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Facilitating a Smooth Transition from Secondary to Tertiary STEM Education: Building a Learning Ecosystem for Organizing and Implementing Extracurricular STEM Learning Activities

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Work-in-Progress: Facilitating a Smooth Transition from Secondary to Tertiary STEM Education: Building a Learning Ecosystem for Organizing and Implementing Extracurricular STEM Learning Activities

Abstract

In recent years, growing emphasis has been placed on STEM education as a foundation for nurturing students' creativity, problem-solving abilities, and engineering thinking for educating future engineers. Extracurricular STEM learning activities have gained increasing attention for their potential to enhance students' interest in science and engineering, develop related skills, and foster their career aspirations and therefore support the transition from secondary to tertiary education. However, how to build a strong learning ecosystem for organizing and implementing extracurricular STEM learning activities, remains under explored. This study adopts a qualitative research design to examine the roles and functions of multiple stakeholders in organizing and implementing extracurricular STEM learning activities to facilitate a smooth transition from secondary to tertiary engineering education. In-depth interviews were conducted with multiple stakeholders, including education administrators, secondary-school teachers, university faculty, and staff from science and technology centers. The results reveal several structural and pedagogical challenges that hinder effective collaboration across educational levels. Particular attention is given to the roles of secondary-school teachers, who serve as key intermediaries in activity design, resource integration, and teacher–student collaboration. Building on these findings, the study suggests ways to strengthen cross-stage coordination, improve resource sharing, and encourage broader stakeholder collaboration. These findings contribute to a better understanding of how collaborative support systems can foster a smoother and more sustainable transition in engineering talent development.

Introduction

STEM education is widely positioned as a key approach for developing students' interdisciplinary competence[1] and innovation capacity[2], particularly in relation to preparing future engineering talent[3]. Integrated STEM scholarship highlights design-based practice and problem solving as core learning outcomes[2], while recent syntheses emphasize that STEM participation is shaped by opportunity distribution[3] and broader system capacity[4]. These arguments suggest that pathway development cannot rely on curriculum reform alone, because students' access to sustained STEM engagement is also conditioned by the support environment that surrounds learning. In this paper, STEM education refers to pre-college learning experiences in secondary school settings that engage students in science, technology, engineering, and mathematics and the cross-discipline areas.

More specifically, our focus is not on STEM instruction in required classroom courses in general, but on extracurricular STEM learning activities organized beyond the national curriculum system. These activities mainly include innovation-oriented micro-courses, school-based courses, clubs, and competition-related learning opportunities. Extracurricular STEM learning has gained attention in this context, as it can expand learning beyond class time and provide participation opportunities that formal curricula may not sustain. Related research indicates that sustained participation can support identity development[5], and that consequential engagement matters for learners from historically marginalized groups[6]. Evidence also links participation time in structured programs to identity-related outcomes[7], while career-connected encounters can shape aspirations by making pathways visible and concrete[8]. Together, these studies position extracurricular STEM learning as a promising context for strengthening pre-college engineering trajectories.

However, extracurricular STEM activities remain difficult to sustain across schools and over time. A STEM learning ecosystem perspective argues that durable opportunities depend on cross-sector coordination[9] and on the implementation capacity of out-of-school time STEM within ecosystems[10]. This perspective also explains how learning supports circulate across places and resources[11], although partnership depth varies widely across in-school and out-of-school collaborations[12]. Critical scholarship further cautions that ecosystems may function like uneven markets when resources are scarce and access depends on local advantage[15], which can produce fragmented participation pathways even when stakeholder intentions are positive.

Teacher perspectives offer an especially grounded entry point into these issues. Research shows that teachers interpret ecosystem partnerships through the realities of school schedules and accountability[13], and they often make external supports workable through local routines and adaptations[13]. Youth pathway studies also highlight brokering mechanisms that help learners navigate opportunities across settings[14], implying that teachers' accounts can reveal how ecosystem participation is assembled, maintained, and constrained. Accordingly, this work-in-progress study asks: How do high school STEM teachers perceive the roles and support functions of ecosystem participants, including schools, government and district actors, families, universities, and out-of-school resources, in building extracurricular STEM pathways that support transition to tertiary engineering education?

Theoretical Framing

We adopted Erdogan's Learning Ecosystem Theory as a framework lens to interpret teachers' accounts of extracurricular STEM implementation. The framework conceptualizes learning opportunities as produced through interactions among actors, actions, and contextual conditions across settings[17]. Within this view, teachers and students work inside formal school structures, while community partners contribute through mentoring, partnering, and resource provision[17]. Social and academic pressures shape what can be sustained through incentives, constraints, and recognition systems that influence participation decisions[17]. In this paper, the ecosystem is operationalized as the stakeholder groups that teachers repeatedly referenced in interviews, including schools, government and district platforms, universities, out-of-school resources, and families.

Methods

This work-in-progress study used a qualitative interview design. As shown in Table 1, 15 high school stem teachers in City S, a Chinese city where STEM education is publicly promoted at the municipal level via local educational policies, have been interviewed so far. These teachers were actively organizing extracurricular STEM activities such as project clubs, extension courses, and competition mentoring. The participating teachers primarily taught general technology, information technology, school-based extended courses, and competition-oriented technical activities. Across these roles, they supported extracurricular STEM learning through project-based design activities, engineering-related making tasks, computing and information projects, and competition mentoring. Semi-structured interviews explored activity design and mentoring routines, as well as stakeholder support, coordination practices, and constraints shaping continuity and transition-oriented work.

The authors are education researchers at a Chinese research university with ongoing research interest on STEM education, teacher support, and engineering education pathways. We recognize that our proximity to STEM reform discourse may predispose us to view cross-sector collaboration as desirable. To address this, we used memos throughout analysis, compared interpretations across transcripts, and grounded analytic claims in participants' accounts rather than assuming that ecosystem collaboration was uniformly beneficial across contexts.

Table 1 Demographic information of interviewees

Pseudonym	**Gender**	**Subject**	**Seniority**
Wang	M	General technique	11 years
Qian	F	Information technology	6 years
Cheng	F	Information technology	12 years
Zhao	F	General technique	5 years
Zhou	M	General technique	2 years
Ye	M	Extended courses	14 years
Zheng	M	General technique	15 years
Jiang	M	General technique	7 years
Sun	M	Information competition	26 years
Xie	M	General technique	14 years
Zhang	M	Information technology	13 years
Chen	M	General technique	13 years
Pan	M	General technique	5 years
Hua	M	General technique	26 years
Jin	M	General technique	5-6 years

All interviews were audio-recorded, transcribed verbatim, and anonymized. All excerpts reported below were translated into English by the authors. Data analysis followed reflexive thematic analysis guidance[18]. We read transcripts repeatedly to build familiarity[18], generated initial codes focused on stakeholder roles and support functions[19], and refined themes through comparison across teachers and schools[19]. Analytic memos were written throughout to document evolving interpretations[18], and coding decisions were informed by qualitative coding guidance on transparency and consistency[20]. Themes were checked against known analytic pitfalls in thematic analysis to support credibility[21]. All coding decisions were documented and cross-referenced using NVivo 12 software, ensuring procedural transparency and an auditable trail.

Preliminary Findings

Teachers framed extracurricular STEM implementation as ecosystem work and collective construction, rather than as an activity sustained by a single school or individual teacher. Across interviews, teachers systematically introduced how stakeholders such as schools, governments, parents, off-campus institutions, and universities, as the main participants in STEM education, jointly build the stem education ecosystem.

a. Schools as Primary Providers of Time, Space, and Local Access

Teachers positioned schools as the most immediate ecosystem participant because it was most visible through space, equipment access, and class hours that directly shaped what students could attempt. Teacher Wang described how specialized facilities functioned as the material "habitat" for sustained projects: "*In terms of space, an entire floor is our technical classrooms. At present there are about ten specialized classrooms in different directions, for example, one for electronic design, one for robotics, and one for 3D printing. Each teacher is responsible for one or two classrooms and teaches courses in their own area. In this way, when we want to offer some specialized courses, at least we have a space with the necessary equipment, a fixed place, and a fixed teacher to run the course. Then the course can go deeper.*"

In this account, the school does not merely provide rooms. It stabilizes a long-term learning setting in which iterative engineering work can occur.

However, teachers also pointed to the unevenness of school provision, which became a constraint that narrowed feasible project scope. Teacher Zhang emphasized that even when a school has resources, allocation rules can still prevent STEM work from being routinized: "*Our school does not provide a dedicated computer room for the General Technique course. Although the school has six computer rooms, they are all used for English exams. They are used very frequently, so we can only squeeze in. Many times we cannot get a slot, especially near the spring exam. Without computers we cannot run the course, and we become very passive.*"

From this view, the school is not only a provider, but also a gatekeeper. Scheduling priorities and exam-related usage patterns can indirectly determine whether STEM learning remains continuous or becomes episodic.

b. Government and District Platforms as Guarantee of Legitimacy and Implementation

Teachers positioned government and district platforms as legitimacy providers that influence whether extracurricular STEM can be publicly framed, professionally supported, and institutionally recognized.Teacher Qian described how curriculum artifacts shaped what could realistically be taught and practiced: "*I actually have some confusion when I use the textbook. The first volume is quite concrete. But the second volume of the new textbook is more empty. There is a chapter where it asks us to build a logistics information system. On the one hand, class hours are limited. On the other hand, the book does not really introduce the practical part. So for me, it is not easy to implement the hands-on practice in this unit.*"

In this sense, policy does not simply set directions. It also shapes the workload and feasibility of teachers' implementation choices, thereby affecting whether STEM activities can become sustained pathways rather than short demonstrations.

c. Universities as Providers of Expertise and Visibility into Tertiary Engineering Pathways

Teachers described universities as expertise amplifiers that expand topic breadth, increase authenticity, and provide visible connections to tertiary engineering domains. University participation most often appeared as lectures, micro-courses, and specialized mentoring. Teacher Pan described a stable format of university involvement within school schedules: "*Our secondary school has connected with universities, including some university research institutes. We invite experts and professors in related fields to give lectures and micro-lessons to our students. Now in our elective class every Wednesday, we invite professors from nearby universities to offer short university-style micro-courses to students about different majors*." Teacher Qian similarly emphasized intensity and coverage: "*Throughout the whole first year of high school, basically every week we invited different experts to give lectures in different areas, including social science engineering, computer science, geography, and biology. At most, there could be five lectures running at the same time in a week*."

These accounts suggest that universities do not only provide advanced content. They also help construct a forward-facing ecosystem pathway by allowing students to encounter disciplinary possibilities earlier and more frequently.

d. Out-of-school Partners as Resource Multipliers but also Sources of Sustainability Risk

Teachers described out-of-school engagement as financially demanding, especially when competitions required high-performance materials and repeated fabrication. Teacher Hua illustrated how enterprise links became a practical condition for maintaining participation at scale: "*I often have to go out to ask for money, ask different companies, and paint a rosy picture for them, telling them the awards we can win, so that companies will invest. Only then can we build the car model to compete. Every small part is expensive, and we need to make at least three or four cars. All kinds of parts cost money, and there is wear and tear. We have to find partner companies. This all relies on my personal connections.*"

This account suggests that out-of-school resources may expand ecosystem capacity, yet access can depend on teacher brokerage and informal networks, which introduces sustainability risks when partnerships are not institutionalized.

e. Parents and families as Regulators of Persistence, Recognition, and Participation

Teachers positioned families as participation regulators whose decisions shape whether students can persist through long project cycles and competition preparation. Supportive parents were described as reducing teachers' operational burden while sustaining student motivation. Teacher Xie emphasized how parent engagement became an ongoing communication infrastructure rather than a one-time consent: "*Parents in our school are very supportive. First, our students' overall quality is quite high. Second, students like these activities. If they invest, they will tell their parents, and about 90% of parents are supportive. Then these activities are easier to run. Some parents hope to win awards, some hope to improve students' abilities, and the expectations differ. Parents often contact me. There are so many parent messages on my phone. Some of them I have never met in person, but we are always communicating. They mainly ask about competition progress and what the student should do next. In our school, especially some parents who value innovation education, they are extremely active in contacting teachers. I feel that parents are quite proactive now.*"

In this account, families help stabilize the ecosystem by sustaining attention, recognition, and logistical cooperation over time.

However, teachers also noted that family stances were not uniform, and mixed attitudes could shape participation patterns. Teacher Pan described how extreme forms of support and resistance were the most visible to teachers and were reflected in students' engagement behaviors: "*In most cases, I think parents do not fully get involved. What I can observe tends to be the extreme cases: either very supportive, where students come to me frequently and there may even be research implementation on weekends, which shows full support; or completely not supportive, where you can clearly feel that the student is always studying in class. The rest are more normal: during the research class they come and carry out the work, and parents are neither strongly supportive nor strongly opposed, they are more neutral.*"

This quote highlights that families can either stabilize or constrain the ecosystem, depending on whether extracurricular STEM is recognized as meaningful learning or viewed as a distraction from exam priorities.

Discussion and Implications

These findings suggest that ecosystem co-construction is real but not automatically coherent. Stakeholders contribute different supports that operate through distinct mechanisms: schools stabilize time and local resources, district platforms provide legitimacy and structured access, universities raise expertise and authenticity, out-of-school resources expand materials and infrastructure, and families regulate persistence and recognition. Teachers integrate these supports into workable routines, and their coordination labor becomes a practical condition for continuity.

The data also point to coordination mechanisms that are actionable within this ecosystem. Schools can protect fixed project time and reduce exam-driven encroachment on extracurricular STEM routines. District agencies can extend initiatives beyond short cycles to support continuity across semesters. Universities can offer predictable mentoring schedules and stable access rules. Out-of-school partners can formalize longer agreements that reduce annual rebuilding. Schools can strengthen sponsorship procedures to reduce reliance on personal networks. Finally, families need clearer communication about the learning value of extracurricular STEM beyond exam scores, since recognition alignment shapes whether students can persist. Justice-centered work argues that equitable STEM pathways require recognition of diverse learning contributions[16], and teachers' accounts here suggest that recognition is a central lever for ecosystem stability and sustainability.

This work-in-progress study offers a teacher-centered entry point into ecosystem design for transition support, while identifying coordination points that can be examined and refined through further multi-stakeholder data.

Conclusion and Future Work

This work-in-progress study examines extracurricular STEM ecosystem co-construction from high school STEM teachers' perspectives. Teachers described schools, government and district platforms, universities, out-of-school resources, and families as ecosystem participants who jointly shape time, space, expertise, legitimacy, and recognition. Teachers emphasized their intermediary role in translating distributed supports into feasible project routines under exam-driven constraints. However, although the participating teachers represented a wide range of experience levels, from 2 to 26 years, the current phase of analysis did not reveal a consistent pattern in ecosystem perceptions based on seniority alone. We will examine possible experience-related differences more systematically as the dataset expands in the next phase of the study. Also, will include additional stakeholder interviews, including education administrators, university faculty, and out-of-school staff, to triangulate role expectations and identify coordination mechanisms that can stabilize transition-oriented extracurricular STEM pathways.

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