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Organizing and Implementing STEM Co-curricular and Extracurricular Learning Activities in High Schools: The Functions and Roles of Teachers

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Work-in-Progress: Organizing and Implementing STEM Co-curricular and Extracurricular Learning Activities in High Schools: The Roles and Functions of Teachers

Abstract

In recent years, STEM education has gained significant attention for its role in fostering innovation and practical skills among students. However, research on teachers' specific roles in organizing and implementing co-curricular and extracurricular STEM learning activities remains limited. This study explores the multifaceted roles and functions of high school STEM teachers in these contexts. Grounded in Erdogan's Learning Ecosystem Theory, the study examines how teachers navigate their roles in activity arrangement and collaborate with other stakeholders at different system levels. A qualitative research approach was used to investigate how high school STEM teachers organize and implement these activities. This study aims to provide a more holistic understanding of STEM teachers' roles, functions, and their interactions with other stakeholders. Our findings highlight the need to strengthen teacher support systems. Such systems can enable teachers to cultivate innovation and interdisciplinary skills among students, thereby enhancing the effectiveness of STEM activities.

Keywords: STEM education, extracurricular learning, teacher roles, learning ecosystem, high school

Introduction

In recent years, with the increasing global demand for technological innovation, STEM education has garnered significant attention worldwide. STEM education focuses on cultivating students' interdisciplinary thinking, practical problem-solving skills, and innovation, making it a crucial part of educational reform in many countries[1]. However, classroom-based instruction alone is insufficient to achieve these goals. Extracurricular activities, particularly in the context of STEM education, offer opportunities for hands-on practice and interdisciplinary learning, enhancing students' innovative thinking and problem-solving abilities[2][3]. Despite the benefits of extracurricular activities, their successful implementation heavily depends on the pivotal role of teachers[4]. Teachers serve not only as designers and organizers of these activities but also need to continuously adapt their teaching strategies to address students' diverse needs[5]. Additionally, they are expected to provide timely guidance and support when challenges arise[6]. Nagdi et al. emphasize that teachers are responsible for ensuring that students can balance the demands of different disciplines while participating in STEM projects. They also highlight the importance of ensuring that students receive adequate support to complete their tasks[7]. However, Herro and Quigley have pointed out that approximately 60% of STEM teachers lack sufficient preparation in teaching methodologies[8]. Moreover, individual differences among students can further increase the difficulty of organizing and implementing STEM learning activities[9]. These challenges underscore the need to strengthen support for STEM teachers in organizing and implementing extracurricular learning activities. By addressing these issues, it is possible to better leverage STEM education's potential to cultivate innovative and problem-solving talents for the future. This current research attempt to first explore STEM teachers' exact roles and functions during various STEM learning activities to offer suggestions for the establishment of future for high school STEM teachers.

Theoretical framework

We adopted Erdogan's Learning Ecosystem Theory as a framework for understanding the roles and functions of STEM teachers within a multi-layered educational context. This theory conceptualizes the learning ecosystem as a dynamic, interconnected structure comprising three main layers: the formal learning environment, the broader learning environment, and the social and academic context[10]. Each layer interacts with the others, shaping students' STEM learning experiences and outcomes (see Figure 1).

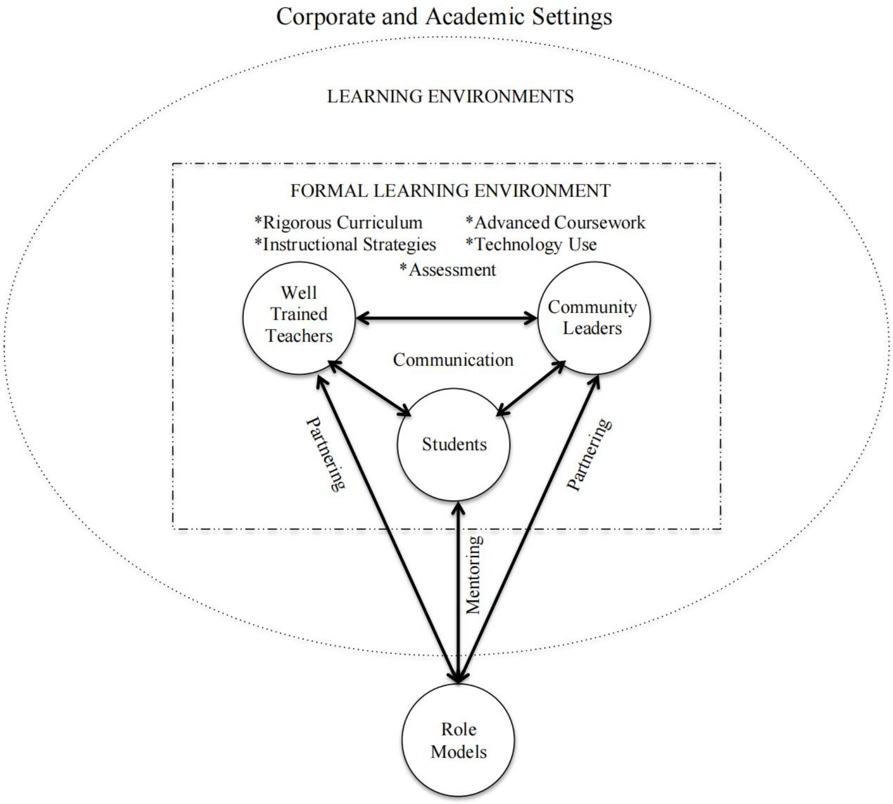

Figure 1 Learning ecological environment construction framework

At the core of the ecosystem is the formal learning environment, where structured educational activities occur. This layer emphasizes rigorous curricula, advanced courses, and the integration of technology to enhance learning. Within this context, teachers play a central role in designing interdisciplinary tasks, facilitating project-based learning (PBL) and inquiry-based learning (IBL)[11][12], and coordinating resources to support student collaboration and problem-solving.

Expanding outward, the broader learning environment includes interactions among teachers, students, parents, and community stakeholders. Here, teachers transition from traditional classroom leaders to facilitators, promoting students' autonomous learning, collaboration, and critical thinking skills. By creating challenging problem-solving scenarios, teachers encourage students to explore independently and apply their knowledge in practical contexts. In this layer, teachers actively engage with parents to foster support for students' STEM learning at home, while also collaborating with community leaders to integrate local resources and expertise into educational activities. Furthermore, teachers play a key role in mediating between students and external stakeholders, ensuring that students' learning experiences are both meaningful and relevant. By facilitating these connections, teachers help bridge the gap between classroom learning and real-world applications, ultimately enhancing students' engagement and achievement in activities.

The outermost layer, the social and academic context, encompasses societal, cultural, and policy-related factors that influence STEM education. Teachers need to navigate this complex layer by balancing national education policies, societal expectations, and institutional priorities. Supportive policies, such as government funding for STEM initiatives and professional development programs, are critical in enabling teachers to design and implement effective learning activities. Additionally, cultural attitudes toward innovation and technology significantly impact student and family engagement.

The interconnections among these layers highlight the complexity of the ecosystem and underscore the pivotal role of teachers as mediators and coordinators. The dynamic nature of the ecosystem requires teachers to continuously adapt to changes in technology, policies, and societal needs. Grounded in this framework, this study explores the multifaceted roles of STEM teachers in organizing and implementing co-curricular and extracurricular activities, as well as the influence of various stakeholders on their roles and functions.

Methodology

This study employs qualitative thematic analysis to explore the roles and functions of high school STEM teachers in organizing and implementing co-curricular and extracurricular activities. Data were collected through semi-structured interviews with four engineering teachers. Thematic analysis followed Braun and Clarke’s (2006) six-phase framework: (1)familiarization with the data, (2)generating initial codes, (3)searching for themes, (4)reviewing themes, (5)defining and naming themes, and(6)producing the report[13]. For example, raw interview data such as “I spend significant time guiding students through project proposals” were initially coded as “mentoring”, which was later grouped with related codes to form the theme “teacher guidance.” Similarly, statements about managing materials and budgets were coded as “resource management.” The analysis began with repeated readings of interview transcripts to sort out the data, followed by an inductive coding process. Initial codes such as “project direction adjustment” and “modeling course adaptation” were generated directly from teachers’ descriptions of their practices. These codes were then clustered into potential themes through collaborative discussions among researchers. During this phase, overlapping codes (e.g. “resource allocation” and “budget management”) were merged into broader categories like “resource coordination,” while fragmented codes were either discarded or subsumed under existing themes. Themes were iteratively refined by revisiting raw data to ensure coherence and relevance to the research questions. To strengthen the trustworthiness of the analysis, member checking was conducted by sharing preliminary themes and representative quotes with participants, who confirmed the interpretive accuracy of their experiences. Furthermore, peer debriefing with external STEM education researchers provided critical feedback to minimize bias. All coding decisions were documented and cross-referenced using NVivo software, ensuring procedural transparency and an auditable trail.

The participants are experienced high school teachers from City S, a Chinese city where STEM education is publically promoted at the municipal level via local educational policies. In particular, these teachers were recruited via professional networks based on their active involvement in organizing science and innovation activities and courses. Although they are not exclusively engineering teachers, they teach subjects closely related to engineering, such as General Technique and Information Technology. In City S, the subject of General Technique covers topics such as engineering design and other engineering related topic in addition to the introduction of some modern techniques(e.g. 3D printing). The perspectives of participants provide valuable insights into the study's research questions, particularly regarding the organization and implementation of STEM-related activities. As shown in Table 1, eight teachers have been interviewed so far.

Table 1 Demographic information of interviewees

Pseudonym	Gender	Subject	Seniority
Michael	M	General technique	11 years
Emma	F	General technique	5 years
Sophia	F	Information technology	12 years
Olivia	F	Information technology	6 years
Kevin	M	General technique	2 years
Travis	M	General technique	14 years
Lucas	M	General technique	15 years
Charlie	M	Information technology	26 years

This work-in-progress will focus on reporting results from the qualitative analysis and present preliminary findings from these interviews with high school engineering teachers.

Preliminary Findings

Currently, this study conducted a thematic analysis of interview texts from high school STEM teachers to explore their roles and functions in co-curricular and extracurricular learning activities. The results are structured into two interconnected parts: the role and function of the teacher, and the influence of other stakeholders on the role and function of the teacher. Each part is supported by qualitative evidence.

a. The role and function of teacher

In terms of the role and function of stem teacher, all 4 participants mentioned that they act as director, guider, event design and organizer, coordinator, supervisor, evaluator and other relevant roles. Among the transcript, the predominant roles are director and event design and organizer. For example, when asked about the functions and roles teachers mainly play in technological innovation activities, Michael, a teacher who teaches general engineering technique, answered:

In the proposal stage, I need to help students adjust the direction of the project repeatedly. Because the direction chosen by students at the beginning may often be what they are interested in, but the feasibility is relatively poor. It also includes whether the existing technology can be done, and whether there is innovation after it is done, and whether it can go deeper in the end. These students themselves are unable to grasp, need the teacher to help students adjust again and again. Therefore, I spent a long time on this part of the work, and the topic selection took almost half the semester, and it was not finalized until June. - Michael

As the developer of the 3D modeling course at her school, Olivia also shared some experiences in the design of the modeling course and the use of the software：

At the beginning of the course, the main content was that I found some models from the Internet and then asked the students to build them according to the scale of the models on the Internet. Later on, because the students' works are very interesting, I will compare the software and the course after taking a round of classes, then generate some new ideas. Therefore, the content I modified later did not change much in the knowledge point, mainly made some modifications to the modeling object. For example, I measured the dimensions of some buildings *in the school, then built them according to the models of some buildings in our campus, and then asked students to complete the modeling task.* -Olivia

Similarly, other roles and functions of the teacher have also gathered a lot of relevant data. For instance, Sophia, an information technology teacher, is capable of making appropriate evaluations of students' test results and practical works, and combine the students' written test results and the result of the work for grade or score assessment.

b. The influence of other stakeholders on the role and function of the teacher

In terms of the influence of different stakeholders on the role and function of teachers, most participants mentioned the effect of school, parents, students, government, out-of-school resources, social atmosphere and role models. Take school and government as examples, schools mostly influence the provision of class hours, venues, funding, equipment, and the establishment of evaluation system. Emma, an information technology teacher, thought the most significant influence of school on her is the class schedule:

In the aspect of research learning, our school has two class hours every week, which is from the support of the management for this matter. For us, it is a very difficult thing to put out two classes a week. -Emma

Besides, the government can influence the macro-direction for project design, which affects the orientation, requirement and assessment of curriculum, and the communication and training of teachers. Also, the government has the decision-making power in the compilation of textbook. Educational policies possess a guiding role in the application of research projects and the support of related resources. Meanwhile, they provide platforms for teacher exchange and training, and guarantee the minimum requirements of class hours. Emma also had some thoughts on the influence of government. She regarded the most obvious effect on her was the development of course direction and resource support:

If the government does not support research-based learning, then perhaps our engineering learning activities will not be organized. For the first two or three years, stem education was nowhere to be found in our educational texts. Policy support can bring more resources, including hardware resources and teaching resources. It is also good for my teaching openness. If I take the initiative to propose some topics that are consistent with the direction of national attention, such as artificial intelligence, the leader will be very supportive, and this kind of invisible incentive is quite important to me. --Emma

Discussion and conclusion

So far, based upon the preliminary findings, we identified STEM teachers' evolving roles within complex educational ecosystems. Erdogan's Learning Ecosystem Theory posits that teachers act as mediators across formal and informal learning layers[10], a perspective echoed in participants' narratives. For instance, Michael's iterative guidance on project feasibility aligns with the observation of Han et al. that teachers in project-based learning environments should balance student autonomy and technical scaffolding[11]. Similarly, Olivia's adaptation of 3D modeling tasks reflects the pedagogical flexibility emphasized by Margot and Kettler (2019) as critical for integrating emerging technologies[14].

However, the data reveal systemic barriers that extend beyond individual adaptability. Teachers' reliance on self-directed learning to navigate AI tools or hybrid assessments underscores a gap between policy aspirations and on-the-ground support. While national policies advocate for STEM integration[15], the absence of localized professional development frameworks leaves teachers ill-equipped to implement interdisciplinary pedagogies[8]. This misalignment mirrors findings from De Neve and Devos (2017), which argue that teacher autonomy without structured collaboration risks fragmented innovation[5]. The strategic alignment of projects with government priorities, while securing resources, inadvertently narrows the scope of student inquiry, a dilemma reminiscent of Freeman et al.(2021) caution against policy-driven curricular homogenization[6].

The study also contributes to discussions on resource allocation. Participants' improvisational strategies exemplify what Bybee (2013) terms "grassroots STEM ingenuity"[16], yet such efforts remain unsustainable without institutional backing. National Research Council (2011) calls for systemic investment in teacher support[15], yet current funding models prioritize compliance over creativity. A potential pathway lies in the proposal for flexible, problem-based learning grants[17], which could formalize teachers' temporary collaborations into sustainable programs.

Crucially, the findings challenge static definitions of teacher roles. While Nagdi et al. (2018) frames STEM teachers as interdisciplinary facilitators[7], participants' experiences suggest a more fluid identity. It can be mentor, policy interpreter, commander and so on. This aligns with Morrison et al.(2021) that effective STEM teaching demands role fluidity to navigate ecosystem complexities[6]. However, such adaptability remains unrecognized in traditional evaluation systems, perpetuating the invisible labor[18].

In conclusion, this study underscores the need for policies that bridge macro-level STEM agendas with micro-level teacher realities. Rather than prescribing uniform training modules, professional development should emulate participants' iterative practices. Meanwhile, peer collaboration and cross-school partnerships are needed[4]. Simultaneously, funding mechanisms should evolve to support context-driven innovation, ensuring that teachers' boundary-brokering efforts translate into sustained systemic change[10].

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