Elucidating the Inspirational Factors in School-Based FabLab Activities and the Development of Independence

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Abstract

How can schools cultivate individuals who engage in creative making? This study investigates the role of school-based FabLabs in fostering student engagement and learning. Through an analysis of activity types, motivational triggers, and formed subjectivity, the findings reveal that students actively engage in both skill acquisition and exploratory challenges, predominantly driven by intrinsic motivation. Participation in school-based FabLabs enhances autonomy, execution skills, technical proficiency, and inquiry ability, while external inspirational factors, such as peer interactions and resource discovery, further stimulate engagement. These results underscore the significance of school-based FabLabs as dynamic learning environments that cultivate self-directed learning, technical skill development, and sustained intellectual curiosity.

Keywords: *STEAM, FabLab, Self-directed Learning, Inspirational Factors, Collaborative Learning Environments*

1. Introduction

In recent years, STEM education, which integrates science, technology, engineering, and mathematics, has gained global prominence (Japan Society for STEM Education, 2017). Additionally, STEAM education in Tennessee, USA, aims to cultivate a workforce that values innovation and equips students with the ability to apply mathematical and scientific thinking to problem-solving (Utsumi, 2024). One initiative to enhance STEM education is the FabLab (Fabrication Laboratory), a concept introduced by Professor Neil Gershenfeld of the Massachusetts Institute of Technology (MIT) (FabLab Charter, 2012). FabLabs are experimental community workshops equipped with various digital and analog machine tools, forming a global network of makerspaces.

In Japan, efforts are underway to align with these international trends. For example, FabLab Kamakura operates as a community-based laboratory that fosters communication through hands-on making and promotes the development of a new business ecosystem (Watanabe, 2013). Additionally, FabLabs have been established within schools (school-based FabLab; hereafter, s-Lab) to support independent learning among junior and senior high school students (Matsuura, 2020; International STEM Learning Association, 2018; Tokutake, 2023). One such case reports the integration of digital fabrication tools, such as 3D printers and laser cutters, into a high school computer lab as part of an information science curriculum. Tokutake (2023) highlights that s-Lab creates an environment conducive to self-directed learning and fosters future engineers. Furthermore, Saito (2024) analyzed students' motivations for participating in Tokutake's (2023) s-Lab and found that "many students find learning itself engaging and are able to work autonomously."

However, it remains unclear to what extent students who belonged to s-Lab participated in activities and what motivated them. A deeper understanding of the learning processes within these spaces could contribute to the effective design of s-Lab environments.

To address this gap, this study conducted semi-structured interviews and questionnaire surveys with three university students who graduated from s-Lab, analyzing their verbatim responses qualitatively to identify key requirements for optimizing student engagement and learning in these environments.

Specifically, our analysis focuses on two aspects: (1) factors that inspire student engagement (Inspirational Factors; hereafter, IF) and (2) the development of independent learning behaviors (Formed Subjectivity; hereafter, FS) in s-Lab. In this study, IF refers to factors that influence students' motivation to learn, while FS is defined as "a learning consciousness that actively utilizes the s-Lab environment as an educational resource."

In this paper, we distinguish between "triggers"—the immediate reasons or impetus for initiating an activity (e.g., a teacher's recommendation or an assignment requirement)—and IF, which are broader motivational elements that sustain or deepen a student's engagement and learning over time.

2. Related Research

To analyze and evaluate the progression of student learning in the s-Lab, we reviewed several studies deemed pertinent to this research.
Niwa et al. (1998) classified five types of physical play based on their analysis of children's play behaviors. This framework offers insights into how different forms of engagement can influence motivation and skill development, which is relevant for understanding learning processes in s-Lab. The five categories are:

- **Challenge Play**: Activities that balance stability and instability, fostering self-confidence and a sense of competition.
- **Motor Skill Acquisition Play**: Involving practice of technically oriented actions (e.g., using horizontal bars or balls) aimed at mastering specific skills.
- **Dizzy Play**: Enjoying sensations of instability and excitement generated by movement, environmental factors, and social interaction.
- **Pretend Play**: Structured around rules and imitation, facilitating creative and role-based engagement.
- **Constructive Play**: Employing materials such as sand, water, cardboard, or blocks to build structures and encourage problem-solving and innovation.

Additionally, Ichikawa (1998) classified high school students' learning motivations into six orientations (Figure 1). These orientations are arranged along two axes: the perceived importance of learning content and the utilitarian dimension of rewards and penalties (i.e., whether the outcomes provide personal gain). These two axes form a 2×3 matrix that categorizes student motivations accordingly.
Furthermore, Haramiishi et al. (2017) developed a 21-item framework to evaluate university students' making skills. This framework assesses key competencies, including initiative, problem-finding ability, interdisciplinary knowledge, and questioning skills.

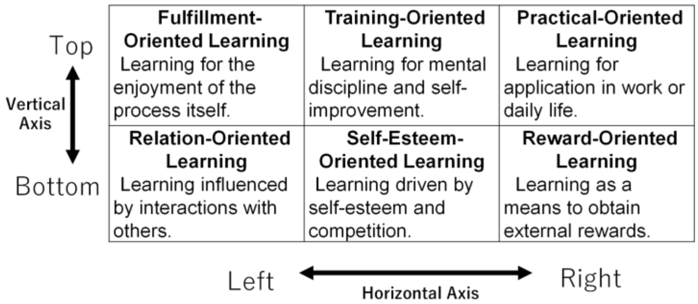

Fig. 1. Two-Factor Model of Learning Motivation
(Based on Ichikawa, 1998, modified by the authors)

3. Purpose of This Study

This study has two main objectives:
(1) to explore how students belonging to a school-based FabLab (s-Lab) acquire various forms of learning, and (2) to identify key requirements for enriching student learning in the s-Lab environment.
To achieve these objectives, we conducted the following surveys and analyses:

(Survey 1) Creation of Learning Activity Records

A **learning activity log** (hereafter, "activity log") was developed for participants to record their experiences in the s-Lab. This log included details such as the content of activities, the initial impetus, and the period during which the activity took place. Drawing on the classification of children's physical play by Niwa (1998), we adapted the categories and, furthermore, classified the initial impetus for each activity based on Ichikawa's (1998) two-factor model. The activity log was shared via Google Spreadsheets, and data were collected once participants completed their entries.

(Survey 2) Semi-Structured Interviews

We conducted individual **semi-structured interviews** (Patton, M. Q., 2014) online with three university students who had previously belonged to the s-Lab. Based on the details recorded in the activity logs, we asked follow-up questions to delve deeper into the reasons behind each activity choice and its initial impetus.

(Analysis 1) Examination of Participants' Making Experiences

To evaluate the relationship between experiences gained in the s-Lab and participants' making skills, we performed a statistical analysis using the data obtained from (Survey 1) in conjunction with a rubric by Haramiishi (2017).

(Analysis 2) Qualitative Analysis Using SCAT

We then applied SCAT (Ohtani, 2022) to the verbatim transcripts of the semi-structured interviews and the information in the activity logs. Through this process, we extracted key phrases and conceptual constructs, focusing on how Inspirational Factors (IF) and Formed Subjectivity (FS) develop in s-Lab activities.

(Discussion)
Finally, we conducted a comprehensive discussion in light of the **objectives** of this study, considering how the findings can inform the design and enhancement of learning experiences in s-Lab environments.

4.1.1. Learning Activity Log

Participants were asked to complete an activity log, indicating their grade at the time of each activity, the approximate period (e.g., April, around spring), the specific content of the activity, and the immediate trigger for starting it (e.g., teacher's suggestion, self-initiated interest). Note that these triggers are distinct from IF, which are conceptualized later through qualitative analysis. This log was created and shared using Google Spreadsheets (Table 1).

Table 1: Table Learning Activity Log

Grade	Month	Activity	Activity Type	Trigger	Trigger Type
10th	Spring	Joined the Math Research Club	Individual Activity	Recommended by homeroom teacher	Relationship-Oriented
10th	N/A	Participated in an online exchange session with other math research groups	Challenging Activity	Instructor's intention	Relationship-Oriented, Fulfillment-Oriented
10th	N/A	Conducted independent research on catenary curves (visualized using Python)	Individual Activity	Interest	Fulfillment-Oriented
11th	Unknown	Created Tetris in Python	Individual Activity	Experimenting whether Python can create games	Fulfillment-Oriented

Additionally, participants were asked to select the type of activity and the type of impetus for each recorded entry. The activity-type options were adapted from Niwa (1998), who classified forms of physical play among young children; multiple responses could be chosen. Below are the categories we developed:

- **Challenging Activities**: Activities driven by motivations such as self-actualization, placing trust in one's confidence.
- **Skill-oriented Activities**: Activities aimed at acquiring specific technical skills.
- **Expectation-driven Activities**: Activities in which participants enjoyed the anticipation or excitement of others' expectations.
- **Individual Activities**: Activities undertaken alone.
- **Team Activities**: Activities undertaken with one or more other individuals.
- **Other**: Activities that did not fit any of the categories above.

For the type of impetus, we employed the two-factor model by Ichikawa (1998), also allowing multiple selections. Once the participants completed the activity logs, we proceeded with semi-structured interviews.

4.1.2. Semi-Structured Interviews

To clarify the nature of activities in which participants had been involved, we conducted semi-structured interviews incorporating the five categories of activities and the two-factor model. During these interviews, we focused on both the triggers that initiated participants' involvement and the broader IF that sustained their engagement, as well as any indicators of FS that emerged from their reflections. These interviews were designed based on Niwa (1998), Ichikawa (1998), and the semi-structured interview methodology of Patton (2014). Each interview took place online, one-on-one, for approximately 30 minutes, after obtaining consent for data protection and voluntary participation.
Sample questions included:

- "Why did you select these specific activity categories?"
- "Why did you choose that particular impetus?"
- "What was the reason for selecting 'Other'?"
- "What motivates you to engage in s-Lab activities?"

All interview responses were recorded, and verbatim transcripts of approximately 20,000 characters in total were produced for subsequent analysis.

5. Analysis Methods and Results

5.1. Activity Types and Triggers in the s-Lab

In this study, we define "triggers" as the immediate factors initiating an activity, whereas Inspirational Factors (IF) refer to elements that sustain or deepen learning motivation. This section examines the types of activities and the triggers experienced by the participants, based on their activity logs.
First, the following numbers show how many times each of the six activity types was selected:
Participant A: 34, Participant B: 4, Participant C: 14
A breakdown of these six activity types for Participants A–C is shown below (with direct quotes from verbatim records in quotation marks):

- **Challenging Activities**: "Participated in an exchange session with the math research club"
- **Skill-Oriented Activities**: "Learned modeling with Blender," "Studied basic Python"
- **Expectation-Driven Activities**: "Created an electronic door lock in the ICT lab," "Developed an app to extract only failing-grade students from Excel files"
- **Team Activities**: "Developed a VR game using Unity," "Created a VR game for the school festival"
- **Individual Activities**: "Developed a smartphone game to perform prime factorization"
- **Other Activities**: "Talked to junior students while working"

Next, we present the number of selections for each of the six trigger types:
Participant A: 22, Participant B: 8, Participant C: 15
The responses for these six triggers are as follows:

- **Fulfillment-Oriented**: "I was interested in AI," "Experimenting to see if Python can create games"
- **Training-Oriented**: "I wanted to study mathematics through programming"
- **Utility-Oriented**: "For increased efficiency"
- **Relationship-Oriented**: "My homeroom teacher recommended it," "I became interested because A invited me"
- **Self-Esteem-Oriented**: "Reported this as part of the math research club's achievements"
- **Reward-Oriented**: "For an exhibit in the school festival"

Using the data in Table 2, a chi-square analysis at the 5% significance level found no statistically significant differences (χ^2=11.92, df=10, p=0.291). This suggests there was no substantial deviation between observed and expected values across the types. Similarly, the data in Table 3 yielded no significant differences at the 5% level (χ^2=14.69, df=10, p=0.144). However, some types showed large, standardized residuals, indicating possible biases. For instance:

- **Activity Type**: A residual of 2.15 for "Skill-Oriented Activities," suggesting a strong focus on acquiring technical abilities.
- **Trigger Type**: "Fulfillment-Oriented" was the most frequent, suggesting that participants were strongly motivated by enjoyment of the learning process itself.

Analyzing these standardized residuals reaffirmed the emphasis on "Skill-Oriented Activities" (residual 2.15) for developing new skills, as well as the prominence of "Fulfillment-Oriented" triggers that highlight the enjoyment of learning. These findings suggest that participants in the s-Lab primarily aimed to learn and enjoy new technologies.

Table 2. Response Results for the Six Trigger Types

Trigger Type	A	B	C	total	%
Fulfillment-Oriented	11	2	7	20	44.4
Training-Oriented	2	2	0	4	9.0
Practical-Oriented	5	2	3	10	22.2
Relation-Oriented	2	2	3	7	15.6
Self-Esteem-Oriented	0	0	2	2	4.4
Reward-Oriented	2	0	0	2	4.4

Table 3. Test Results for the Six Activity Types

Activity Type	Observed Value	Expected Value	Standardized Residual	Test Result
Challenging Activity	11	8.33	0.79	
Skill-Oriented Activity	15	8.33	2.15	▲
Expectation-Driven Activity	6	8.33	-0.91	
Team-Based Activity	5	8.33	-1.25	
Individual Activity	11	8.33	0.79	
Other	4	8.33	-1.59	

▲ Significantly Higher, ▽ Significantly Lower

5.2. Relationship between Activities and Making Skills

To clarify how participants' activities relate to various making skills, we analyzed them using the 21-item evaluation indicators developed by Haramiishi (2017). Two authors (the first and second) determined which making skills were relevant to each activity recorded by the three participants. A mark of "1" indicated relevance, and "0" otherwise.

As shown in Table 4, a wide range of making skills can be cultivated through the three participants' activities. A chi-square test and residual analysis of these data showed a chi-square statistic of 212.92 with 20 degrees of freedom, yielding an extremely small p-value (p < 2.2e-16). This indicates a significant difference between observed and expected values, suggesting bias across the types.

Moreover, the standardized residuals revealed that autonomy (6.09) and skill/technical abilities (6.09) were substantially above the expected values, while discipline (-3.30) and stress management (-3.30) were below. These results highlight particularly strong occurrences of "autonomy," "capacity to execute," "skill/technical abilities," and "questioning skills." The s-Lab thus seems to function as an environment conducive to practical, hands-on learning. In addition, participants tended to engage more actively in "Challenging Activities," "Skill-Oriented Activities," and "Individual Activities," implying that the s-Lab encourages both new technological challenges and the pursuit of new competencies. Because such engagement also corresponded to a "Fulfillment-Oriented" trigger, it indicates that participants approached these activities with both autonomy and intrinsic motivation.

Table 4. Results of Residual Analysis

Label	Observed Value	Expected Value	Standardized Residual	Test Result
Autonomy	31	10.90	6.09	▲
Proactive Engagement	4	10.90	-2.09	
Execution Skill	29	10.90	5.48	▲
Problem-Finding Skill	16	10.90	1.54	
Planning Skill	9	10.90	-0.58	
Creativity	17	10.90	1.85	
Communication Skill	3	10.90	-2.39	
Listening Skill	2	10.90	-2.70	
Flexibility	2	10.90	-2.70	
Situational Awareness	6	10.90	-1.49	
Discipline	0	10.90	-3.30	▽
Stress Control Skill	0	10.90	-3.30	▽
Management Skill	2	10.90	-2.70	
Leadership Aptitude	2	10.90	-2.70	
Idea Generation	16	10.90	1.54	
Collaboration	4	10.90	-2.09	
Skill & Technical Skill	31	10.90	6.09	▲
Craftsmanship	15	10.90	1.24	
Design Skill	6	10.90	-1.49	
Interdisciplinary Interest & Knowledge	6	10.90	-1.49	
Questioning Skill	28	10.90	5.18	▲

▲ Significantly Higher, ▽ Significantly Lower

5.3. Analysis of Environment and Learning

This study sought to determine how IF in the s-Lab setting influence students' learning. We employed SCAT (Ohtani, 2022) for our qualitative analysis, following the steps below:

1. **Conceptualizing Prompts**
   We extracted (1) key terms, (2) paraphrased words, (3) explanatory phrases, and (4) conceptual constructs (Table 5).
2. **Creating a Storyline and Theoretical Description**
   Using the conceptual constructs, we developed a storyline capturing the context in which participants' needs arose and then formulated a theoretical description (Table 6).
3. **Forming the Types**
   From the conceptual constructs obtained, we identified types of **IF** and **FS**.

Drawing on these SCAT-derived concepts, Tables 7 and 8 show the relationship between the s-Lab environment and Participants A–C in terms of learning. Table 7 outlines the IF identified in this study, along with examples of subsequent changes in awareness. For instance, Participant B, after receiving an "invitation," shifted from being unable to act on his own to adopting a mindset open to new challenges—suggesting that an IF such as "invitation" can serve as a trigger for initiating new activities in the s-Lab. Meanwhile, Table 8 introduces types of FS and specific examples of corresponding learning behaviors. In one case, Participant C developed autonomy in "environmental management," proactively leveraging the s-Lab as a learning resource to broaden opportunities for intellectual curiosity and collaboration. Overall, the findings indicate that four types of IF encourage learning motivation, while two types of FS facilitate the use of the s-Lab environment as a resource, collectively forging an interactive relationship between the s-Lab and Participants A–C.

5.4. Summary of the Analysis Results

Table 5. SCAT Analysis of Learning Activities

No.	Speaker	Text	(1) Key Phrases in the Text	(2) Paraphrased Phrases	(3) Concepts Explaining the Phrases	(4) Theme / Constructed Concept
1	A	Oh, if you don't enable SSL, you get a warning, right? So, yeah, if I wanted to put the web server online as it was, I *had to* enable SSL.	SSL / warning / web server / publish / had to	Mandatory step / compliance	Explanation of why it was necessary	Justification for the necessity of this activity
2	Author	Basically, it was necessary for 37, 38, 37, 39, 40, and 41, so yeah.	37, 38, 37, 39, 40, 41 / necessary	Activity number / required	Checking whether the activity was necessary	Confirmation of the necessity of the activity
3	A	Uh, yeah. I mean, it wasn't just necessary, but like, I *had* to do it. I couldn't move on to the next step without it, so, yeah, I *had* to.	Necessary / next step / had to	Required / next step / awareness / understanding	Understanding what comes next and taking proactive action	Recognizing one's activity status and engaging proactively
4	Author	So, how did you end up joining ICTLab? You mentioned A invited you and that's how you got interested. Can you tell me more about what kind of conversation you had? Like, what did they say that made you curious?	ICTLab / Joining Trigger / A / Invitation / Interest	Activity Location / Background of Joining the Community / Peer Influence / Encouragement / Becoming Interested	How personal connections contribute to getting involved in activities	Encouraging detailed exploration of the reasons behind joining an activity
5	B	Well, ICTLab was started by the people before us. A was already interested in programming too, and when I enrolled, he suggested we try it out together. I thought, "Why not?" and just gave it a shot.	ICTLab was established / Predecessors / A / Interest / Invitation	Birth of a New Community / Peers / Interest / Invitation	Getting introduced to a new activity by someone / Joining because of prior interest	Being influenced by others' interests and deciding to join an activity
6	Author	You said you studied basic programming languages. Did you already understand the basics, or were you told, "Start with this first" or something like that?	Basic Language / Understanding / Recommended	What was relied upon when starting an activity	What references were used when beginning the activity	Understanding how someone gets started with an activity
7	B	With Python, I just kinda went with it. Someone suggested, "Why don't you give it a try?" so I did.	Python / Trying it out	Basic Language / Guidance	Being directed toward achieving a goal	Being introduced to a pathway for achieving a goal
8	Author	So far, I've been studying programming, but somehow, I don't really relate it to 3D printers. Do programming and 3D printing actually have a deep connection?	Programming / 3D printer / No link / Relation	Confirmation of whether the current activity relates to past activities	Verifying the relevance of one's past activities and current interests	Verifying the connection and triggers between past activities and current interests
9	B	There may not be a direct connection. It was just that at that time, a friend at ICTLab was making things with a 3D printer, and as I watched them create more and more, I thought it looked really interesting and decided to try it.	A friend at ICTLab / Observing / Interesting / Starting	Being attracted by others' activities and starting one's own	Influence from others' activities leading to new engagement	Starting new activities influenced by others' interests
10	Author	I like programming and want to study it more, but I wonder if everyone at ICTLab is studying programming for the same reason. I'd like to know more.	Liking programming / Wanting to study / ICTLab only / Studying	Limiting the learning environment	Necessity of defining one's learning environment	Reason for limiting the learning environment
11	B	The reason I kept studying at that time was simply that I enjoyed learning programming languages. Also, having a group of friends to learn and practice programming with made it even more fun.	Programming / Learning / Friends / Together / Fun	Learning environment / Peers / Studying together / Enjoyment	Psychological security maintained in a peer-based learning environment	Maintaining psychological security while continuing activities in a peer-supported space
12	Author	Yes. Next, I worked on developing a Unity-based VR project, and I also taught this to my juniors. So, would you say that was a main focus?	VR / Development / Juniors / Teaching / Main focus	Teaching juniors as a goal	Encouraging responses about the purpose of activities	Encouraging responses about the purpose of activities
13	C	I didn't initiate the idea of creating a VR game—rather, it was the juniors who started it. Well, I didn't originally think about it, but as I was teaching them, I figured that VR might be useful for me too, so I decided to study it a bit.	VR / Game / Initiating an idea / Juniors / Teaching / Useful / Studying	Teaching juniors and simultaneously learning from the process	Collaboration in activities leads to personal learning	Collaboration in activities connects to personal learning
14	Author	The reason I wanted to share my activities with others was because I originally belonged to a math research club. But there was a reason why I shifted to ICTLab. What was that reason?	Activity / Sharing / Math Research Club / Transitioning to ICTLab / Reason	Changing the activity environment / Reasons for transition	Reason for changing one's activity environment	Reason for changing one's activity environment
15	C	There were more people interested in information technology, and also, I simply wanted a broader space for sharing activities. It wasn't just about moving from the math research club to ICTLab, but more about expanding the activity space.	IT-related interests / Interests / Expanding the activity space	Expanding spaces for activities based on personal interests	Expanding the spaces where one's intellectual curiosity and activities can be shared	Expanding one's intellectual curiosity and spaces for sharing activities

The goal of this study was to explore how students in an s-Lab acquire knowledge and skills, and to identify requirements for enhancing that learning. The main insights are as follows: Students frequently performed "Challenging Activities" and "Skill-Oriented Activities," with "Fulfillment-Oriented" triggers being most prevalent. This indicates that the s-Lab fosters self-directed learning. However, fewer triggers related to collaborative activities or reward motivations were noted, suggesting the need for designing activities that leverage IF to promote collaboration and support various learning objectives. s-Lab activities strongly enhanced "autonomy," "capacity to execute," "skill/technical abilities," and "questioning skills," demonstrating that the s-Lab offers a practical environment for developing applied competencies. Meanwhile, "discipline" and "stress management" appeared relatively low, implying that adjustments in activity design or teaching approaches might be beneficial.

We identified both IF and FS operating within the s-Lab. New technologies and social interactions can function as learning triggers, while a learner's proactive approach to using the s-Lab environment (FS) was also evident. Although the s-Lab effectively promotes motivation and supports self-directed learning, further development of IF and deeper engagement with FS—such as improved environmental management—remain areas for ongoing research.

Collectively, these findings suggest that an s-Lab is highly conducive to developing technical skills and learner autonomy. Future efforts should aim to diversify triggers and IF, encouraging students to undertake collaborative work and novel challenges more autonomously. In doing so, the s-Lab can continue evolving into an environment that offers deeper and more varied learning experiences.

Table 6. Storyline and Theoretical Description

Storyline
The interviewer asked Participant A to explain why this activity was necessary, leading to a [confirmation of the necessity of the activity]. In response, Participant A [recognized their own activity status and engaged in the activity autonomously].Next, Participant B, after being prompted to [elaborate on the background of starting the activity due to interpersonal interactions], revealed that they had been [drawn into the activity by others who shared their prior interests and consequently participated in a new activity]. Furthermore, when asked [how they started the activity], or when asked about [the relationship between their continued activity and the new interest they developed], they responded by [seeking guidance from others to achieve their goal]. This led to the confirmation that [interest in others' activities can serve as a trigger for initiating one's own activities]. Additionally, when questioned about [the reason for restricting their activity environment], it became clear that they [continued their activities in an environment that ensured psychological safety and included peers]. On the other hand, Participant C exhibited a motivation to [engage in collaborative activities, connecting their own learning through cooperation]. Finally, when asked about [the reason for modifying their own activity environment], it was revealed that they aimed to [expand spaces for sharing their intellectual curiosity and activities].
Theoretical Description
In the school-based FabLab (s-Lab), students sometimes [recognize their own activity status and engage in activities autonomously]. Additionally, they may [be drawn into new activities by others who share their prior interests]. Moreover, [receiving guidance from others to achieve their goals] or [being inspired by others'activities] can serve as triggers for initiating their own activities. Furthermore, regarding [the reason for restricting their activity environment], the primary factor was [ensuring psychological safety and continuing activities in an environment with peers]. When asked [to clarify their activity objectives], participants showed motivation to [engage in collaborative activities that connect to their own learning]. Additionally, when asked about [the reason for modifying their own activity environment], it became evident that they aimed to [expand spaces for sharing their intellectual curiosity and activities].

Table 7. Inspirational Factors and Their Role in Learning

Inspirational Factor	Specific Example of Inspirational Factor	Awareness After Inspiration	Utterance Content	Mediation for Learning
Invitation	Someone inviting	Challenge to engage in activity	"Initially, when ICTLab* was established, it was by our generation. Originally, "Rossi" was also interested in programming, but when we entered school, he invited me, saying, 'Do you want to try it together?' So, I decided to give it a try, and that's how it started." (2)	Being drawn into new activities by others who share their prior interests.
Instruction/ Advice	Someone teaching	Desire to design one's own activities	"Regarding Python, at first, I just tried it as I was told." (2)	Receiving guidance from others to achieve one's goals.
Collaboration	Content one wants to learn	Expectation of acquiring new knowledge	"Someone else initiated a VR project, and since I had never done it before, I decided to learn a bit while teaching them." (3)	Engaging in collaborative activities that connect to one's own learning.
Discovery	Interest/curiosity in the context of tasks	Interest and curiosity towards resources	"A friend was making things with a 3D printer at ICTLab, and as I watched them continuously creating, I thought it looked really interesting and decided to start." (2)	Being inspired by others' activities as a trigger for one's own.
Inevitability	Situation where an unavoidable task arises	Willingness and determination to follow through	"To proceed to the next stage, I had to do it; it was something that had to be done." (1)	Recognizing one's own activity status and engaging in activities autonomously.

Table 8. Categories of Formed Subjectivity and Learning Actions

Category of Formed Subjectivity	Emerging Learning Actions	Utterance Content
Environmental Management	Expanding spaces to share one's intellectual curiosity and activities	"There are many people who are more interested in information-related topics. ICTLab, too. Also, it's not just that the shared space moved from the Mathematics Research Club to ICTLab, but rather, it was about broadening the space for activities." (3)
Collaborative Knowledge	Maintaining psychological safety and continuing activities in an environment with peers	"Having an environment where I could learn programming together with like-minded peers was really enjoyable for me." (2)

6. Comprehensive Discussion

From these findings, we can summarize the requirements clarified in this study as follows:

1. **Analysis 5.1** indicated that students in the s-Lab engage in activities with both enthusiasm and a willingness to tackle new challenges.
2. **Analysis 5.2** showed that s-Lab activities notably elicit the making skills of “autonomy,” “capacity to execute,” “skill/technical abilities,” and “questioning skills.”
3. **Analysis 5.3** revealed that students’ activities in the s-Lab are driven by **IF**—sparked by exposure to new technologies or interactions with peers—and supported by **FS**, where they utilize the environment as a learning resource.

In light of these requirements, teachers overseeing an s-Lab are encouraged to design educational settings that deliberately promote both students’ making skills and the cultivation of IF and FS. While the s-Lab clearly provides an effective context for self-directed learning, creative teaching strategies can further maximize its impact. A particular contribution of this study is its qualitative elucidation of students’ learning characteristics in the s-Lab, as well as the IF and FS that emerge within such an environment.

Nevertheless, because participants in this investigation had relatively few team-based activities, factors related to “discipline”—one identified making skill—were not sufficiently explored. Furthermore, this study did not comprehensively or quantitatively evaluate all possible IF. Hence, the following points emerge as future tasks:

1. Investigate cases where team activities are actively integrated, examining which IF stimulate “discipline.”
2. Increase the number of participants to expand the dataset and develop indices for holistically evaluating the diverse learning environment of s-Labs.

Such endeavors will advance our understanding of how s-Labs can accommodate a broader range of learning objectives and continue to enrich students’ educational experiences.

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