Internalizing STEM learning activities, and pursuing valued and recognized by others are seen as a basic process in developing interests and identity (La Guardia, 2009). STEM learning experiences should allow students to (i) more flexibly consider their own choices and thoughts in engaging with real-world issues, e.g., neighborhoods and society, through the transformation of their values and goals from being externally imposed to personally owned (i.e., autonomy); (ii) develop capability to accept new challenges and opportunities for their growth and mastery, and to express their achievement and ideas to others, e.g., users in the community (i.e., competence); and (iii) engage with key relationship partners, e.g., the users of their solutions, and share their goals and values (i.e., relatedness); (ii) develop competencies to capitalize on new opportunities for growth and mastery, and to express their success (i.e., competence) (La Guardia, 2009; Vincent-Ruz & Schunn, 2018). Students who successfully internalize their learning experiences during STEM activities are hold stronger STEM interest and identity. Accordingly, community engagement that better satisfies students' needs in integrated STEM learning could foster stronger STEM and identity.

Research Gap

Studies on the development of STEM interest and identity have highlighted issues regarding student equity and have assessed how the development of underrepresented groups—girls and Black people—can be fostered better (Cohen et al., 2021; Godwin et al., 2016; Kim et al., 2018). The majority of such studies have suggested providing role models and mentors in classrooms. Moreover, certain studies have ignored integrated STEM learning and focused on individual STEM disciplines instead (Godwin et al., 2016; Kim et al., 2018; Vincent-Ruz & Schunn, 2018).

Interest is an enduring preference for certain aspects, disciplines, and activities (Renninger & Hidi, 2011), whereas identity refers to "how individuals know and name themselves, who one is or wants to be, and how one is recognized by others" (Goos & Bennison, 2019; Kim et al., 2018). Stronger STEM identity is proportional to stronger STEM interest. Both aspects include feeling- and value-related components. Identity can be distinguished from interest based on other recognition and a social aspect. Identity and interest are developed over time in stages, socially constructed in coordination with others, and built by internalizing others' learning experiences. This internationalization can be explained by the "needs satisfaction" concept of SDT.

It is very important that students start early to develop STEM interest and identity (Cohen et al., 2021). Community-based learning is well documented in higher education (often known as "service learning"; Barton et al., 2017; Karasik, 2020) but not in primary education. Very few studies have used needs satisfaction to explain how community-based learning can foster STEM interest and identity in integrated STEM education.

The Present Study and Methodology

Research Goals

As discussed in the previous sections, through community-based learning, primary school students may feel more related to the community, more competent to understand and solve problems, and a stronger sense of autonomy, resulting in the development of a more positive STEM interest and identity. Thus, this study used SDT to explain how community-based learning fosters STEM interest and identity. More specifically, it examined how two experimental communities—community engagement (CE) and non-community engagement (NCE)—affect the development of STEM interest and identity. Moreover, the study used needs satisfaction for autonomy, competence, and relatedness to elucidate how community-based learning fosters the development of STEM interest and identity.

The three main research questions assessed in this study are as follows:

- Does community engagement enhance better needs satisfaction and STEM interest and identity?
- Does needs satisfaction predict STEM interest and identity development?
- How does community engagement support the needs for autonomy, competence, and relatedness?

The following hypotheses were proposed:

H1: Compared with the NCE group, the CE group perceives higher needs satisfaction for autonomy, competence, and relatedness.
H2: Compared with the NCE group, the CE group develops stronger STEM interest and identity.
H3: Needs satisfaction significantly predict the changes of STEM interest and identity.

Research Design and Procedure

This study adopted a mixed-methods sequential explanatory design with deductive reasoning. A total of 141 primary 6 students belonging to two schools from the same district were included in the study. The schools were partnership schools of a project the first author leading. Two science, two mathematics, and two technology teachers from each of the schools were recruited and received 18-h workshops on STEM education, SDT, and design thinking. The students were aged 11–13 years (48% male and 52% female) and had an average academic performance and social economic background (i.e., the students from both schools had similar learning abilities and family backgrounds). Each school was assigned to one of the two experimental groups—CE (72 students) and NCE (69 students). The students were recruited from two different schools to avoid communication between the two groups. Communication could lower the long-term reliability of the experimental design by affecting the students' learning in design-based projects.

In the design-based projects, the students used the five iterative phases—empathize, define, ideate, prototype, and test—to find solutions to their identified STEM problem in 16 weeks. They are required to use their STEM knowledge to support and explain their ideas and prototype (the ideate, prototype, test phrases), and communicate with teachers in the define phrase and audiences in the sharing session, i.e., poster showcasing. The students were reminded to use their STEM knowledge in the curriculum. For example, science: the knowledge of the topics “sound, light and electricity”; technology: making using low (e.g., cardboard) and high (e.g., kitten bots) technology materials; mathematics: measures (e.g., estimate the result of measurements), shape (e.g., recognize the concepts and properties of different shapes), data handling (e.g., organizing and representing statistical data, using approximate values and appropriate scales to construct statistical charts and interpret them); engineering: engineering thinking—propose different solutions, and choose the best-fit solutions.

The community-based learning is designed using the ideas of SDT needs satisfaction—the students can choose their users (autonomy) and receive specific feedback (competence and find learning more relevant relatedness). The community is a public estate that has a local shopping mall, elderly nurse center, and social wealth center. The social economic status of the community is below average in the Hong Kong SAR. Therefore, the users could come from a restaurant, the centers, a retail shop. The students in the CE group expressed what they want to approach in the stage of empathize and get the teachers endorsement. This study was ethically approved by the corresponding author’s university. Consent was obtained from all of the students and their parents before study initiation. Before the study, the students completed a 20-min questionnaire. In 16-week teaching, every week, the students had to work on two 35-min lessons in groups of 4–5 (for a total of 18 groups in each school) for their STEM design-based project. Each of the student groups identified its own problem and designed and provided corresponding solutions. In each of the phases, the CE group could reach out to the community around their school and was encouraged to communicate with the members. Empathize: the students went out and talk to targeted users for understanding their needs; define: they defined the possible problems, and got their teachers’ endorsements; ideate: they proposed at least two solutions/ideas for their defined problems with explanations using STEM knowledge mentioned. They also went out and presented their ideas to the users and seek for their comments; hereby, they chose the best solution for the users. Prototype: they created a prototype for the solution using their chosen materials; test: the group went out to show or test the prototype to the users in the community, and seek for more comments for improvement.

In contrast, the NCE group stayed in the school throughout the learning period. In other words, the group only talked to their classmates or teachers. In the last week, the two groups presented a poster showcasing their work and explicitly shared how they applied STEM knowledge in solving their problems. External guests, and the users, and parents, students, and teachers within the schools were invited to join the showcase. They listened to the student short sharing and asked relevant questions. After the showcase, the students again completed the 20-min questionnaire. Moreover, 27 students from the CE group were randomly selected for semi-structural interviews. In each interview, a group of three students were asked how community engagement satisfied their needs in 40 min. Six students neither provided consent nor completed both of the questionnaires. However, they continued the STEM learning activities as part of their schoolwork; hence, their data were not included in this study. This arrangement was adopted to avoid affecting the students’ right to learn.

Questionnaires

Pre- and post-questionnaires were used to collect data to answer the first and second research questions. Both of the questionnaires measured demographic data and STEM interest and identity; in contrast, needs satisfaction was measured only in the post-questionnaire. Each measure was rated on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The questionnaires were checked by twelve teachers from the two schools to ensure that the students understood the wording and language.

To assess the students' needs satisfaction, the Basic Psychological Need Satisfaction and Frustration Scale (Chen et al., 2015), which was validated by Van der Kaap-Deeder et al. (2015) for use in younger children, was used. We deleted the Frustration part, resulting in 12 items. The items were checked by two teachers, and an international SDT scholar to increase the validity. The reliability of the items is checked using Cronbach's α that presented in the results. The questionnaires began with the phrase "In this integrated STEM design-based project," The four items for perceived autonomy satisfaction (Cronbach's $\alpha = 0.77$) were "I feel free to choose which activities I do," "I do the things I do because I really want to do them," "I choose to do the things I do because I want to do them," and "I find the things I do really interesting." The items for perceived competence satisfaction (Cronbach's $\alpha = 0.77$) were "I can do things well," "I am good at what I do," "I can achieve my goals," and "I am good at difficult tasks." The items for perceived relatedness (Cronbach's $\alpha = 0.72$) were "The people that I like, also like me," "I feel close to the people I care about," "I have warm feelings toward the people I spend time with," and "I feel close to and connected with the people who are important to me." The measure is validated using content, construct, and discrimination validity. This study adopted an instrument validated by Tyler-Wood et al. (2010) that measures the STEM interest among primary school students (Cronbach's $\alpha = 0.88$). Confirmed the following items in younger children: "I find STEM interesting," "I find STEM exciting," "I find STEM fascinating," and "I find STEM means a lot." The measure is validated using content, construct, and discrimination validity.

The final measure was STEM identity. Items assessing recognition by others and self were adapted from Cohen et al. (2021). The items for perceived recognition by others (Cronbach's $\alpha = 0.97$) were "My family sees me as a STEM person," "My classmates see me as a STEM person," and "My classroom STEM teachers see me as a STEM person." The item for self-recognition was "I see myself as a STEM person." The measure is validated using content (the items were checked by SDT scholars), construct (confirmatory factor analysis was used), and discrimination validity (cross loadings were used).

T-tests were performed to test H1; analyses of covariance (ANCOVAs) were conducted to test H2. Regression analyses were used to test H3—how strong the two relationships between (i) needs satisfaction (all three needs together) and change of STEM interest, and (ii) needs satisfaction and change of STEM identity.

Semi-Structural Interviews

This study used semi-structural interviews to understand how community engagement support the needs for autonomy, competence, and relatedness. This allowed us to follow the voice and interpretations of the participant through sample questions. The questions intended to ask how the community satisfy the three needs. They include "[general] Did the users in the community help you? How?" [Autonomy] How did you define your problems? How did you make your choices? [Competence] How did you get feedback from the community? How did you interact with the users? [Relatedness] Did your solution contribute to the community? How? How do you feel like in this community learning?" These questions were used in SDT-based studies in studies with similar age of students (Chiu, 2022; Chiu et al., 2021, 2022, 2023).

To analyze the interview data, the autonomy, competence, and relatedness satisfaction in SDT served as an analysis framework to identify how community engagement supported basic student needs in the CE group. Three main themes for coding are autonomy, competence, and relatedness. The two research assistants coded the data independently and then compared their coding to check for consistency. They both have experienced in conducting interview about SDT-based needs. The corresponding author moderated the decisions in case of conflicts. The analyses intended to see what activities in the community engagement support the three needs, see Table 1.

Results

Descriptive Statistics

Table 2 presents the descriptive statistics of all of the measures (i.e., the mean and standard deviations of the pre- and post-questionnaire scores for both groups). The Cronbach's α values of all of the measures were > 0.90, indicating high reliabilities. The skewness and kurtosis values ranged from -1 to 1, indicating normality. The results of *t*-tests indicated that the mean scores of pre-STEM interest [$t(139) = 0.26$, $p = 0.79$] and pre-STEM identity [$t(139) = 0.10$, $p = 0.92$] did not significantly differ (all p values > 0.50) between the groups (H1). Thus, the schools were found to have similar STEM education environments before the project. The two experimental groups did not differ in terms of their pre-questionnaire scores.

The posters presented by the two groups indicated that the prototypes of the CE and NCE groups can be classified into ten (intelligent recycle bins, sensors for saving energy, smart wheelchairs, etc.) and four (solar cooker, hydroponic farm, solar cars, and homemade air conditioning) different products, respectively. The CE group performed more community-based work, whereas the NCE group focused more on classroom learning.

Table 1 Coding and results of the interview data

Main themes	Code	Sub-themes (percentage of participants)	Examples
Autonomy	- Get new ideas from the community - Get inspired from the community - Improve problem definition, solution and design	Inspiration from the community (100%)	- We got inspired from talking with the users. (AutoIn1) - This idea came from the user I spoke to when we got out in the neighborhood. (AutoIn2) - I felt I had more ideas to choose for our decisions after talking with the users. (AutoIn3)
	- Make my own choice in the community - Learn in a more open learning environment	Learning outside the classroom (100%)	- It was new and different to learn in the neighborhood. I could ask any questions that I wanted to. (AutoLg1) - I could choose what I wanted to ask and do in the community. (AutoLg2) - I could choose the person I wanted to talk with in the community. (AutoLg3)
Competence	- Receive specific and relevant feedback - Receive timely feedback	Feedback from users (100%)	- The feedback of the user was helpful, very constructive. Better than my teacher. (CompFb1) - The comments on my ideas are very specific. I know where and how to modify our ideas. (CompFb2) - I found the comments given to us encouraged us to think more to improve our solutions. (CompFb3)
	- Feel more successful - Feel more capable - Feel more chances to solve the problem	Low failure rate (70%)	- I always can do better. (CompFa1) - Asking the users questions solved our problems. (CompFa2) - We learned more about the issues after talking with the users. (CompFa3)

Table 1 (continued)

Main themes	Code	Sub-themes (percentage of participants)	Examples
Relatedness	- Feel connected relevant - Feel being belonged - Love the learning	Affective learning (100%)	- Learning with the community was fun and inspiring. I like it a lot. I want to have more learning opportunities like that. (RelaAl1) - I could collect authentic data. It is different from receiving data in classrooms. (RelaAl2) - We could take actions in the community, which gave us a lot of fun. (RelaAl3)
	- Find the learning meaningful - Find their solution useful - Feel they help others	Social good (100%)	- We created something (an electronic tool) that can help people. (RelaSg1) - I found learning STEM useful and meaningful. (RelaSg2) - This idea would help people. (RelaSg3)

Table 2 Descriptive statistics from the pre- and post-questionnaires used in the study

		Pre-questionnaire		Post-questionnaire	
Group	Measures	Mean	*SD*	Mean	*SD*
CE (N=72)	STEM interest	2.97	1.04	3.93	0.71
	STEM identity	2.80	1.00	3.95	0.69
	Autonomy satisfaction	-	-	4.25	0.50
	Competence satisfaction	-	-	3.97	0.72
	Relatedness satisfaction	-	-	3.85	0.71
NCE (N=69)	STEM interest	3.01	1.01	3.21	1.02
	STEM identity	2.81	0.93	3.08	0.95
	Autonomy satisfaction	-	-	3.27	0.73
	Competence satisfaction	-	-	2.89	0.93
	Relatedness satisfaction	-	-	2.83	0.91

Effect of Community Engagement on Autonomy, Competence, and Relatedness

T-tests results showed that the CE group perceived a significantly higher autonomy satisfaction [t(139) = 8.86, $p < 0.001$], competence satisfaction [t(139) = 7.80, $p < 0.001$], and relatedness satisfaction [t(139) = 7.41, $p < 0.001$] than the NCE group. These also served as manipulation checks and indicated that the community engagement was effective for needs satisfaction in this study.

ANCOVAs were conducted to test H2 after the assumptions of homogeneity of variance were met (i.e., all p values were > 0.50). The p values of interest and identity were 0.21 and 0.91, respectively, as per Levene's test. As summarized in Table 3, the CE group reported significantly stronger STEM interest than the NCE group [$F(1, 138) = 52.95$, $p < 0.001$, $\eta^2 = 0.28$]; the CE group also reported significantly stronger STEM identity than the NCE group [$F(1, 138) = 39.02$, $p < 0.001$, $\eta^2 = 0.22$].

Overall, the results reveal that community engagement satisfied the students' needs for autonomy, competence, and relatedness and fostered stronger STEM interest and identity.

Table 3 Post-questionnaire ANCOVA results for the two groups

Post-questionnaire (pre-questionnaire as covariate)					
Variable	Group	Adjusted mean	*SE*	*F*	η^2
STEM interest	CE	3.94	0.08	52.95***	0.27
	NCE	3.07	0.08		
STEM identity	CE	3.96	0.08	39.02***	0.22
	NCE	3.21	0.08		

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Predict STEM Interest/Identity Development from Needs Satisfaction

Linear regression analyses revealed that the needs satisfaction significantly predict STEM interest and identity with F(1, 139) = 24.64, $p <$ with $R^2 = 0.51$ and STEM identity, F(1, 139) = 15.59, $p <$ with $R^2 = 0.54$, respectively. Accordingly, the needs satisfaction predicts the STEM interest and identity development.

How Does Community Engagement Satisfy the Needs?

The analyzed data indicated how engaging a community with STEM learning can support autonomy, competence, and relatedness satisfaction, see Table 1. Cohen's kappa coefficient of the two coders is 0.91, suggesting their agreements are very high. The results revealed two components in each of the needs satisfaction. Autonomy satisfaction components are inspiration from the community and learning outside classrooms; competence satisfaction components are feedback from users, and low failure rate; and relationship satisfaction components are affective learning and social good.

Autonomy Satisfaction

Inspiration from the Community All of the students expressed that their conversations with the community provided them unexpected information that inspired them to identify and clarify their problems. The students felt that they had more choices and, because the community broadened their views by giving more ideas or problems, they could take up topics that were not introduced in their classrooms. These are some of the excerpts from the interviews.

- "We got inspired from talking with the users." (AutoIn1)
- "This idea came from the user I spoke to when we got out in the neighborhood." (AutoIn2)
- "I felt I had more ideas to choose for our decisions after talking with the users." (AutoIn3)

Learning Outside the Classroom All of the students stated that they experienced greater freedom when learning outside the classroom. They found the process to be different and fresh and completed their projects in a new way. They were able to collect views and ideas from and exchange ideas with new people (i.e., not teachers, parents, or classmates). These are some of the excerpts from the interviews.

- "It was new and different to learn in the neighborhood. I could ask any questions that I wanted to." (AutoLg1)
- "I could choose what I wanted to ask and do in the community." (AutoLg2)
- "I could choose the person I wanted to talk with in the community." (AutoLg3)

Competence Satisfaction

Feedback from Users All of the students expressed that the user feedback helped them clarify their problems in a better way and improve their proposed solutions. Moreover, they felt that compared with teacher feedback, user feedback was different, highly specific, and fit-to-purpose. The students could understand where and how to improve their ideas after receiving the specific feedback.

- “The feedback of the user was helpful, very constructive. Better than my teachers.” (CompFb1)
- “The comments on my ideas are very specific. I know where and how to modify our ideas.” (CompFb2)
- “I found the comments given to us encouraged us to think more to improve our solutions.” (CompFb3)

Low Failure Rate Approximately 70% of the students felt that they experienced failure in the design process. When they faced challenges and difficulties in the process, they would reach out to the community for answers. They felt that they could get their difficulties resolved by engaging with the users in the process.

- “I always can do better.” (CompFa1)
- “Asking the users questions solved our problems.” (CompFa2)
- “We learned more about the issues after talking with the users.” (CompFa3)

Relatedness Satisfaction

Affective Learning All of the students reported that learning in the community was fun, interesting, and inspiring. They loved that they could be authentic (e.g., talk with and collect data from the users) in the neighborhood and could apply what they learned in their classrooms to the process.

- “Learning with the community was fun and inspiring. I like it a lot. I want to have more learning opportunities like that.” (RelaAl1)
- “I could collect authentic data. It is different from receiving data in classrooms.” (RelaAl2)
- “We could take actions in the community, which gave us a lot of fun.” (RelaAl3)

Social Good All of the students found the learning meaningful. They created something that the users appreciated and used and felt that their work helped the users in the community. The students actually understood the purpose of learning the various disciplines of STEM.

- “We created something (an electronic tool) that can help people.” (RelaSg1)
- “I found learning STEM useful and meaningful.” (RelaSg2)
- “This idea would help people.” (RelaSg3)

Discussion

This study aimed to use SDT to explain how community-based learning fosters STEM interest and identity in integrated STEM education. It presents four empirical implications. First, compared with the students who focused on classroom learning, those who engaged in learning with the community reported higher needs satisfaction for autonomy, competence, and relatedness (H1). This suggests that compared with classroom learning, community-based learning supports the three innate needs of primary school students in a better manner and leads to greater autonomous motivation (see SDT; Ryan & Deci, 2017, 2020). The students who actively engaged themselves with the community experienced freedom and felt they had more choices (i.e., autonomy) in terms of their design-based projects. This could be because community-based learning is less bounded and restricted than classroom learning (Miller, 2012; Quigley et al., 2017). The community offered richer, more open learning opportunities to the students; the students could choose the place/people they wanted to interact with. Moreover, the students could assess specific feedback from their targeted users, which made them felt respected and more capable of completing their projects (i.e., competence; Quigley et al., 2017; Rogers, 2017). The community offered an iterative and interactive feedback learning environment to the students; the students felt that they could have any of their questions answered. Furthermore, the students felt that their work contributed to the community and that they designed STEM solutions for social good. This helps students become strong citizens in the community (Mor Barak, 2020), making themselves and their community stronger and more resilient. Moreover, the community provided the students with a learning context they were familiar with and cared for. Overall, in most studies assessing student needs satisfaction, school teachers are the primary and major needs supporters (Ahmadi et al., 2022; Chiu, 2021a, b; Maulana et al., 2016). This study investigated how teacher motivation behaviors effectively satisfy student needs in classrooms and, using a new perspective, suggested that the community is an alternative needs supporter in integrated STEM learning.

Second, in the design-based projects, the students who engaged in community-based learning perceived stronger STEM interest and identity than those who engaged in classroom learning (H2); moreover, they valued the integrated STEM learning process more and formed a stronger preference for STEM activities. All of these factors foster the development of STEM interest (Renninger & Hidi, 2011). The students felt recognized by others (e.g., users in the community and peers in the group) and realized the social construction of their identity. This helps develop a more positive STEM identity (Hill et al., 2010; Vincent-Ruz & Schunn, 2018). The stronger STEM interest and identity can be explained by the first empirical implication (i.e., needs satisfaction in SDT). The development of STEM interest and identity requires the internalization of activities and pursuits valued by others (Goos & Bennison, 2019; Kim et al., 2018; Renninger & Hidi, 2011). According to SDT, motivated students are more likely to successfully internalize their learning experiences during integrated STEM activities, and they perceive stronger needs satisfaction and hold a more positive STEM interest and identity.

The third empirical implication is that needs satisfaction for autonomy, competence, and relatedness strongly predict the changes of STEM interest and identity (H3). Therefore, STEM learning activities such as community engagement that satisfying the three needs are more likely to foster STEM interest and identity development. This can be explained by the results of the qualitative analyses, which revealed how community engagement satisfied the students' three needs. In terms of autonomy, learning outside the classroom provided the students a sense of freedom and inspired them to tackle challenges through new and authentic learning targets. In terms of competence, specific and iterative feedback from the community resulted in a low learning failure rate. Moreover, in terms of relatedness, the students followed their passions to choose what they wanted to contribute to the society. In other words, the students considered their own choices, interests, and thoughts when engaging with the community and felt a sense of ownership when learning (autonomy), explained and showed their work (ideas and solutions) to the users (competence), and interacted with the essential stakeholders (relatedness).

The last empirical implication is to contribute the existing literature by adding an additional eastern your children study/perspective. Community-based learning is less common in the eastern culture, comparing to the western culture. The plausible explanation is that eastern schools are more academic focus and organize fewer outside school activities in STEM. The findings of this study suggest that using neighborhood approach could work better foster STEM interest and identity. This stronger interest and identity have strong associations with academic performance and career pursuit in STEM (Honey et al., 2014; Stohlmann et al., 2012).

Conclusions

The findings have two theoretical contributions, and three practical suggestions for researchers, policy makers, and practitioners.

Theoretical Contributions

The abovementioned empirical implications contribute to integrated STEM learning by advocating the importance of needs satisfaction in long-term design-based learning (Chiu, 2022). Moreover, they highlight the roles of community engagement in needs support for integrated STEM learning among younger children (primary school students). The benefits of community engagement are well investigated and documented among older children (Barton et al., 2017; Karasik, 2020). Furthermore, most universities offer service-learning programs (i.e., community engagement programs) to undergraduate students, and some universities even classify these programs as mandatory or core. However, only little data are available on the benefits of community engagement for younger children (Trott, 2019). This study offers empirical evidence that STEM teachers should consider community engagement (e.g., design-based projects) when curating integrated STEM learning. Its findings may encourage STEM primary school curriculum experts to re-examine their theories and instructional models by incorporating the themes of community engagement.

The empirical implications also contribute to the SDT literature by presenting detailed evidence on the role of community engagement in the development of STEM interest and identity (Ryan & Deci, 2020). To the best of our knowledge, no SDT-based studies have used needs satisfaction to explain the development of STEM interest and identity. So far, SDT-based studies focused on how teacher motivation behaviors affect student engagement in classrooms (Ahmadi et al., 2022; Chiu, 2022; Reeve & Halusic, 2009). The present study used a different perspective, emphasizing that support from the community is also important, particularly in integrated STEM learning. Moreover, STEM interest and identity are personal values. This study's findings imply that personal values, including freedom, ownership, respect, fun, and citizenship, are associated with the community (Kennedy et al., 2013; Waite, 2011). Therefore, other personal values, such as interest and identity, are also influenced by needs support in learning environments. Future studies should consider needs satisfaction as a framework to assess the development of personal values in integrated STEM learning.

Practical Suggestions

This study offers policy makers, curriculum experts, and STEM teachers three practical suggestions to foster STEM interest and identity among students. STEM policy makers and curriculum experts should include community-based learning in the school curriculum and run territory-wide professional teacher development workshops. These workshops could introduce the benefits of community engagement in integrated STEM learning, particularly for younger children (i.e., primary school students). Moreover, they could provide the schools/teachers a list of recommended community partners (e.g., shopping malls, local community centers, museums, and suburban villages) and organize knowledge exchange activities to let schools/teachers talk with the partners.

Second, compared with the other integrated STEM learning outcomes (e.g., disciplinary knowledge and twenty-first century skills), student interest and identity are more abstract. STEM teachers may have limited pedagogical knowledge on the development of STEM interest and identity and are recommended to use community-based learning when the main learning objectives involve STEM interest and identity. They could use community engagement-related poster presentations as a capstone in design-based projects and develop school-based service-learning programs (like that in high school curriculum) for integrated STEM learning (Mooney & Edwards, 2001).

The final suggestion is that teachers should satisfy students' innate needs when STEM activities are organized outside of the classroom. Such environments are more open, and the learning in such conditions is restricted to or not controllable by the teachers. Teachers could take advantage of such environments that support the students' three innate needs and could encourage autonomy by setting a board theme that allows the students to freely choose the topic they want for their design-based projects. Moreover, teachers could promote competence by preparing sample questions for students to ask, running workshops to strengthen student communication skills, and creating self-assessment rubrics for community engagement. They could also promote relatedness by working with nursing homes, elderly healthy centers, and regional community centers.

Limitations and Future Directions

This study used SDT to explain how community support fosters STEM interest and identity in integrated STEM learning. Unlike most SDT-based studies focusing on teacher support, this study assessed how community engagement satisfies students' innate needs. This study had three limitations. First, STEM interest and identity are perceived as personal values, and it is very important for these values to last among primary school students. Additional studies using a longitudinal design are recommended to further investigate the longitudinal effects of community engagement on the STEM learning outcomes. Second, a gap between primary school student interest/identity and their actual choice of STEM activities is possible. Further research using objective measures, such as providing choices for extra-curricular activities, is needed to validate and expand the findings of the present study. Finally, this study did not document specific activities in the community engagement or examine the effectiveness of the activities. Future studies should adopt intervention- or design-based models to support pedagogy or good practices for community-based learning in integrated STEM education.

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Declarations

Ethical Approval This study got ethical clearance from the corresponding author's university.

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