STEM Education Review

ORIGINAL ARTICLE

STEM-based principles and strategies to cultivate students' social and emotional learning

Qing Su[1], Shaoqing Guo[1,2*]

[1]School of Educational Technology, Northwest Normal University, Lanzhou 730000, Gansu Province, China
[2]Institute for Intelligent Education, Northwest Normal University, Lanzhou 730000, Gansu Province, China

ABSTRACT

Cultivating and developing the social-emotional abilities of students is a realistic educational requirement. Such cultivation includes the development of skills related to self-awareness, self-management, social awareness, and relationships, as well as the ability to engage in responsive decision-making, with these skills, students will be equipped with the necessary character and key abilities to adapt to future society. To better understand how Science, Technology, Engineering, and Mathematics (STEM) education can contribute to social and emotional learning (SEL), this study designs a STEM course named "The Yellow Riverbank Is Beautiful—Bridge and Lanzhou". By designing and delivering the pedagogical approach of this STEM project as well as assessing the students, the study proposes the principles of STEM education to develop students' SEL. These principles include: creating contexts focusing on real-world, developing social emotions through disciplinary practices, establishing interpersonal relationships of equality and mutual support. Also proposed teaching strategies, including: creating social contexts, planning activity sequences, evaluating students' behavior.

Key words: social and emotional learning, STEM education, design principle

INTRODUCTION

Education is one of the largest application areas for the construct of social and emotional learning (SEL). In recent years, the reform of basic education has gradually shifted from only focusing on students' knowledge learning to cultivating students' ability for adapting future life. Two decades ago, the Collaborative for Academic, Social, and Emotional Learning (CASEL) defined SEL. SEL is the process by which children, adolescents, and adults acquire and apply the necessary knowledge and skills to understand and manage emotions, set goals, show empathy for others, establish positive relationships, and make responsible decisions.[1] The emphasis on SEL is rapidly growing at all levels of the education delivery system and in professional and continuing education programs.[2]

The *Compulsory Education Curriculum Program* was officially released in April 2022. To fulfil students' social development, the plan emphasized the need to cultivate students' patriotic feelings, social responsibility, innovative spirit, and practical abilities to develop citizens who possess a well-rounded education that includes moral, intellectual, physical, aesthetic, and labor development.[3] Such cultivation requires training to enhance social cognition, social emotions, and social responsibility.[4]

In China, it is important to promote education reform to move beyond prior methods of teaching that are out of touch with society and life, for students to successfully navigate life and society and develop concern for society.[5] Research has demonstrated that SEL is critical to students' development, adjustment,

***Corresponding Author:**
Shaoqing Guo, School of Educational Technology, Northwest Normal University, No.967, East Road, Anning District, Lanzhou 730000, Gansu Province, China. Email: guosq1995@163.com; https://orcid.org/0009-0009-1298-7117
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and success.[2] Science, Technology, Engineering, and Mathematics (STEM) education which is driven by real tasks or problems helps students apply knowledge and solve problems through practice and exploration, and cultivates students' advanced thinking abilities through innovation, collaboration, and communication. However, researchers have found that students in STEM often feel alienated, which can negatively impact learning outcomes.[6] The paper focus on the outcomes of applying SEL in STEM course in high school. The goal of this paper is to provide suggestions and inspiration for the practice of SEL and STEM education.

LITERATURE REVIEW

In the early 20th century, American psychologists Terman and Sears observed and collected data on thousands of children for 50 years. Through this half-century long study, Terman and Sears determined that the most obvious difference between high and low achievers was not their intelligence but rather their quality of volition. In addition, their research demonstrated that one's ability to handle social and interpersonal relationships as well as one's general social-emotional abilities have a significant impact on an individual's success and happiness.[7] According to Elias *et al.*, social-emotional ability is defined as an individual's ability to achieve social goals during internal development and interactions with others.[8] It is a core ability that children and adults master and apply to their growth and is related to the individual's adaptation to social development.[9] A series of evidence-based studies on SEL have shown that improving students' social-emotional abilities can reduce risk factors in adolescent development,[10] improve academic performance,[11] enhance students' sense of belonging at school,[12] decreases problem behavior,[13] and promotes their potential for future career success.[14]

As a willful ability to cope with social development, adapt to social life, and apply emotions in different situations, social-emotional ability can be acquired through learning, connecting, and applying in specific situations, just like intellectual development.[15] According to CASEL, SEL is necessary for everyone's daily life, which includes five core competencies (Table 1): self-awareness, self-management, social awareness, interpersonal relationships, and responsible decision-making.[16]

Besides the SEL framework proposed by CASEL, other international organizations and countries are also actively exploring this framework. Based on CASEL, the Australian Council for Educational Research (ACER) developed a definition of Social and Emotional Well-Being (SEWB), which is divided into seven dimensions: general SEWB, resiliency, active social orientation, job orientation, school indicator, family indicator, and community indicator.[17] The Social and Emotional Aspects of Learning (SEAL) project implemented by the Department for Education and Skills (DFES) in 2005 aims to develop the supportive qualities and skills necessary for students to manage their studies and lives in universities. The SEAL classifies SEL into self-awareness, management of emotions, motivation, empathy, and social skills, and the implementation has resulted in significant improvements and gains in student behavior and academic performance.[18] In 2015, *Education 2030 Framework for Action* by United Nations Educational, Scientific and Cultural Organization (UNESCO) clarified that education should not ignore the development of cognitive skills and should pay more attention to students' social-emotional skills. In addition, this framework incorporated SEL into the global education policy agenda.

With a consensus on SEL among countries and organizations around the worldwide, many high-quality SEL cultivation programs have been launched in response to local experiences and culture features. The RULER SEL practice includes recognizing emotions in self and others, understanding the causes and consequences of emotion, labeling emotions accurately, expressing emotions appropriately, regulating emotions effectively, which promoted by the Yale Center for Emotional Intelligence (YCEI) built an achievement model based on ecosystem theory and established a complete set of implementation plans for completing the system.[19] Research has shown that the RULER program improved teachers' and students' SEL, developed an atmosphere of emotional support and good communication within the school and classroom, and enabled pupils to respect their peers, be disciplined, and improved their academic performance.[6] A similar SEL program funded by the UK government has been effective in advancing SEL in British schools. The schools have witnessed encouraging results and significant improvements in student behavior and academic achievement through three

Table 1: CASEL framework

Core competencies	Specific description
Self-awareness	The ability to understand one's emotions, thoughts, and values and how they affect behavior in different contexts
Self-management	The ability to effectively manage one's emotions, thoughts, and behaviors in different situations to achieve goals
Social awareness	The ability to understand and empathize with perspectives from different backgrounds and cultures
Relationships skills	The ability to establish and maintain healthy and supportive relationships with different individuals and groups, as well as the ability to communicate effectively
Responsible decision making	Ability to make constructive choices about personal behavior and social interaction in different contexts

CASEL: the Collaborative for Academic, Social, and Emotional Learning.

strategies: school-wide promotion, in-class instruction, and teachers' professional development.[20]

Despite differences in the conceptual framework and practice of SEL across countries, the findings confirm the role of SEL in school teaching and learning, pointing to its importance in improving teaching quality, personal achievement and student development in basic education. Practical research has shown that SEL can be taught, modeled, and developed through systematic curriculum design and teaching practices.[21] Adolescence is a key period for the development of social-emotional competencies, and the core literacy-based curriculum reform places more stress on adapting to lifelong learning and future talents in society, therefore, schools should pay more attention to the development of students' social-emotional competencies.

DESIGN AND METHODS

Course design

This paper develops a STEM course, named "The Yellow Riverbank Is Beautiful—Bridge and Lanzhou" for senior one students' using Lanzhou as the urban background. The STEM course was designed focusing on the five core competencies of CASEL framework. Learning goals and objectives were a central element of the syllabus and the course in order to enable each student to achieve the best knowledge outcome. Adapted from Conley,[2] Table 2 shows the SEL core competencies domain in the STEM project.

Pedagogical approach

Creating realistic project contexts

Lanzhou, the capital of the Gansu Province, is the only provincial capital city through which the Yellow River passes, forming a unique geographical environment with two mountains and one river. To promote economic development and facilitate citizens' lives, more than 30 bridges have been designed and constructed in the Lanzhou section of the Yellow River.

As a high school student living in Lanzhou, living and studying cannot be separated from the bridges on either side of the Yellow River. Therefore, this study takes "Bridge and My Life" as the background and proposes two situational questions to students in the creation context: (1) Living in Lanzhou, there are many bridges around us on both sides of the Yellow River. What impact have these bridges had on the students' own friends, family, and elders' work, studies, and life? (2) What has the construction of bridges brought to the economic and social development of Lanzhou?

Through these questions, the STEM course was situated within the real life of students, guiding students to pay attention to the relationship between the STEM course and their social-emotional feelings and, inspiring them to focus on real life and social issues.

Forming the project groups

According to complex system creativity theory, the diversity of teacher and student roles can improve students' interpersonal skills and promote creative problem-solving.[22] In this STEM course, students divided into groups. Each group was asked to sign a learning agreement. The contents of the learning agreement are as follows: "In this course, we are a learning community. In order to ensure that we are able to complete our project, we mutually agreed as follows: (1) All of us are equal members of the learning community. (2) We cooperate sincerely in completing the project. (3) When differences arise, let's listen and respect each other. (4) During the project activities, we actively share ideas with each other and work together to get the project completed excellently. (5) The teacher is our learning partner. We need to take initiative to ask for his advice when we are in trouble. (6) Each of us is required to perform his or her job diligently and help others actively".

Signing this learning agreement is aimed to provide students with the tools they need to establish and maintain healthy and rewarding relationships, and to act in accordance with social norms.

Designing problem chain

After situating the STEM course within a real-world life context for the students, the course asks students to design a bridge for Lanzhou, as a bridge designer, and produce

Table 2: SEL core competencies domain in the STEM course

Core competencies	Anchor standards
Self-awareness	Accurately assessing one's strengths and limitations, having positive mindsets, and possessing a well-grounded sense of self-efficacy and optimism
Self-management	Delay gratification, manage stress, control impulses, and persevere through challenges in order to achieve personal and educational goals
Social awareness	Understanding social norms for behavior and recognizing family, school, and community resources and supports
Relationships skills	Communicating clearly, listening actively, cooperating, resisting inappropriate social pressure, negotiating conflict constructively, and seeking help when it is needed
Responsible decision making	Consider ethical standards, safety concerns, accurate behavioral norms for risky behaviors, to make realistic evaluation of consequences of various actions, and to take the health and well-being of self and others into consideration

SEL: Social and emotional learning; STEM: Science, Technology, Engineering, and Mathematics.

models to participate in bidding and testing. Such a project integrates relevant disciplinary knowledge, conducts disciplinary practice, and promotes problem solving. To address project-driven questions, the STEM course designs a problem chain, as shown in Table 3.

As shown in Figure 1, students accomplish rich disciplinary activities in projects *via* problem chain. To complete the first problem in the problem chain, students need to learn more about the role of bridges in the development of Lanzhou through such activities as visiting museums and interviewing relatives. This is a major learning activity to develop their social awareness. The second problem of the problem chain allows students connect learning to their lives by explaining the categories of bridges and their features using bridges in Lanzhou as an example, which also develops their social awareness. In designing and building models of bridges as well as load-bearing tests, students work together in groups to complete projects. During this

Table 3: Disciplinary practice problem chain

Problem chain	Discipline practice	SEL
What is the relationship between bridges and the lives of Lanzhou citizens?	Visit the Lanzhou Bridge Museum to understand the history and development of the bridge construction in Lanzhou Interviewing relatives and elders nearby to learn about the changes brought by the construction of bridges to the city's development and citizens' lives	Social awareness
What are the common types of bridges? What is the relationship between the deformation, stress, and bearing capacity of each type of bridge?	Take the city of Lanzhou as an example to learn the structure of different bridge types Understand the effects of different bridge stresses on the load bearing and strength of different bridge types	Social awareness
Bridge design	Understand the general principles of design Design bridge models as groups Drawing the design as groups in three-view drawing	Self-awareness Self-management Relationships skills Responsible decision making
Make bridge model	Learning about the stabilization of structures and applying it to make bridge models Working in groups, making the bridge model using the given materials based on the design drawings	Relationships skills Responsible decision making
Does the bridge model meet the outcome requirements?	Present the bridge model to the classmates Load bearing test on bridge model	Responsible decision making

SEL: Social and emotional learning.

Figure 1. Discipline practice. (A) Report for the problem one. (B) Bridge design. (C) Make bridge model. (D) Display of bridge model. (E) Load-bearing test.

period, they are required to communicate, exchange ideas, understand others' perspectives, and make responsible decisions when faced with disagreements. These are aligned with several of the other SEL core competencies.

Evaluating students' performance

Student's overall performance was measured *via* three parts. First test focuses on the reports of the students' research for the problem one. This test not only includes the textual, data, academic and scientific standardization of the reports, but more significantly, the students' understanding of the relationship between bridges and life in Lanzhou, *i.e.*, their social awareness, as shown in their reports. The second test was based on the activity of students working in groups to design and build bridge models. This test focuses on the specification of the bridge design drawn by the students, the responsible decisions made in the design of the bridge and the specification that the bridge model is made to satisfy the structure's stability. The third test is based on the post-course reflections written by students as the basis for assessment. By analyzing the students' post-course reflection texts, it is possible to find out not only about what the students learned during the project, but also, and more importantly, about how the students performed in SEL such as their evaluation of themselves and their team during the project.

Data collection and analysis

The research aimed to assess the quality of class activities integrating SEL strategies. The hypothesis question was as follows: The course design and pedagogical approaches mentioned above can not only promote students' SEL, but also enhance students' motivation and interest in STEM courses. The research mainly used textual analysis to analyse students' reports and academic portfolios in STEM courses to access the changes in their performance on SEL.

RESULTS AND DISCUSSION

Instructional strategies that include brain-friendly strategies such as SEL, make the classroom a supportive and welcoming place where all students experience the joy of learning and contribute to enhancing students' performance. Moreover, SEL helps to reduce teacher stress and create more positive engagement with students.[23] By using SEL, students were encouraged to effective learners developing self-awareness, social-awareness, relationship skills.

The pedagogical approach described in this paper can contribute to making teaching and learning processes more fruitful and rewarding. SEL led to improved student behavioral skills. Peer support mediates between relationship skills and academic achievements. At the end of the STEM course, students discovered that the knowledge acquired and the project's success were thanks to the collaboration with their peers and teachers. Student A:"Through this project, we have learned the meaning of teamwork." Student B:"This project covered lots of physics and geography knowledge, which are all poor for me. By learning and discussing with my peers in the group and communicating with the teacher, I seemed to find that these subjects were not so difficult to learn." Student C:"Members of our group are weak in their hands-on skills. Through asking other groups for advice or questioning the teacher, we learned lots of tips that helped us to be able to complete the model of the project."

Besides this, the real problems and activities from the surroundings (*e.g.*, visiting museums, interviewing relatives, *etc.*) allow the students to feel that the learning of the project is related to themselves and to the city in which they live. This, in turn, leads students to gradually pay attention to the life and social phenomena around them. Student D:"Through the project, I learned that there are so many bridges in Lanzhou for the first time, and that the location of each bridge is so important to our lives." Student E:"After learning this project, I began to care about the construction of the city streets on my way home and started to think about how these constructions would affect my life."

Student F:"The bridges have been integrated into the blood of the city, and are essential to Lanzhou's social development and people's lives, carving out a character that is specific to the people of Lanzhou." Student G:"Through our studies, we gradually realized the importance of bridges to the Lanzhou people. If I could become a real bridge designer in the future, I would like to design and make bridges for the city I live in to facilitate the lives of the citizens."

In observing the two activities in which students completed the bridge model design and making, the study found that because of the research in problem one, students' designs were no longer arbitrary, but they were able to design from the viewpoint of urban development and citizens' lives. At the same time, during the design and making process, the study found that students were able to make logical and responsible decisions in response to controversies by searching for information or asking the teacher.

Finally, from the feedback of the students, the study found that the vast majority of students enjoyed the design of the STEM course. The prevailing attitudes are summarized in the following extracts. Student H:"This was a very fun class, I learned a lot." Student I:"The hands on experience was extremely valuable for understanding complex concepts and information related to physics, geography." Student J:"Failures are also a learning experience. We experienced many failures in the design and construction of the bridge model, and

though we were unhappy, in the end we found that we learned more by reflecting on our failures."

Design principles for social and emotional learning in STEM education

SEL improves student development by using subject knowledge learning as a medium to boost students' social cognitive levels and social understanding. By connecting knowledge learning and social practice, students can generate enriching emotional reflections about society, thereby guiding students to care about and participate in society, establish appropriate social concepts, and form a sense of social responsibility.[2] In recent years, STEM education has transformed traditional education (which was out-of-touch with practical living), opening up a new paradigm of comprehensive and innovative talent cultivation and becoming an inevitable trend in educational development.[24] STEM education utilizes real-world projects (problems) as its driving forces. Through the integration of different disciplinary knowledge, students learn by doing, thus acquiring knowledge and skills, and applying those skills to cultivate higher-order thinking skills. The situational and practical characteristics of STEM education have a certain degree of compatibility with SEL, including the development of teamwork skills, complex problem solving skills, critical thinking skills, self-management, and responsibility. Regarding teamwork skills, during the study of STEM project, students are expected to engage in collaborating with other members and sharing ideas and resources. Such collaborative activities help students develop abilities to communication with others, understand others' view, and respect for others. Regarding complex problem-solving skills, STEM courses encourage students to analysis problems and apply their acquired knowledge and skills to find problems' solutions. Through solving complex problem, students can improve their social-emotional skills. Regarding critical thinking skills, STEM courses require students to be critical thinkers by evaluating the information they searched and making responsible decision. This skill is essential for developing students' SEL as it helps them to differentiate between facts and opinions to avoid being influenced by false information. Regarding self-management, STEM courses usually require students to possess excellent time management and organization skills. Accordingly, students learn how to set goals, distribute resources, and manage their time, all of which are critical elements in developing social-emotional skills. Lastly, regarding responsibility, STEM courses encourage students to take responsibility for their own actions and outcomes. Through such practices, students develop social-emotional skills associated with learning to assume responsibility and attend to the needs of others. STEM education can follow the following principles to cultivate SEL.

Creating contexts focusing on real-world

The relevant theories and practices of SEL have shown that creating authentic social contexts that closely connect students' learning with real life-helping students form correct social value orientations and guiding students to care about society is keys to successful SEL.[25] Caring for and participating in society enables students to assume social responsibility and form positive social emotions. STEM education has situational characteristics that emphases the application of knowledge to real-world life *via* interesting and challenging problems that require students to problem solve to acquire knowledge and develop abilities.[26] Therefore, when cultivating social emotions in STEM education, attention should be paid to creating situations that focus on real-world problem guiding students to achieve an awareness and understanding of social emotions.

Developing social emotions through disciplinary practices

Discipline practices are practical way of cultivating students' social emotions by understanding disciplinary knowledge and forming disciplinary thinking through experience and activities. Practices are also important features of STEM project emphasis students' hands and brains and enhances participation in the learning process. In the discipline practices of STEM courses, students participate in and experience the entire process of knowledge acquisition. Students' study begins with problems and use their skills to solve the problems. The discipline practices in STEM courses take the problems as clue, and based on problem-solving, students acquire discipline knowledge and cultivate discipline literacy along the way. Through STEM courses' engaging practical activities, students are guided by the concept of "learning by doing" to achieve the integration of knowledge and action. STEM courses could be similarly used to cultivate social emotions, as students could be guided to establish correct social values through discipline practices by actively assuming their own sense of social responsibility, making responsible decisions in problem-solving and continuously reflecting on the impact of their own behaviors on society.

Establishing interpersonal relationships of equality and mutual support

Though human beings are inherently social beings, only through socialization can they gradually establish their social essence. Education can be used to cultivate people into social beings.[27] Research has shown that creating a supportive environment of safety, cooperation, and equal and supportive interpersonal relationships are important aspects of effective SEL.[12] From the SEL perspective, learning community should be a harmonious, interactive, and flexible place[28] where students help and appreciate each other. STEM courses include working as groups to collect and analysis learning materials, propose and validate assumptions, complete learning tasks, and evaluate learning

outcomes. When cultivating social emotions in STEM courses, it is necessary to build an equal and supportive teacher-student and student-student relationship. Through project activities and evaluation indicators, students participating in STEM courses should be guided to get along with others and deal with conflict appropriately. In practices, teachers should encourage students to express unique insights and guide other students to praise and appreciate their peers' outstanding performance. In addition, when peers encounter difficulties, teachers should guide students to take the initiative and actively help. When students want to give up, their peers can encourage them to be persistent in order to complete the tasks. Peer support should also encourage students to provide constructive opinions, tolerate and appreciate others, form good interpersonal relationships, and improve their social-emotional skills.

Strategies and methods for fostering social and emotional learning in STEM courses

Effective implementation of SEL courses has attracted increasing attention from researchers. Osher summarized effective SEL courses practice standards as those that (1) meet the developmental level of students through adjusting tools, language, activities, and curriculum arrangements to suit their developmental level and cognitive, social, and emotional skills; (2) are culturally relevant in consideration of cultural diversity and the appropriateness of the values, attitudes, behaviors, and meanings contained in culture and SEL related concepts; (3) offer systematic, that is, taking an ecological perspective that focuses on the cultivation of students' social-emotional skills as well as on the quality of the environment in which learning occurs; (4) employ a comprehensive lens to evaluate the effectiveness of SEL implementation *via* systematic changes within schools, families, and communities; (5) emphases inquiry, research on memory evidence for the methods implemented by SEL; (6) remain forward-thinking with a constant focus on exploring new ways to conduct SEL.[29] In subsequent research, using the acronym SAFE, Durlak *et al.* defined the characteristics of the most effective SEL methods as those that are Sequenced (involving a series of interconnected and progressive learning activities), Activate (guiding students to participate in active learning), Focused (emphasizing activities that focus on learning and developing social-emotional skills), and Explicit (clearly expressing the SEL goals). Studies have shown that the key to promoting SEL is to establish a closed loop of learning activities; first helping students understand why social-emotional skills are important and how to use them, then creating opportunities and learning activities for students to acquire these skills, and finally providing timely feedback.[30,31]

Creating social contexts

For this study, we created situations that originated from real society and real experience in keeping with the "Focused" aspect of SAFE characteristics of SEL implementation. To meet the "Focused" requirements, students' goals for SEL, such as self-awareness, self-management, social awareness, interpersonal relationships, and responsible decision-making, should be clarified. Furthermore, students should be informed of what social-emotional skills are required for each STEM education project and why these skills are important.

Planning activity sequences

Given that practicality and problem-solving are the main characteristics of STEM education, after a period of practices, students who complete projects and engage in problem-solving are not only able to acquire knowledge but also deeply understand the application of knowledge. Therefore, to meet the "Sequenced" aspect of SAFE characteristics of SEL, STEM courses plan learning activities based on practical issues to form a project problem chain. In this study, the design began with a social context created to clarify the questions driven by the STEM project. These driven questions are the starting point of project-based learning, referring to a series of situational, challenging, and meaningful open questions designed in advance by teachers, activity designers, or students regarding a real thing or event. These questions are jointly explored and answered by teachers and students during mathematical project activities, and the corresponding activity products are generated. A good driving question should be open, challenging, consistent with the evaluation criteria and stimulate students' interest. Therefore, when proposing STEM driving issues for fostering social emotions, special attention should be paid to the relationship between driving issues and real social situations to arouse students' concern and interest in real-world life, and to clarify the purpose of the project. Subsequently, through these planned project problem chains, students are guided to practice and make responsible decisions about issues, which cultivates social emotions. Notably, when planning the STEM problem chain, evaluators should focus on the milestones which represent progress in the project as these can provide feedback. In addition to subject knowledge and subject competencies, social-emotional skills should also be specified in the milestones such that social-emotional skills are clearly and concretely broken down for each node, to achieve the project learning objectives.

Evaluating students' behavior

Starting with the end and continuing the evaluation are the characteristics of STEM education aimed at evaluating students' behavior and knowledge acquisition during the completion of STEM courses. The evaluation of STEM courses is diverse and rich, encouraging students to truly engage in learning through process and summary evaluations. The evaluation of STEM courses should consider the learning goals, determine whether consistency was achieved in goal practice outcome

evaluation, examine the evaluation of students' cognition, abilities, especially social-emotional skills, and use process evaluation to prove the occurrence of learning practice. Simultaneously, the evaluation of STEM education projects begins with the end and reverse design, which combines evaluation with learning and run-through practices. In assessing SEL, teachers will be able to monitor whether students can effectively communicate and negotiate with their peers in completing STEM courses to complete tasks together as well as how well they can adopt appropriate solutions when conflicts arise within the group, identify their own emotional reactions, and adopt appropriate methods to adjust their state of mind to maintain a consistently good emotional state in STEM education projects. During student reporting and sharing of STEM projects, teachers can take notes and observe whether students are empathetic, that is, able to think from the perspective of others, attend to their emotional changes, provide appropriate support, express their views clearly and coherently, and understand others' opinions and feelings.[32]

CONCLUSION

Human success and well-being are increasingly governed by social-emotional competence-a core competency in the 21st century.[33] In recent years, SEL has received a great deal of attention as a result of core literacy-based curriculum reform that encourages the development of builders and successors who possess the necessary characters and key competencies to adapt and thrive. From the SEL perspective, this study initially examines the principles of STEM education that can cultivate students' SEL, providing new ideas for the practice of STEM education and SEL. Future research will continue to focus on curriculum development, practical models, and evaluation schemes of SEL in STEM education, with the aim of deepening the reform of basic education and implementing the fundamental task of cultivating morality and people's SEL.

During the promotion of the STEM education program, all learning and practical activities incorporated teamwork, division of labor, respect for peers, and mutual help into the assessment criteria, guiding students to actively participate in collaborative learning and work together to complete discipline practices. In addition, students were encouraged to assume different roles and tasks, such as team leaders, designers, and material managers. When students expressed different opinions or experienced conflicts in disciplinary practice, they were pressed to understand others through communication. In the discipline practice of STEM education projects, students reporting and sharing activities are arranged from research to model production. In reporting and sharing, students are gradually taught to share, accept, and tolerate different perspectives, understand the strengths of others, and work with peers to find solutions to problems, thereby acquiring the social emotions of living in harmony with them.

DECLARATION

Author contributions

Su Q: Writing—Original draft, Conceptualization, Resources. Guo SQ: Writing—Review and Editing.

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Informed consent

The authors declare that they have obtained appropriate informed consent from persons or their guardians appeared in the figures to be published in this article. They have given their consents for their images to be published in the journal.

Conflict of interest

The authors declare that there is no conflict of interest.

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