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Promoting STEM learning perseverance through recognizing communal goals: understanding the impact of empathy and citizenship

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Abstract

Background Previous research has indicated that placing emphasis on communal goals within the field of science, technology, engineering, and mathematics (STEM) education can yield beneficial learning outcomes. However, there remains a relative dearth of investigation into the factors that contribute to the success of STEM education programs integrating communal goals. In the present study, we sought to explore the roles of two constructs that prioritize the interests of others, namely empathy and citizenship, in promoting STEM learning perseverance within the context of a STEM-based community service learning (CSL) program. Specifically, we proposed that empathy would be associated with STEM learning perseverance through its relationship with citizenship, within a sample of 275 secondary school students from Hong Kong who participated in the said program.

Results Using structural equation modeling (SEM), the results revealed that empathy is significantly and positively associated with STEM learning perseverance, both directly and indirectly, through citizenship. The results held even after controlling for the demographic variables of school membership, gender, and age.

Conclusions This research highlights the association between understanding the needs of the community (empathy) and students' desire for community involvement (citizenship), which subsequently influences their perseverance in STEM learning. This relationship is particularly pronounced in educational settings where communal goals are emphasized.

Keywords Empathy, Citizenship, STEM learning perseverance, Communal goals

Most science, technology, engineering, and mathematics (STEM) fields have a reputation for solitary pursuits but lack communal connections (Allen et al., 2021). This is especially true in the fields of mathematics and science, which are often viewed as hard disciplines and abstract in nature (Matthew & Pritchard, 2009). Nonetheless, they form the epistemic foundations for engineers to design technology which addresses complex real-world problems. Motivating teachers and students to teach and learn these subjects in an integrated manner is challenging (Chai, 2019; Nalipay et al., 2022). Appropriate motivators should be identified and integrated into STEM curricula to sustain students' learning efforts. Because of the idea that most STEM fields provide little opportunity to collaborate with and help others, many students hesitate

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to pursue STEM careers (Allen et al., 2015; Fuesting & Diekman, 2017; Fuesting et al., 2021).

STEM education and research are imperative to societal development (Li et al., 2022; Marín-Marín et al., 2021). They play a crucial role in economic and social progress. They are vital in developing socially responsible and environmentally sustainable solutions and in addressing a wide range of social issues, from improving social justice to alleviating health and economic disadvantages (Chiu et al., 2023; Freeman et al., 2019). Hence, beyond the mastery and ability to apply technical STEM knowledge, STEM learners must also be instilled with empathy, caring, and compassion (Canney & Bielefeldt, 2015; Gunckel & Tolbert, 2018; Hess et al., 2012; Huang et al., 2022). Integrating communal and social goals may provide a purpose for students to persevere in learning STEM (Allen et al., 2021; Kayan-Fadlelmula et al., 2022).

Past studies on communal goals in STEM mostly focused on students' interest in pursuing STEM careers and addressing underrepresentation in STEM fields and were conducted in higher education contexts (e.g., Allen et al., 2015, 2021; Fuesting et al., 2021). In addition, research shows that students' motivation to learn STEM starts to decline as early as when they reach secondary school (Gok, 2022). Hence, learning more about the factors that contribute to secondary students' STEM motivation could be helpful in designing programs to address this decline. Furthermore, it makes sense to promote students' motivation in STEM learning during secondary school, before they decide on which higher education specialization they wish to pursue. Moreover, most studies in this area involved samples from Western, educated, industrialized, rich, and democratic (WEIRD; Henrich et al., 2010) countries (e.g., Allen et al., 2021; Boucher et al., 2017). The current study focused on a relatively underrepresented sample from an Asian population.

To date, very few studies have been conducted on this topic among Asian samples (e.g., Brown et al., 2018). A comparison between U.S. and Asian (Chinese and Indian) students found country level variations in STEM interest, in favor of Asian students, which may be attributed to differences in how communal goal opportunities in STEM are perceived. Communal engagement was found to contribute to communal opportunity perceptions in STEM (Brown et al., 2018). These findings offer credence to the notion that communal experiences in STEM education matter to Asian students as well, and they serve as a useful springboard for further research into the communal constructs that influence students' motivation in learning STEM in non-WEIRD contexts. The current study intended to expand the literature by looking into the STEM learning perseverance of secondary students from Hong Kong in an integrated STEM and community service learning (CSL) context, where communal goals are emphasized. Moreover, we investigated two other-oriented constructs that are possibly associated with STEM learning perseverance in this context: empathy, or one's ability to view and understand things from others' perspective (Hasso Plattner Institute of Design, 2010) and citizenship, or one's sense of involvement in the community (Binkley et al., 2012).

Theoretical perspective: communal goals in STEM

There are two fundamental values that guide motivation: agentic and communal values. Agentic values focus on self-oriented goals that benefit the individual. It entails aiming for power and achievement as well as personal recognition and success. On the other hand, communal values focus on communal or other-oriented goals that benefit the collective. It involves building and sustaining relationships, collaboration, and giving back to one's community (Allen et al., 2015, 2021; Bakan, 1966; Pöhlmann, 2001).

While self-oriented and communal goals are not incompatible and can be complementary (e.g., Grant, 2008; Grant & Berry, 2011; King & McInerney, 2019; King et al., 2023; Nalipay et al., 2022; Nalipay et al., 2023b; Xie et al., 2023), STEM fields are often perceived as providing ample opportunities for the achievement of self-oriented goals, but are less likely to fulfill communal goals (Diekman & Steinberg, 2013; Diekman et al., 2015). For those who value social relationships and have strong prosocial beliefs, this may result in goal incongruity, which may dampen their motivation to pursue STEM careers (Boucher et al., 2017; Diekman et al., 2017). When learners see STEM fields as critical to building connections with others and serving communal purposes, they tend to view it more favorably, which may lead to higher persistence (Diekman et al., 2017; Henderson et al., 2022). It is suggested that to motivate learners to engage in STEM, apart from focusing on the scientific content and processes, its contributions to solving societal problems must also be emphasized (Belanger et al., 2017).

Past studies have demonstrated the benefits of promoting communal goals in STEM education (e.g., Diekman & Steinberg, 2013; Diekman et al., 2015). Emphasizing communal goals has helped address underrepresentation in the STEM fields and has been found to increase underrepresented learner interest, motivation, engagement, and persistence (e.g., Allen et al., 2015, 2021; Boucher et al., 2017; Henderson et al., 2022; Trott & Weinberg, 2020). For instance, first-generation students were more intrinsically interested in science when they believed that it was instrumental in the achievement of prosocial communal purpose goals (Allen et al., 2015). In an experiment, women became more persistent and intrinsically motivated to learn science when their communal perceptions of it were increased (Allen et al., 2021). In a longitudinal study of college women, higher perceptions of communal goal affordances led to higher persistence intentions (Henderson et al., 2022). Moreover, children from minority backgrounds became more engaged in science education with an emphasis on the link between science learning and solving real-world problems that would lead to social benefits (Trott & Weinberg, 2020). Similar findings were found in a review study in engineering and computing (Boucher et al., 2017), further reinforcing the idea that providing opportunities for learners to work with and help others is significant in the STEM fields. However, most of these studies were conducted in Western contexts and not so much is known about the role of communal goals in STEM education in Asian contexts.

Considering the importance of communal goals in STEM, we integrated STEM education with CSL and examined the factors that predict learning perseverance in this context. Despite the fact that the benefits of communal goals in STEM were demonstrated in past studies, the underlying mechanisms that contribute to learning perseverance in this context remain poorly understood (Allen et al., 2019). Hence, in this study, we examined the roles of two communal constructs, empathy and citizenship, in the promotion of STEM learning perseverance in a learning context that emphasizes communal goals. The findings of the study could provide information about specific factors that can be targeted when integrating communal goals in STEM education.

Communal goals in STEM via integration of community service learning

Service learning refers to rendering service activities as part of a course or class (Vogelgesang & Astin, 2000). CSL is a type of service learning activity wherein students engage in and reflect on an organized service activity that addresses the needs of the community, allowing them to gain a deeper understanding of the course content and a greater appreciation of the discipline and civic responsibility (Bringle & Hatcher, 1995). CSL, which emphasizes direct field-based experience over merely acquiring formal knowledge, has been linked to improved student competencies (Tijsma et al., 2020) and deemed as an effective pedagogy that can be utilized for advancing the common good (Zlotkowski & Duffy, 2010). A considerable amount of research provided evidence for CSL's associations with positive learning outcomes, such as improved science fascination, values, and STEM career affinity (Collins et al., 2020), higher levels of self-efficacy and more positive self-concept (Gerholz et al., 2018; Huang et al., 2021), and increased learning persistence (Reed et al., 2015). It has also been associated with better communication and problem-solving skills (Burton & Winter, 2021), as well as creative thinking, collaboration, perseverance, and STEM career interests (Huang et al., 2022). In other words, allowing students to interact directly with people in a needy community is a powerful source of motivation for them to persist in integrating knowledge to design solutions.

In the current study, we integrated CSL with STEM education, which allowed the students not only to gain mastery of technical STEM knowledge but also to work toward proposing a solution for real-life problems faced by people in the community (i.e., communal goal). A study by Belanger et al. (2017) found that among college students, including a service-learning project in the description of an engineering course increases the students' course interest and perceptions that the course fulfills communal goals. Their study provides support that engaging students in an actual experience of integrated STEM-based CSL program could be associated with greater STEM learning perseverance. As to this integrated STEM-based CSL program, it was an 8-week program in which the students were taught about community service and STEM knowledge. For the community service aspect, students interacted with community housing residents and social service staff in order to gain a contextualized understanding of the needs of the residents. For the STEM aspect, they were taught about topics such as coding, the Internet of Things, and smart home devices. The students then used their STEM knowledge to design solutions for the problems faced by community housing residents (for more details, see Huang et al., 2022). The integration of CSL in STEM education emphasizes how technical STEM knowledge can be utilized to achieve communal goals.

Finding solutions for community problems and advancing the common good can be quite challenging. Yet, studies provide support for students' increased learning perseverance when they believe that STEM is instrumental in achieving communal goals (e.g., Henderson et al., 2022; Reed et al., 2015). Hence, we are interested in factors that could contribute to students' learning perseverance in this context. Perseverance is the continued effective striving despite obstacles or failure (Dweck & Leggett, 1988). It is a crucial disposition for learners to have in the problem-solving process and a common attribute of students focused on learning and mastery, characterized by continuity, focus, and disregard of time (Wilburne & Dause, 2017). Understanding aspects that could influence students' perseverance in this learning context could be helpful in designing better ways of integrating communal goals in STEM education. Among the factors that could play significant roles in students' learning perseverance are communal constructs, such as empathy and citizenship. We proposed that empathy and citizenship would be associated with STEM learning perseverance.

Empathy and citizenship as communal constructs

We construed empathy and citizenship as other-oriented constructs that reflect communal goals. Empathy refers to one's efforts to understand other people's ways of and reasons for doing things; their physical and emotional needs; and their views of the world and how they make sense of it (Hasso Plattner Institute of Design, 2010). Citizenship involves having a sense of belonging, as well as participation and solidarity in solving problems that affect the community. Moreover, it entails social and moral responsibility and a sense of involvement in the community (Binkley et al., 2012; Landrum, 2002). There has been much discourse regarding how agentic versus communal constructs are conceptualized (e.g., Abele & Wojciszke, 2014; Frimer et al., 2011). Abele and Wojciszke (2014) proposed that the two can be differentiated in terms of their value or profitability for the self versus others. Utility value, or the extent to which a task assists in goal attainment (Wigfield, 1994), can be classified as agentic (self-oriented) or communal (other-oriented) (Brown et al., 2015). Frimer et al. (2011) posited that agency promotes the interest of the self, whereas communion promotes that of others; and agency entails increased psychological distance, while communion entails decreased psychological distance. Because both empathy and citizenship inherently put others' perspectives, welfare, and interests ahead of oneself and bring an individual closer to others (i.e., by viewing the world from other people's standpoint, and seeing oneself as a part of the community), they can therefore be considered communal constructs. Hence, it can be argued that individuals oriented toward communal goals, relative to agentic goals, would tend to demonstrate greater empathy and citizenship. Indeed, numerous studies have categorized empathy and terms related to citizenship (e.g., community, solidarity, responsibility, involvement) as reflective of communal traits, motives, and goals (Abele & Wojciszke, 2014; Benson-Greenwald et al., 2023; Frimer et al., 2011, 2015).

Empathy

To connect communal goals with STEM learning, developing students' empathy toward the community's needs is necessary. STEM fields have been deemed to be compatible with teaching empathy and other socioemotional skills, and this could increase learners' interest and appreciation for STEM and its applications (Garner et al., 2018; Nalipay et al., 2023a). When applying STEM knowledge in developing solutions and creating meaningful innovations, it is important to empathize with the people whose problems are being addressed. For example, engineers must consider the various perspectives of the people who might be affected by their designs when they address problems and propose potential solutions. Empathy in design thinking could help learners to be more cognizant and attentive to the human elements of the problems or tasks, which could facilitate problem solving (McCurdy et al., 2020). In engineering, empathy is regarded as a core skill that is teachable and learnable, a practice orientation, and a professional way of being (Walther et al., 2017).

The important role of empathy in STEM education has been shown in previous studies. For example, elementary and middle school girls who participated in an outreach event were told about engineering being a caring profession that is associated with empathy, communal goals, and responsibility. This helped them develop an engineering identity, which could encourage engineering aspirations and help close the gender gap in engineering (Denton et al., 2022). Seventh-grade students who were asked to propose their own real-world problem-based design thinking task incorporated various STEM content and practices in the process, and expressed significant characteristics of empathy (McCurdy et al., 2020). Another study presented engineering activities in science museums designed to enhance girls' engineering engagement via narratives and empathy in activities. The activities resulted in the girls exhibiting more engineering practices (Peppler et al., 2022). These studies provided support for empathy as an important other-oriented construct for STEM learning.

Citizenship

The development of citizenship is considered an important aspect of science education, given the increasing importance given to sustainability and socio-scientific issues (Vesterinen et al., 2016). For instance, while the role of scientists in solving environmental problems is recognized, the structural causes and the social, economic, and political aspects of the problem also need to be acknowledged. This indicates that citizenship and science education are intertwined, and suggests that students should be given the opportunity to view a career in STEM as a means to contribute to the society's betterment (Vesterinen et al., 2016).

Past studies have provided support for the integration of citizenship and STEM education. For example, a new pedagogy used the citizen science approach, which engages citizens in the research process to identify and find solutions to communal issues, supported by the Internet of Things. The students participated in the collection and analysis of data pertaining to communal environmental issues. This promoted students' citizenship and engagement in both the community and at school (Santos et al., 2023). In an interview with international gifted students and potential scientists, they were asked about what they would do to make the world a better place. The students discussed not only the role of science, but also talked about social, economic, and political factors. They revealed taking personal responsibility and participatory actions and preparing for the future, and viewed citizenship as a process that involves constant self-development (Vesterinen et al., 2016). Furthermore, it was found that when humanitarian case studies were incorporated into technical education courses, it could facilitate students to consider the community and promote student engagement, citizenship, and higher levels of learning (Berndt & Paterson, 2009).

The literature provides support for the importance of other-oriented constructs, such as empathy and citizenship, to STEM education. However, the specific process in which they contribute to student learning remains underexplored. We proposed that empathy would be associated with STEM learning perseverance via citizenship in a learning context where communal goals are emphasized (i.e., STEM-based CSL program).

The roles of empathy and citizenship in STEM learning perseverance

Drawing from the perspective of communal goals in STEM, we examined the relationships of empathy and citizenship to STEM learning perseverance. Empathy and citizenship are 21st-century skills that have been deemed crucial for long-term personal and professional success (Ee et al., 2014; Jong et al., 2021) and could play an important role in improving learners' interest and capacity for STEM learning (Garner et al., 2018; Lee et al., 2012). In recognition of STEM education as an important means of developing solutions for community problems and improving the lives of the people in the community, it is possible that when learners exhibit other-oriented values, such as empathy and citizenship, they will be motivated to persevere in learning STEM. An enhanced sense of responsibility toward others demands one's commitment and endurance to see things through (Wong & Wong, 2013). Hence, in this study, we proposed that empathy would be associated with STEM learning perseverance through citizenship.

Empathy has been considered an important construct in understanding citizenship (Taylor et al., 2010), and empathic individuals are more likely to engage in citizenship behaviors (Joireman et al., 2006). Numerous studies have demonstrated empathy as a predictor of citizenship in various contexts. For example, among those working in the hospitality industry, perspective taking, a cognitive form of empathy, predicted citizenship behaviors through empathic concern. This supports the idea that empathy plays a role in motivating helping behaviors (Ho & Gupta, 2012). Among nurses, empathy was found to be an important resource in promoting positive work experiences and organizational citizenship behaviors (Pohl et al., 2015). There are also laboratory experiments that demonstrate the effect of empathy on citizenship (Batson et al., 1997; Dovidio et al., 1990; Eisenberg & Miller, 1987).

The stimulus-organism-response theory (S-O-R) posits that stimuli in the environment (S) affects an individual's internal state (O; cognitive and emotional states, such as perceptions and psychological experiences), which subsequently leads a person to form an attitude or behavior (R; expressions of attitude or behavior) (Jiang et al., 2010; Mehrabian & Russell, 1974). Using this theory, Yin and colleagues (2021) examined and found support for corporate social responsibility (CSR) as a stimulus, predicting empathy as an internal state, which in turn, predicted citizenship behavior as a response. Although the context of the present study is different, CSR and CSL are comparable as they share the same goal of improving community well-being through individuals' involvement and engagement with the community (Chang et al., 2014). Given that, it is also possible that in the context of a STEM-based CSL program, empathy would predict citizenship. Although the relationship between empathy and citizenship has been established in other contexts (e.g., in the service industry; Ho & Gupta, 2012), most studies in STEM education investigate these two constructs separately.

The literature on empathy and citizenship supports the notion that when individuals gain a better understanding of the needs of the people in their community (i.e., empathy), they are likely to experience greater social responsibility, involvement, and desire to help the community (i.e., citizenship). In the STEM education context, empathy and citizenship have been associated with positive outcomes, such as STEM learning interest and engagement (e.g., Denton et al., 2022; Garner et al., 2018; Peppler et al., 2022; Santos et al., 2023). It can be inferred that learners who empathize with the people in the community and those who are more inclined to get involved and help the community would be more motivated to learn STEM (e.g., Denton et al., 2022; Santos et al., 2023). Hence, they would be more likely to persevere in learning STEM, especially if it supports communal goals. We, therefore, hypothesized that empathy would be associated with citizenship, which in turn, would be related to the students' STEM learning perseverance.

The present study

The present study aimed to examine a model of empathy associated with STEM learning perseverance via citizenship among secondary school students who participated in an integrated STEM-based CSL program in Hong Kong. In the said program, communal goals were emphasized, as students were not only taught about technical STEM knowledge but were also provided with an opportunity to engage with community housing residents to learn about their situation and problems and design a product that would help solve those problems (see Huang et al., 2022). The study aims to provide a better understanding of the underlying process involved in the promotion of students' perseverance in such learning context and could contribute valuable information toward the success of such programs.

Method

Participants and procedures

The participants of the study were 275 secondary students (the recommended sample size for the model with a medium effect size of 0.15, $\alpha = 0.05$, and power = 0.80 is $n = 98$, based on G*Power; Faul et al., 2009) from three schools in Hong Kong. In the educational context of Hong Kong, the banding system is a school classification system based on students' academic performance. The schools are categorized into three groups: Band 1, representing the top, Band 2, the middle, and Band 3, the bottom in terms of academic performance. In this study, School 1 is a Band 1 school, where students are generally of higher academic performance relative to other schools in Hong Kong. School 2 is a Band 2 school, where students are of average level academic performance. School 3 is a Band 3 school, where students are of lower level academic performance. However, School 3 is a pioneering school in STEM education, and the school emphasizes the integration of empathy with STEM learning. It is one of the early adopters and promoters of STEM education, and stresses the importance of STEM to unleash students' full potential. In their practice, they also advocate instilling values and empathy through STEM education. In the learning process of the program, students from the three schools used the same learning materials, including teaching slides, worksheets, and videos for self-directed learning. The learning videos on STEM topics, especially the hands-on sessions, were especially prepared to meet the needs of diverse learners. Suppose students encounter any difficulties with the hands-on part, they can watch the videos to learn from them. To control for school effects, we added school membership as covariate.

The sample consisted of 52% boys and 48% girls, most within ages 12 to 13 years old (76%). Before participating in the project, the students already had some fundamental knowledge about coding with Scratch. However, the content the students learned from the project was new to them. The study made use of the posttest data from an eight-week crossover program of STEM and community service education. (Note: the variables were measured before and after the program. Pretest–posttest comparison using t-test for paired samples ($n = 272$) showed that the participants' empathy, citizenship, and perseverance significantly increased in the posttest ($t = 6.645$, 5.835, and 5.665 ($df = 271$), $p < 0.001$, respectively.) Posttest data were used in the analysis to take into account the context of the program. The students spent six weeks learning STEM and community service knowledge and two weeks finalizing their design of a product prototype that would help the community (Huang et al., 2022). The procedures of the study have been reviewed and approved by a research ethics committee, and informed consent was sought prior to the implementation of the project.

Measures

Empathy was measured using a scale adapted from Vossen et al. (2015). The scale has 4 items (e.g., "I talk to people in the community who need help so I can better understand their needs."). Citizenship was assessed using a self-constructed scale with items based on Fullan and Langworthy's (2014) definition of citizenship, "global knowledge, the sensitivity to respect for other cultures, active involvement in addressing issues of human and environmental sustainability (p. 22)," and Nguyen et al.'s (2021) study, where they measured students' global citizenship from three dimensions: awareness, skills, and attitudes. We adapted these conceptualizations of citizenship to fit the context of the program. The scale has 3 items (e.g., "In the STEM lessons, I hope to use STEM knowledge to improve the lives of people in my community."). STEM learning perseverance was measured using a scale adapted from Datu et al.'s (2017) measure of perseverance of effort. The scale has 4 items (e.g., "In the STEM lessons, I always try my best to complete every task I am assigned."). All three scales were rated from 1 (strongly disagree) to 6 (strongly agree). The Chinese language version of the scales was administered to the students. The empathy, citizenship, and perseverance scales' internal consistency coefficients were Cronbach's $\alpha = 0.903$, 0.904, and 0.929, respectively. Covariates were measured using information on the participants' school, gender, and age. Dummy coding was used for the nominal data (UCLA, n.d.). Since the participants came from three schools, dummy codes 0 (no) and 1 (yes) were used for School 1 and School 2, to indicate whether they attend the school or not (responses of 0 in both School 1 and School 2 indicate that they attend School 3). Gender was coded 1 (boy) and 2 (girl). Age was categorized into 12–13 years (1), 14–15 years (2), and 16–17 years (3).

Data analysis

Structural equation modeling (SEM) with MLR (maximum likelihood parameter estimates with standard errors and a chi-square test statistic) estimator was conducted. Mplus version 8.3 (Muthén & Muthén, 2019) was used for the analysis. We followed the two-step approach in SEM suggested by Anderson and Gerbing (1988). First, we conducted a confirmatory factor analysis (CFA) to assess the validity of the measurement model. Then, we added the structural relations among the variables and analyzed the full SEM. Empathy was entered as the independent variable, citizenship as the mediator, and STEM learning perseverance as the outcome. We first tested a model without the covariates (Model 1), then another model where we included school membership, gender, and age as covariates to see if the results would hold after controlling for these variables (Model 2). We used the following fit indices and cutoff values to evaluate the models: chi-square (χ^2); root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR) (≤ 0.05 indicates a good fit, while ≤ 0.08 is acceptable); and comparative fit index (CFI) and Tucker-Lewis index (TLI) (≥ 0.95 indicates a good fit, while ≥ 0.90 is acceptable) (Hu & Bentler, 1995).

Table 1 Means, standard deviations, and correlations of the study variables

	M	*SD*	1	2
1. Perseverance	4.64	0.98	–	
2. Citizenship	4.44	1.05	0.810***	–
3. Empathy	4.64	0.89	0.761***	0.739***

*** $p < 0.001$

Results

Table 1 shows the means, standard deviations, and bivariate correlations of the study variables. STEM learning perseverance was positively related with both empathy and citizenship, and citizenship was positively associated with empathy. Results of the CFA showed that the model has good fit to the data ($\chi^2 = 83.176$, $df = 41$, $p < 0.001$; RMSEA = 0.061 (90% C.I. = 0.042, 0.080); SRMR = 0.032; CFI = 0.972; and TLI = 0.963), providing support for its measurement validity. All the items loaded significantly in their respective factors, and all the factors positively correlated with each other. Table 2 shows the factor loadings and factor correlations for the measurement model.

Results of SEM for Model 1 (without the covariates) showed that the proposed model of empathy positively

Table 2 Standardized factor loadings and factor correlations for the measurement model

Factor loadings		**Estimate**	**S.E**	**p-value**
Empathy				
1. When people talk to me about their views on community service, I listen carefully		0.837***	0.027	< 0.001
2. I try to understand how people feel about community service		0.846***	0.029	< 0.001
3. When people have a need for community services, I want to know the reasons behind it		0.841***	0.027	< 0.001
4. I talk to people in the community who need help so I can better understand their needs		0.821***	0.028	< 0.001
Citizenship *In the STEM lessons…*				
1. I think it makes sense to combine STEM and community service		0.864***	0.031	< 0.001
2. I hope to use STEM knowledge to improve the lives of people in my community		0.897***	0.019	< 0.001
3. I hope to participate in more hands-on activities that use STEM knowledge to solve real-life problems		0.854***	0.024	< 0.001
Perseverance in learning STEM *In the STEM lessons…*				
1. I always try to solve the problems I encounter		0.810***	0.025	< 0.001
2. I always try my best to complete all the tasks assigned by the teachers		0.897***	0.018	< 0.001
3. I always try my best to complete all the tasks assigned in my group		0.886***	0.022	< 0.001
4. I always try my best to complete every task I am assigned		0.919***	0.015	< 0.001
Factor correlations	1	2		
1. Empathy	–			
2. Citizenship	0.818***	–		
3. Perseverance	0.826***	0.868***		

*** $p < 0.001$. The survey questions were originally in Chinese associated with STEM learning perseverance via citizenship has good fit to the data ($\chi^2 = 83.176$, $df = 41$, $p < 0.001$; RMSEA = 0.061 (90% C.I. = 0.042, 0.080); SRMR = 0.032; CFI = 0.972; and TLI = 0.963). Empathy was significantly and positively associated with STEM learning perseverance, both directly and indirectly, through citizenship (see Fig. 1). Likewise, the results of SEM for Model 2 (with covariates) demonstrated good fit to the data ($\chi^2 = 152.648$, $df = 77$, $p < 0.001$; RMSEA = 0.060 (90% C.I. = 0.046, 0.074); SRMR = 0.052; CFI = 0.961; and TLI = 0.950). The relationships among empathy, citizenship, and STEM learning perseverance held even after controlling for the covariates (see Fig. 2).

We also tested alternative models to examine the robustness of the proposed model. Because many studies in the past have demonstrated gender gaps in STEM careers in favor of men (e.g., Cimpian et al., 2020), we examined a moderated-mediation model (Model 3), where we added gender as a moderator. Results showed that Model 3 had poor fit ($\chi^2 = 10.934$ ($df = 2$, p = 0.004), RMSEA = 0.127 (90% CI = 0.061, − 0.206), CFI = 0.983, TLI = 0.939, SRMR = 0.031). Because the study used

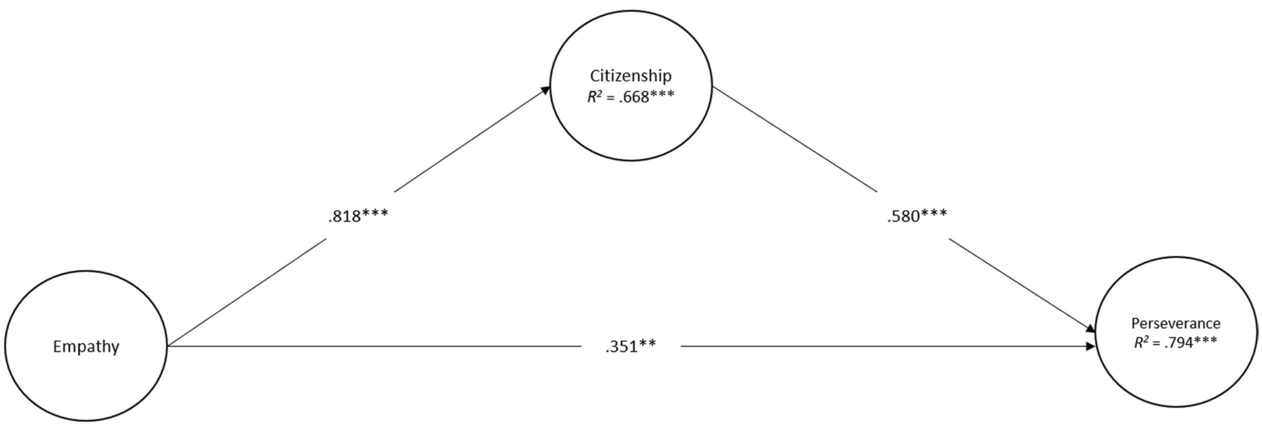

Fig. 1 Results of SEM for Model 1 (without covariates). All coefficients are standardized. **p < 0.01, ***p < 0.001. Indirect effect of empathy on perseverance: β = 0.474, p < 0.001

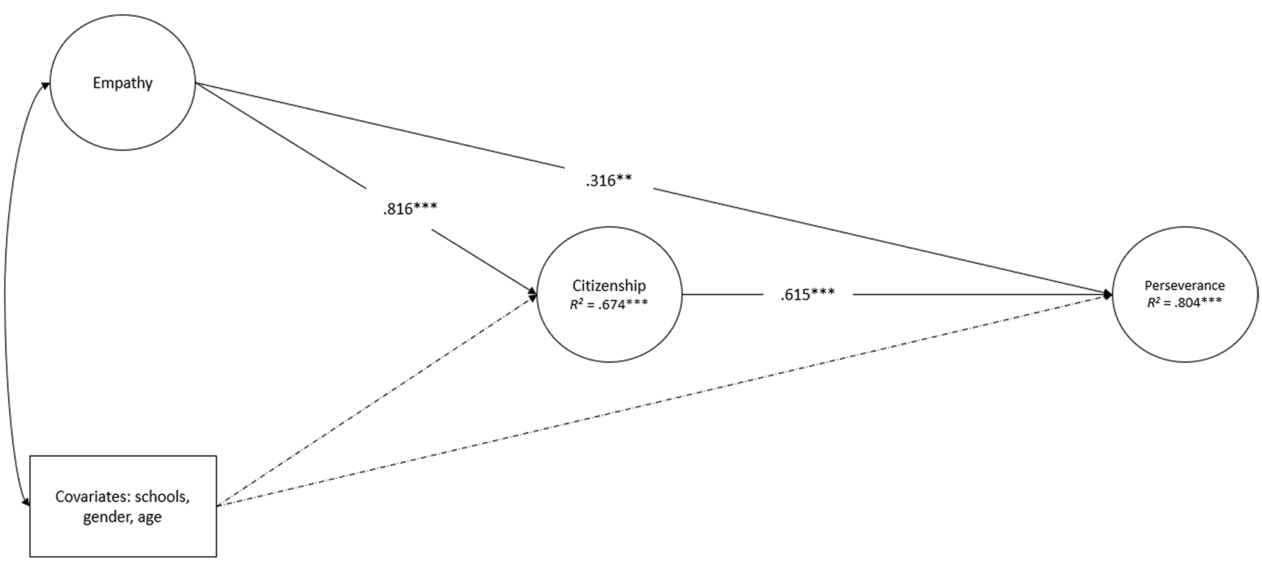

Fig. 2 Results of SEM for Model 2 (with covariates). For the purpose of clarity, only the main variables are shown. All coefficients are standardized. **$p < 0.01$, ***$p < 0.001$. Indirect effect of empathy on perseverance: β = 0.502, $p < 0.001$. Direct effects of covariates on citizenship: School 1 (β = 0.043, $p = 0.416$), School 2 (β = 0.011, $p = 0.848$), gender (β = − 0.084, $p = 0.053$), and age (β = − 0.023, $p = 0.630$). Direct effects of covariates on STEM learning perseverance: School 1 (β = 0.019, $p = 0.696$), School 2 (β = 0.114, $p = 0.022$), gender (β = 0.060, $p = 0.079$), and age (β = 0.092, $p = 0.008$)

cross-sectional data, we tested another model where citizenship is the independent variable and empathy is the mediator (Model 4). Results revealed that Model 4 also had acceptable fit ($\chi^2 = 148.863$ ($df = 77$, $p < 0.001$), RMSEA = 0.058 (90% CI = 0.044, 0.072), CFI = 0.963, TLI = 0.952, SRMR = 0.050). Citizenship predicted perseverance directly ($\beta = 0.608$, $p < 0.001$) and indirectly via empathy ($\beta = 0.255$, $p = 0.002$).

Discussion

The study examined whether empathy is associated with STEM learning perseverance through citizenship in a sample of secondary students who participated in an integrated STEM-based CSL program in Hong Kong, where they used their STEM knowledge to design products that would help solve problems encountered by the people in the community. The study drew from the perspective of communal goals in STEM fields, focusing on constructs that focus on the benefit of the collective. Findings revealed that empathy is related to STEM learning perseverance directly, and indirectly via citizenship. The findings held even after controlling for covariates such as school membership, gender, and age. Students who have better understanding of the views, feelings, and needs of the people in the community were more likely to be willing to do their best in accomplishing their tasks and overcoming the problems they encounter in learning STEM. The results also suggest that a possible reason for such relationship was the students' belief that learning STEM would equip them with knowledge and skills to improve the lives and solve the problems of the people in the community.

STEM fields are mostly known for providing opportunities for the fulfillment of agentic goals. However, highlighting that it can also be instrumental in the achievement of communal goals could be a way to motivate students to learn STEM (Boucher et al., 2017; Diekman et al., 2017). Indeed, Brown et al. (2018) contended that the disparities in STEM interest between U.S. and Asian students can be attributed to Asian students perceiving more communal prospects in STEM, which can be developed through increased communal engagement in STEM. This study expanded these findings identifying empathy and citizenship as communal constructs that can be targeted in STEM programs that promote communal engagement.

The finding that empathy predicted STEM learning perseverance is consistent with prior research linking empathy to increased STEM motivation (e.g., Denton et al., 2022; McCurdy et al., 2020; Peppler et al., 2022). Empathizing with others allows STEM students to have a better understanding of people's thoughts and feelings, problems and needs, and the values that people hold. It gives students a glimpse of other people's lives and experiences (Hasso Plattner Institute of Design, 2010). It may help to alert students to pay attention to the nuanced needs of the people involved, and hence, make them more mentally prepared to exert the effort needed to address complex real-world problems. This could enable them to approach STEM in a more humanistic manner, making it more meaningful to them in terms of enhancing not only their own but also other people's lives (McCurdy et al., 2020). The realization that STEM can serve communal purposes could make students view it more positively (Diekman et al., 2017), and hence, could encourage them to persevere in learning STEM. The results also provided evidence for citizenship as a link between empathy and STEM learning perseverance. The better the students understand the problems and needs of the people in the community, the more inclined they are to get involved and help people. Viewing STEM as instrumental in helping others could motivate students to persevere in learning STEM. This is consistent with past studies that support the inclusion of citizenship in STEM education (e.g., Santos et al., 2023; Vesterinen et al., 2016).

To examine the robustness of the proposed model, we tested alternative models. There has been persistent gender gaps in STEM careers in favor of men (Cimpian et al., 2020). Yet, associating STEM professions with communal goals and empathy has been found to help close such gender gaps (Denton et al., 2022; Peppler et al., 2022). We found that Model 3 (moderated-mediation model, with gender as moderator) had poor fit, suggesting that in the context of the current study, gender difference is not a relevant factor in STEM learning perseverance. To account for the cross-sectional and correlational nature of the study, we tested Model 4 (with citizenship as independent variable and empathy as mediator) and found that such model also had acceptable fit. Citizenship predicted perseverance directly and indirectly via empathy. Hence, despite the literature (e.g., Ho & Gupta, 2012; Pohl et al., 2015) and theory (S-O-R; Yin et al., 2021) suggesting the precedence of empathy over citizenship, a bidirectional relationship between the two is also possible. Given the limitations of the current methodology in inferring causal relations (Rohrer et al., 2022), we suggest that future studies further explore Model 1 and Model 4 using experimental and longitudinal methods to clarify the causal relationships among the study variables. Indeed, Rohrer (2018) suggested that causal inference be explored in a much slower, deliberate, and collaborative manner, as the conditions under which standard mediation procedures can succeed are very limited (Rohrer et al., 2022). Nevertheless, the study provided support for viable models that can further be tested in future studies using more rigorous methods for a pedagogical activity that involves providing students opportunities to interact with real people to understand their real needs. It is suggested that teachers invest time in structuring such activities, which can address the problems of lacking authentic learning in schools.

There are some limitations of the study. The study used cross-sectional, observational data and examined correlational relationships which does not necessarily imply causation (Rohrer, 2018). Hence, caution must be taken in interpreting causal inferences. Nevertheless, the study was able to provide support for viable models of empathy and citizenship predicting STEM perseverance that future studies can further examine using methods that allow causal interpretations. Moreover, the use of self-report data could increase its proneness to biases, such as social desirability bias. It is also possible that the use of a survey may not capture some nuances in the constructs. Future studies are suggested to supplement the survey data with other forms of assessments, e.g., interviews, behavioral observations.

Conclusions

The study sheds light on the importance of considering communal constructs in the domain of STEM education. It also extends prior literature which has mostly focused on WEIRD samples by studying a relatively underrepresented sample of secondary students from Hong Kong. In particular, we found empathy for the people in the community and greater citizenship linked to STEM learning perseverance. This reinforces the importance of cultivating these values as a viable pathway toward facilitating STEM learning. It also provided evidence for empathy and citizenship as constructs that can be targeted in programs that intend to emphasize communal goals in STEM learning. Although past studies have established that highlighting communal goals in STEM fields could promote STEM career interests (Allen et al., 2015, 2021; Fuesting et al., 2021), this study extended this by examining factors that influence students' perseverance in such learning contexts. It also provided a better understanding of the underlying mechanisms that contribute to the success of programs integrating CSL and STEM education and highlighted the importance of communal goals in STEM fields.

Author contributions

MJN—conceptualization, formal analysis, writing—original draft; BH—conceptualization, methodology, writing—review and editing, project administration; MSYJ—conceptualization, methodology, writing—review and editing, project administration, supervision, funding acquisition; CSC—conceptualization, writing—review and editing, supervision; RBK—conceptualization, writing—review and editing, supervision.

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Data availability

The datasets used and/or analyzed during the current study are available from the authors on reasonable request.

Declarations

Competing interests

The authors declare that they have no competing interests.

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