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Enhancing STEM Learning through Extracurricular Activities: Insights from Japanese Students

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ABSTRACT

I examine the impact of STEM extracurricular activities at Japanese Colleges of Technology (KOSENs) through qualitative analysis of semi-structured interviews with twelve prize-winning students from a private KOSEN. The research explores how these activities foster confidence, curiosity, and interest in STEM careers, promoting scientific inquiry through open-ended research experiences. Students value the autonomy to choose research topics, finding individual projects more engaging and enriching than group work or traditional coursework. The findings underscore the importance of extracurricular research in enhancing both academic and personal development, offering real-world applications of STEM education. The study highlights KOSEN's role in nurturing critical thinking and independent learning, contributing to student growth and future career readiness.

Keywords: Colleges of Technology KOSEN, Extracurricular Activities, STEM Education, Undergraduate Research Experiences

INTRODUCTION

In higher education, diverse curricular and extracurricular experiences, including research activities, are recognized as "High-Impact Educational Practices" that enable students to engage and showcase their learning at different stages systematically (Kuh, 2012). Undergraduate Research Experiences (UREs) deepen students' STEM commitments and allow them to apply theoretical knowledge

practically, enhancing understanding and engagement (Gentile et al., 2017; Whitehead et al., 2024). UREs also build students' interest, confidence, and technical abilities while fostering community and self-direction, especially among engineering students (Fisher, 2013; Slovacek et al., 2019; VanMeter-Adams et al., 2014).

Seow & Pan (2014) describe three theoretical models that illustrate different impacts of extracurricular activities (ECAs) on academic outcomes: The Zero-Sum model, which suggests a negative effect by diverting focus from academics; the Developmental model, which sees a positive impact through the enhancement of non-academic skills; and the Threshold model, which asserts that benefits persist until a certain level of involvement, after which they may negatively affect academic performance. Ribeiro et al. (2024) conducted a narrative synthesis of 39 articles from various scientific fields, revealing that ECAs significantly boost university students' academic success and employability, with predominantly positive outcomes. While ECAs are part of the norms and deeply integrated into Japanese higher education, research on their effects—particularly related to UREs and STEM activities—is limited. On the international level, prior studies have primarily focused on university students, leaving a gap in understanding ECAs' impact on younger learners in specialized institutions like Japanese Colleges of Technology (KOSENs).

This research addresses this gap by analyzing the effects of STEM ECAs at KOSENs. Unlike other higher education institutions, KOSENs are higher education institutions of engineering that uniquely enroll students directly after compulsory schooling at age 15. KOSENs' iterative curricula promote active, student-centered, and inquiry-based learning methods to enhance the generic skills, creativity, and adaptability required to meet modern societal and industrial needs (Rashed, 2023). Beyond classroom learning, KOSENs offer a range of ECAs shared among KOSEN institutions and held on regional and national levels. KOSEN ECAs such as Robot Contests, Programming Contests, Design Competitions, Annual English Presentation Contests, and KOSEN Athletic Meeting aim to foster students' student's overall development, enhancing their communication, teamwork, and leadership skills (Shimoda & Maki, 2018).

Previous studies about ECAs at KOSENs are few and primarily focus on technical, organizational, and faculty aspects, often assessing student satisfaction through quantitative surveys (Doi et al., 2022; Kitamura et al., 2023; Tokoi et al., 2020). However, there is limited insight into students' personal experiences and achievements through these activities. Understanding the effect of STEM ECAs at KOSENs is significant, given the increasing emphasis on early STEM engagement to promote technological innovation and career readiness, which requires UREs.

This study aims to identify how KOSEN students perceive STEM ECAs centered around UREs and assess whether these activities benefit them beyond the structured curriculum. It investigates individual experiences and examines the

broader educational impact of STEM fairs, research activities, and presentations compared to the formal curriculum and prior experiences. By filling the identified research gap, this study contributes new insights into how STEM ECAs influence younger students' academic and career paths and provides a foundation for future research comparing these impacts across educational levels and tertiary institutions.

METHODOLOGY

Institution Overview and Research Context

This study was conducted at the International College of Technology Kanazawa (ICT) in Japan, established in 2018 as the successor to Kanazawa Technical College. Focusing on STEM education, ICT integrates STEM knowledge into real-world applications and emphasizes international academic standards and experiential learning. ICT's unique five-year program prepares students with comprehensive technical and engineering skills. It supports global career aspirations by conducting STEM courses in English.

Students at ICT have varied educational backgrounds, including Japanese compulsory public schools and international schools within Japan or overseas. They also have diverse initial language proficiencies, contributing to a rich cultural and linguistic mix educational environment at ICT.

The ICT's STEM Fair Project is designed as a practical platform for students to apply theoretical knowledge to real-world problems. Since 2018, students researched diverse issues such as environmental sustainability, health innovations, programming, machinery, and technological advancements like AI and robotics (Rashed, 2024). It is structured into three phases. Initially, students submit detailed proposals with titles, objectives, methods, and budget estimates, which include specifics on data collection methods and settings for second-year students. These proposals may highlight possible social or environmental impacts and require faculty approval to ensure educational relevance and feasibility. Following approval, students conduct research over the summer, preparing poster presentations evaluated in a formal September session on scientific accuracy, presentation clarity, and visual effectiveness. High achievers receive awards recognizing their comprehensive engagement with the research topics.

This study provides crucial insights into STEM programs, pinpointing how well ECAs align with student expectations. The results aim to contribute to broader discussions on educational development within KOSENs, potentially guiding future initiatives to improve student involvement and learning achievements.

Participants & Ethical Considerations

The participants are twelve first- and second-year ICT students, eight males and four females, winners of the 2023 STEM Fair Project. This prize-winning status selection reflects a thorough understanding of the research and presentation processes. Their varying academic and personal backgrounds and experiences ensure a diverse representation.

All participants provided informed consent, having been fully briefed on the study's purpose and assured of their voluntary and anonymous participation. Approval was secured from the Institutional Review Boards to ensure compliance with ethical standards for research involving human subjects. The Ethics Review Committees at Kanazawa Institute of Technology and International College of Technology, Kanazawa (Approval No. 2308001), and Kanazawa University (Approval No. 2023-78) granted ethical approval.

As a chemistry professor, I conducted semi-structured interviews in a quiet meeting room to create a comfortable and uninterrupted environment. The students' familiarity with the interviewer encouraged open expression. Each interview, lasting 50 to 80 minutes, was video-recorded, transcribed, anonymized, and analyzed using MAXQDA software for qualitative data management.

Responses were not predetermined, so I employed grounded theory using induction and deduction (Strauss & Corbin, 1998) through iterative analyses. This process refined concepts and achieved theoretical saturation (Kennedy & Lingard, 2006), focusing on theory development rather than sample expansion (Charmaz, 2000). The study maintained theoretical sensitivity, avoiding preconceptions, while progressively coding data from descriptive to conceptual, supported by memos. Constant new data comparison with existing codes and literature further refined the theoretical framework. My constructivist and interpretivism epistemological perspectives (Weed, 2009), believing individuals shape their realities, informed the data analysis, focusing on participants' subjective views without assuming predetermined correct responses.

RESULTS

Table 1 presents the defined codes from the initial coding process, paired with example quotations. It also shows the core categories developed during the focused coding phase, capturing students' perspectives on the impact of implementing STEM ECAs at KOSEN.

Table 1:

The Students' Perspectives on the Impacts of Applying STEM ECAs at KOSEN

Codes	Core Categories	Example Quotations
Elementary school Junior high school Cram schools EIKAIWA Previous STEM activities or classes	Students' backgrounds (social, personal, educational)	"And, I got in a competition with the name FLL ... That is STEM. Using STEM." "No, I have not. I learned about it in this KOSEN."
Topic Reasons for topic choice	STEM Research Inspirations	"I want to make no litter in the ocean. Clean ocean using engineering! I tell many people to know about this topic and many persons to notice the problem."
Research question Observation Research background Experiment/Test Data collection Data analysis Conclude and report data Steps Research gaps	Scientific method	"The way to start! It is difficult to continue, but the scientific method guided me!"
Time length Difficulties Support Enjoyments	STEM research experiences	"Difficult to find accurate and consistent information!" "Organizing and analyzing data was time-consuming!" "Excited when I could find data and make the equation!" "When it succeeded!"
Prize expectation Opinions about peer presentations	Peer`s presentation & prize-winning expectations	"I was happy, but I regret that I could have tried harder. To have a good project, you must not be satisfied!"
Previous school science Projects STEM project Differences	STEM Fair Project compared with science projects in compulsory education	"Completely different!" "Independent research!" "Real-life problem!"
Previous poster Presentations English poster presentation Engineering design projects	Comparison between poster presentation experiences	"STEM is not a requirement! Curiosity is the motivation!"

Codes	Core Categories	Example Quotations
STEM poster presentation differences		
Research & presentation skills Other developed skills	Skills developed through STEM Fair Project	"Experimenting skills such as posing questions while researching! More organized! How to use graphs!"
Future Research Future Career	Future STEM research plans and career choices	"I'm not decided, but… I will try more things up here."
ED vs. STEM fair Team vs. individual	Extracurricular and curricular activities at KOSEN	"STEM fair is a good event to research something. …. If I don't have STEM Fair, There was no more chance to do it."

The following subsections demonstrate the emerged core categories through iterative analysis when theoretical saturation was achieved.

Students` Backgrounds

Students' personal, social, and educational backgrounds shape their interests in a specific educational program or institution. Why did the participants choose KOSENs? What is their awareness, understanding, and previous experiences of STEM education? Does their understanding of STEM education develop through this extracurricular activity experience?

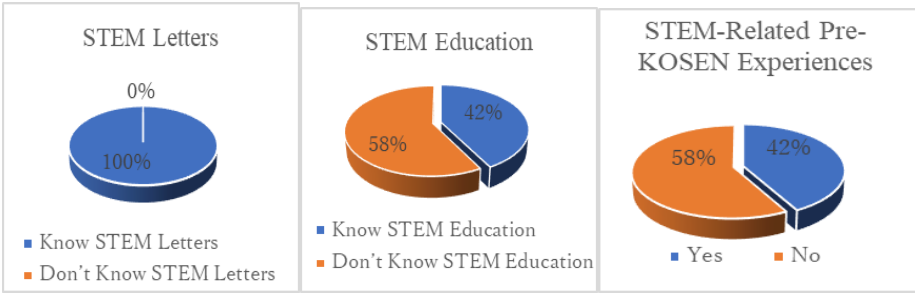
The participants have different personal traits and life orientations. They are from different prefectures in Japan, ranging from small islands to urban areas, which provide personal experiences that differ depending on their socioenvironmental demographics. They come from varied educational backgrounds. Some attended international schools, others attended public schools in Japan, and some students had mixed experiences with public and international schools.

Before enrolling in KOSEN, some students had limited or no exposure to STEM-related activities, while others had more extensive experiences. Some students participated in unofficial extracurricular programs (NARAIGOTO) like the First Lego League (FLL) (https://www.firstlegoleague.org/) or VEX Robotics (https://www.vexrobotics.com/), which allowed them to engage in hands-on STEM projects and competitions, including international events such as the World Robotics Olympiad (WRO) (https://wro-association.org/). Some students participated in summer school programs or community events to promote girls' interest in STEM. In contrast, news articles introduced others to STEM topics: "because it is getting more popular. I read about it in the news." For some, KOSEN was their first exposure to STEM. Regardless of their prior experiences, all

students share a superficial understanding of STEM, the acronym for Science, Technology, Engineering, and Mathematics. See Figure 1.

Figure 1

STEM Definition and Previous Experiences



Analysis indicates many KOSEN students had a limited initial understanding of STEM, with exposure generally informal and minimal: "Some of the teachers told me what STEM is."

After enrolling in KOSEN, some students' recognition of the interdisciplinary connection in STEM is limited: "I know the letters of STEM, but other than that, I am not really familiar with other meanings of STEM." Some misunderstand STEM education as "Learning technology in English," perhaps because they perceive STEM as a foreign concept that has not originated in Japan, stating, "The STEM concept has started in other countries, not much in Japan. I think it started in MIT and around there."

Students with a correct understanding of STEM appreciated its interdisciplinary nature, noting, "It is not only one subject, and they connect," and "All four subjects are connected... we use all of this to develop technologies." They recognized how these interconnected disciplines enhance their ability to tackle complex real-world problems, saying, "because in modern society we use all of this to develop technologies and to make this world better… We all need these to develop all those things that we use to find solutions." This deeper insight primarily developed through their education at KOSEN, highlighting a contrast with their earlier formal education in Japan, which did not introduce them to STEM comprehensively. Additionally, their interest in broader international perspectives and language skills, often enhanced by activities like attending English conversation schools or having private tutors, contributed to their enthusiasm for STEM at KOSEN. The students' interests in KOSENs and STEM were driven by

the manifold background personal, social, formal, and informal educational experiences.

STEM Research Inspirations

Table 2 shows that students chose their STEM research topics based on various factors, including personal interests, experiences, family influence, career goals, and societal or environmental concerns. The projects demonstrate connections across multiple STEM fields. Topic diversity underscores the value of open-ended, student-driven ECAs in enhancing KOSEN students' grasp of how STEM disciplines interrelate and apply to real-world scenarios beyond what is taught in the structured curriculum.

Table 2

Research Topic Choices & Inspiration

STEM Fair Research Topics	Choice Reason & Inspiration
Spacecraft one-fourth scale replica	Career aspirations
Earthquakes-resistive-building structures	Preparedness for disasters, future relocation
Logos designs and colors	Personal interest in designs and their impact
Urban sustainable planning	Personal and career interest in architectural sustainable development method
Car engine designs (Air Engines)	Career aspiration and personal curiosity
Sustainable fertilizers	Familial influence and personal interest in agriculture and environmental sustainability.
Food enzymes	Familial influence and personal interest

STEM Fair Research Topics	Choice Reason & Inspiration
Car engine design (Lego engine)	Career aspirations
Marine debris investigation	Environmental & community issues
Cloth shrinkage	Personal interest based on hobby-related real-life problems
3D Image processing	Personal interest in future technology.
Covid-19 prediction	Personal experiences

Scientific Method

Students across both STEM and non-STEM disciplines report similar gains from UREs, such as enhanced independence and improved communication skills (Stanford et al., 2017; Craney et al., 2011). However, STEM students benefit more significantly in areas like formulating research questions and gaining opportunities for publication (Thiry et al., 2012). At KOSEN, scientific thinking and inquiry courses prepare students to effectively apply these methods in their independent extracurricular research, utilizing the scientific method to establish clear objectives and conclusions.

Thiry et al. (2012) observed that research benefits vary with students' experience: beginners gain fundamental research skills and confidence, while more experienced students develop advanced scientific reasoning. Participants in the study showed diverse adherence to the scientific method in their STEM projects. Some rigorously followed all steps, from hypothesis formation to data analysis, while others streamlined the process, focusing more on experimentation. Despite these variations, all students utilized the scientific method as a core framework to guide their investigations, creatively adapting it to meet their unique research needs.

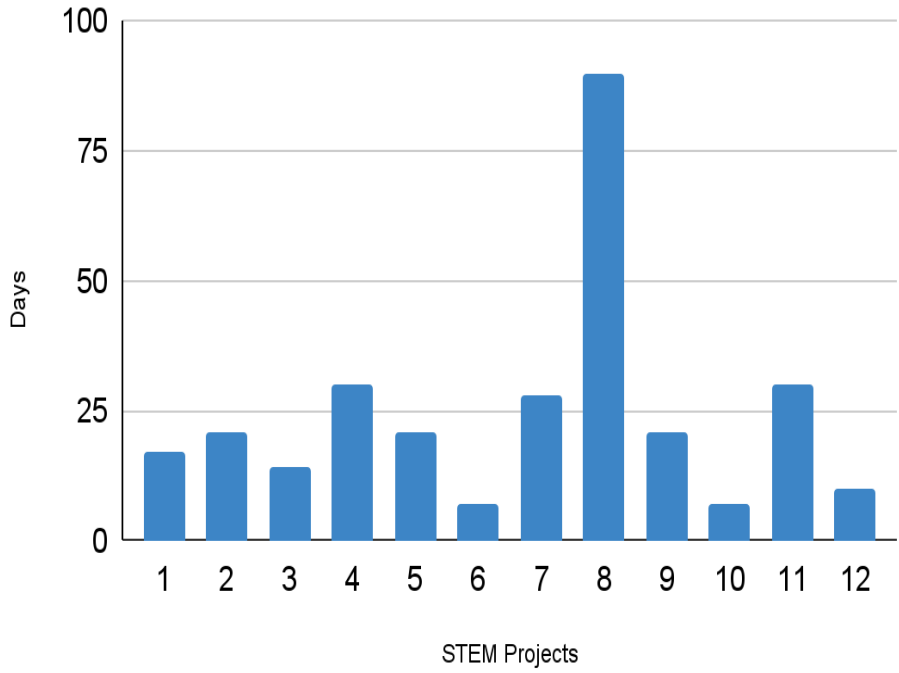
STEM Research Experiences

Figure 2 shows significant variation in the completion times for STEM projects, ranging from a few weeks to over a month. Typically, the research, planning, and data analysis stages take longer than experimentation or construction. The time

needed depends on the project's complexity, available resources, and the student's prior experience and commitment to the topic.

Figure **2**

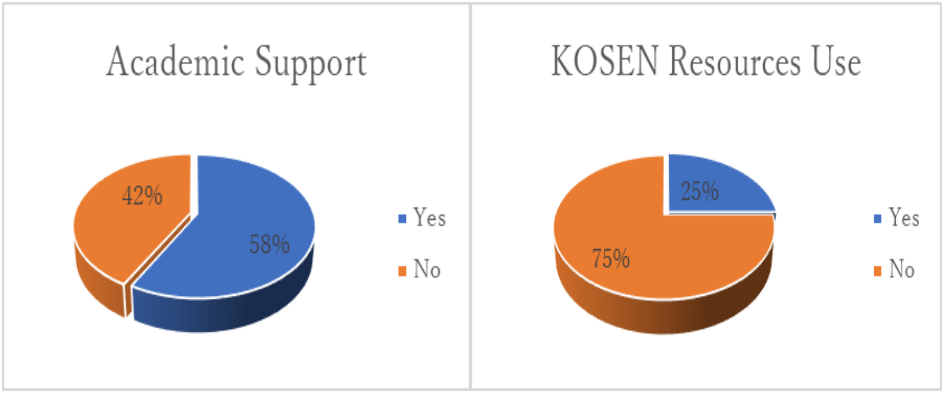
STEM Fair Project Time Length



Students valued KOSEN's accessible resources, such as 3D printers, laser cutters, and Lego parts, for their projects. STEM professors provided guidance on analytical techniques and complex equations, and English professors assisted with presentation skills. While family and external experts also provided technical advice, some students primarily relied on their own efforts, with just logistical support from family, as illustrated in Figure 3. This varied support significantly influenced the students' project outcomes and experiences.

Figure 3

Academic Support & KOSEN Resources



The research process was both exciting and challenging for participants. Initially enthusiastic about conducting university-level research, they quickly faced hurdles such as finding reliable data and affordable materials, described as "finding the same technology! Cheap & affordable!" Participants struggled with developing effective equations and prototypes—"It did not work at the beginning!"—and experienced difficulties with experimental conditions, including "Material contents! Match conditions in the Experiment! Analyzing data! First time! Choosing colors! Controlling factors!".

Despite these challenges, participants relished overcoming these hurdles, with significant moments of success in data collection and prototype development bringing particular excitement. The creativity involved was also enjoyable: "Fun discovering new facts!" "Fun because I could design something!" The climax of their efforts led to impressive results beyond their initial expectations: "The result was not something I could imagine!" "Interesting & futuristic results!", even surprising their families: "My father was surprised that I made it!". Ultimately, the research process was intellectually stimulating and rewarding, highlighting scientific inquiry's dynamic yet demanding nature.

Peer Presentations and Prize-winning Expectations

Students admired the diversity of their peers' STEM presentations, praising particularly complex projects like a Lego engine build. They also highlighted thorough, creative presentations on topics ranging from food enzymes to environmental issues and technology. Some found the COVID-19 probability modeling notably interesting and challenging. Overall, they valued

learning from the various interests and skills displayed through these presentations.

Despite not expecting awards and recognizing their own areas for improvement, many students were pleasantly surprised and proud to receive recognition. Some saw their peers' projects as more advanced, which sparked feelings of regret over their own achievements. Ultimately, they found the STEM research process rewarding and felt accomplished. Their reflections showed a deep understanding of the iterative nature of scientific discovery and technological innovation, emphasizing its importance in advancing knowledge and technology, enhancing global understanding, and fostering new applications.

STEM Fair Project Compared with Science Projects in Compulsory Education

Students found the STEM Fair at KOSEN far more advanced and integrative than the simple experiments, observations, or kit-following activities of their earlier elementary and junior high projects, known as JIYUKENKYU. At KOSEN, students independently select topics, develop hypotheses, design experiments, produce prototypes or models and analyze data to present findings, utilizing extensive school resources for in-depth technical research. The projects tackle real-world problems, offering a comprehensive approach that significantly enhances research, analysis, and presentation skills beyond previous educational experiences.

Comparison Between Poster Presentation Experiences

KOSEN students participate in poster presentations in English and Engineering Design (ED) courses, each tailored to different educational outcomes. English presentations focus on improving communication skills, emphasizing delivery over content accuracy to engage the audience effectively. Conversely, ED presentations aim to balance the design process and data accuracy, highlighting the management of challenges and design thinking procedural steps. On the other hand, STEM Fair projects stress scientific accuracy with an emphasis on precise data collection and analysis, aiming for comprehensive research processes. These projects allow students to explore topics of personal interest, showcasing a research-centric approach unique to STEM Fair activities. Curricular ED projects in KOSEN typically emphasize teamwork and focus on creating functional prototypes tailored to specific user needs, contrasting with STEM Fair projects' more individual and exploratory nature, which prioritize scientific inquiry. While ED projects address practical applications and meet external requirements, STEM Fair projects engage students in scientific research driven by personal interests. This progression from English presentations through ED to STEM Fair reflects

increasing complexity and sophistication, especially evident at STEM Fairs, where high expectations and structured feedback enhance the presentation and research qualities. These experiences collectively develop skills ranging from scientific research to communication and practical problem-solving, with students valuing the autonomy and depth offered by STEM Fair projects over the more structured group tasks in ED projects.

Skills Developed Through STEM Fair Project

KOSEN's STEM Fair projects significantly enhance students' educational journey. According to participants, these projects improve students' English proficiency in scientific and technical terms and advance their presentation and poster design skills. They build vital research and data analysis capabilities and strengthen their determination, perseverance, and motivation to complete long-term projects. Participating in these projects allows students to apply their classroom knowledge practically, gaining experience in scientific methods, hypothesis testing, and analytical skills, thereby enhancing their ability to communicate complex ideas effectively. Ultimately, the STEM Fair equips students with essential skills for STEM careers, such as scientific inquiry, critical thinking, problem-solving, and clear communication.

Future STEM Research Plans and Career Choices

Participants are keen to continue their existing STEM research projects and explore new topics. They have shown interest in environmental issues like microplastics, snow power generation, and diverse fertilizers. Additionally, they aim to advance their research techniques by incorporating more technology and conducting further experiments. Some believe improvements can be made to their posters and presentations to make them clearer and more convincing. These students exhibit a wide array of STEM interests and are committed to enhancing their understanding through continued research, whether by expanding on current projects or initiating new ones.

Participants are still exploring their career options, utilizing the diverse educational opportunities at KOSEN to identify their interests and potential career paths. Some are drawn to engineering sectors such as aerospace, automotive, or environmental, with a keen interest in integrating new technologies like AI and automation. Others lean towards design and visual arts, aiming to use these skills in fields such as automotive design. After attending Startup ECAs, some are considering entrepreneurship as a way to pursue their varied interests more freely. Students appreciate the hands-on projects and ECAs provided by KOSEN as crucial experiences shaping their future career choices.

Extracurricular and Curricular Activities at KOSEN

Encouraging ECA participation is a predictor of the student's educational satisfaction (Çubukçu, 2024). Students recognize ECAs as vital complements to their KOSEN curriculum, offering essential opportunities for exploring interests and potential careers. They recognize that these activities vary in impact, depending on individual goals and motivations. As one student noted, "I think we really need the ECAs. The classes are mainly to develop basic knowledge and to help me find what I am actually interested in. By understanding this, I use this knowledge and observations to help me in the ECAs."

KOSEN's curriculum lays the foundational "input" of knowledge and skills, while extracurricular activities serve as "output" platforms, applying learning in practical contexts to boost engagement. Some students favor educational extracurriculars like the STEM Fair, viewing leisure activities as less substantial "time fillers." Conversely, others value recreational activities for stress relief and social engagement, noting, "It relieves your stress and sometimes things you learn just by having fun… and I think it really gives you a chance or place where you can have the interest, be interested in some of the fields." Overall, students appreciate the balance between academic and recreational activities, which serves diverse interests and diversifies the educational experience.

Students appreciate the balance KOSEN offers between foundational knowledge and skills from the curriculum and the practical applications provided by ECAs. These platforms for fun and stress relief through sports, music, and outdoor adventures are also generally considered satisfactory. This balance accommodates diverse interests and facilitates meaningful learning experiences and social interactions.

DISCUSSION

Based on the results, KOSEN students prefer nontraditional, interactive STEM education over rote memorization and test-oriented methods typical of Japanese compulsory education. One student reflected, "In junior high, it was all about memorizing for tests, which wasn't fun. I wanted a school that offered a different style of learning—not like public junior high schools."

In Japan, STEM education lacks a standardized curriculum within formal education systems, with no clear consensus on content and teaching methods; however, in informal education settings (NARAIGOTO) actively engages in STEM activities, such as robotics and digital fabrication, though these STEM activities tend to align more with technology education without a distinct STEM framework (Yata et al., 2020). This research confirms that initial comprehension of STEM concepts varies among KOSEN students. However, their experience at KOSEN significantly improves their understanding of how these disciplines intertwine and their broader applications. This emphasizes the importance of

KOSEN in fostering advanced critical thinking and suggests enhancing STEM education from early stages to deepen students' insights into the goals and significance of STEM across all educational levels.

Research highlights the profound educational benefits of UREs across disciplines, noting that students often gain a deeper understanding of their fields and the scientific process, alongside increased confidence in their scientific abilities (Lopatto, 2004; Nagda et al., 1998; Russell et al., 2007; Seymour et al., 2004). Unlike any STEM undergraduates, KOSEN students are younger and probably uncertain or not wholly familiar with the nature of specific academic or career pursuits. KOSEN curricula foster scientific thinking and inquiry, but the depth of understanding in specific STEM fields and the ability to make informed academic and career choices can vary. The STEM Fair project enhances academic and career choices by allowing students to choose their research topics, allowing for more personalized and meaningful exploration. Personal interest, familial influence, industry trends, and future career aspirations influenced students' choices of research topics. KOSEN students' STEM research projects, while not always directly related to their course content, benefit from the foundational skills in mathematics, physics, engineering design, and data analysis learned through their KOSEN education. These skills enable them to independently pursue diverse research interests, applying critical thinking, problem-solving, and technical skills acquired at KOSEN to their own innovative projects. The KOSEN curriculum provides students with the tools and mindset for engaging in independent, innovative STEM research through extracurricular activities like the STEM Fair. These comprehensive experiences help students develop a clearer vision of their potential research and career paths, highlighting the unique value of individual research projects over group work by fostering autonomy and self-confidence.

The analysis highlights not only students' individual ECA research experiences but also broader educational, social, and emotional aspects. It underscores the need for realistic expectations, valuing hands-on problem-solving, ongoing support, and managing the emotional challenges of academic pursuits. Additionally, it stresses the importance of self-assessment, peer comparison, goal achievement, and recognition.

CONCLUSIONS

This STEM extracurricular activity deepened students' grasp of scientific research methods and the interconnection between various STEM disciplines, enabling the application of this knowledge in real-world and technological contexts. It also introduced students to STEM research and presentation, broadening career perspectives and extending benefits beyond the standard curriculum. These findings emphasize the importance of providing flexible, guided research

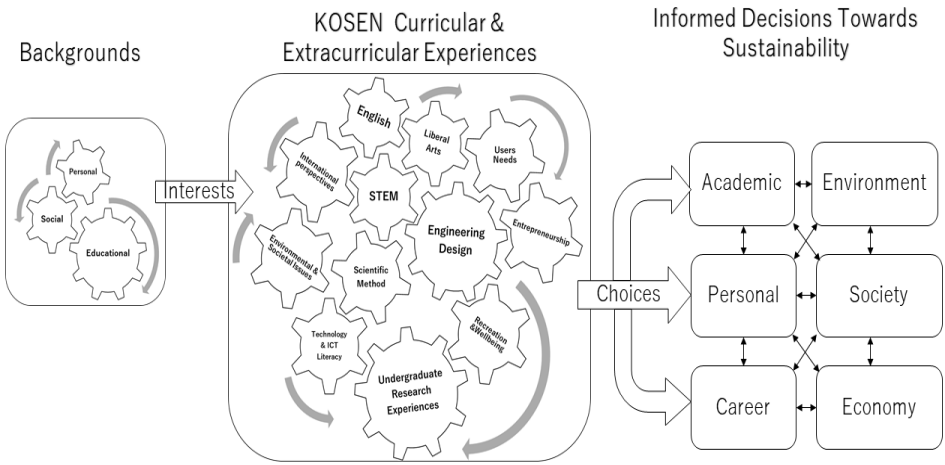
opportunities. Students' personal interests, which guide their topic choices, distinguish extracurricular activities from formal coursework.

STEM ECAs focusing on UREs at KOSENs offer educational multilayer experiences that expand students acquired academic and professional skills, preparing them for future careers and promoting personal and academic growth. These activities foster a sense of community through projects that tackle real-world issues and require strategic decision-making. Although challenges like time restraints and resource limitations over the summer holiday remain, the positive impacts suggest that KOSENs should continue supporting and expanding these programs and provide organizational solutions for the defined obstacles.

However, the current study's findings may be limited by the scope and size of the selected sample. To build on these results, future research should broaden the sample to include more diverse student populations. Comparative studies involving students from other KOSENs or similar institutions would provide valuable insights and could serve as a control group, helping to confirm or expand upon these findings.

Figure 4

Theoretical Mechanism of KOSEN Education in Students' Lives



The KOSEN curriculum provides foundational STEM knowledge and fosters problem-solving and design-thinking skills through inquiry-based learning. ECAs at KOSEN allow students to apply this knowledge to real-world issues, societal needs, and technological advancements. Both curricular and

extracurricular experiences are integral, acting like gears in the educational process. Figure 4 illustrates how these experiences interconnect where the gear size metaphorically represents the effort needed to achieve impacts, emphasizing each element's role in the educational process. Students' personal, social, and educational backgrounds lead to their interest in STEM education at KOSEN. They enroll in KOSEN seeking an unconventional higher education institution that provides multiple comprehensive experiences. For them, the well-balanced KOSEN curricular and extracurricular experiences deepen their understanding of what they can and need to do in the future. They can make informed personal, academic, and career choices based on this. This balanced educational approach helps students from various backgrounds deepen their understanding and make informed decisions about their futures, preparing them to contribute to society on multiple fronts actively.

This study implies that KOSEN's educational model possibly exemplifies how higher education institutions can contribute to sustainability through its iterative and comprehensive approaches. To confirm that, there is a critical need for further quantitative and qualitative research on the design, impacts, and challenges of applying STEM ECAs across all national, public, and private KOSENs to support the current findings focusing on educational policies, theories, and practices. Such studies are expected to enrich and influence the STEM educational methods for higher education institutions in Japan and internationally.

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APPENDIX
List of Definitions

Extracurricular Activities:
The literature lacks a universally accepted definition of extracurricular activities. To maintain consistency, this study adopts Bartkus et al.'s (2012, p. 698) definition: "Extracurricular activities are academic or non-academic activities conducted under the school's authority but outside regular class time, without being part of the curriculum. They do not involve grades or academic credit, and participation is optional for students."

STEM Education:
STEM has various definitions across educational contexts. This study follows the recent, comprehensive definition from the NSTA (2020), which describes STEM education as "an experiential learning pedagogy where knowledge and skills are

applied through real-world projects or problems focused on developing college and career readiness proficiencies."

JIYUKENKYU:
This Japanese term means independent or free research, referring to self-directed research projects assigned to elementary and junior high school students during the summer holidays.

NARAIGOTO:
This Japanese term refers to acquiring self-improvement skills and knowledge through informal, interest-based activities. It encompasses learning new skills or expanding knowledge outside formal education. For further context, see this article: (https://www.jef.or.jp/journal/pdf/197th_younger_generation_2.pdf).

EIKAIWA:
A Japanese term that translates to "English conversation." It refers to private or group lessons where students focus on practicing spoken English, typically emphasizing real-life communication rather than strict grammar or writing, helping learners gain confidence in speaking English to improve their conversational skills for travel, business, or personal growth.

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