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

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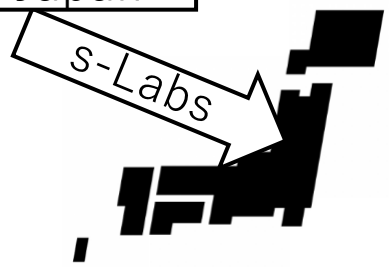
What are School-Based FabLabs?

MIT, Berlin

- FabLabs originate from MIT (Gershenfeld, 2012) as digital fabrication workshops.
- Open Design City(Berlin): Associated with “open (source) design” on the Web, linked to “city planning” in the real world, and “open” to citizens.

Japan



- School-Based FabLabs (s-Labs):
- Adapted for educational settings, equipping students with hands-on STEM/STEAM learning experiences.
- Increasingly used in Japan for fostering self-directed learning and technical proficiency.

s-Labs

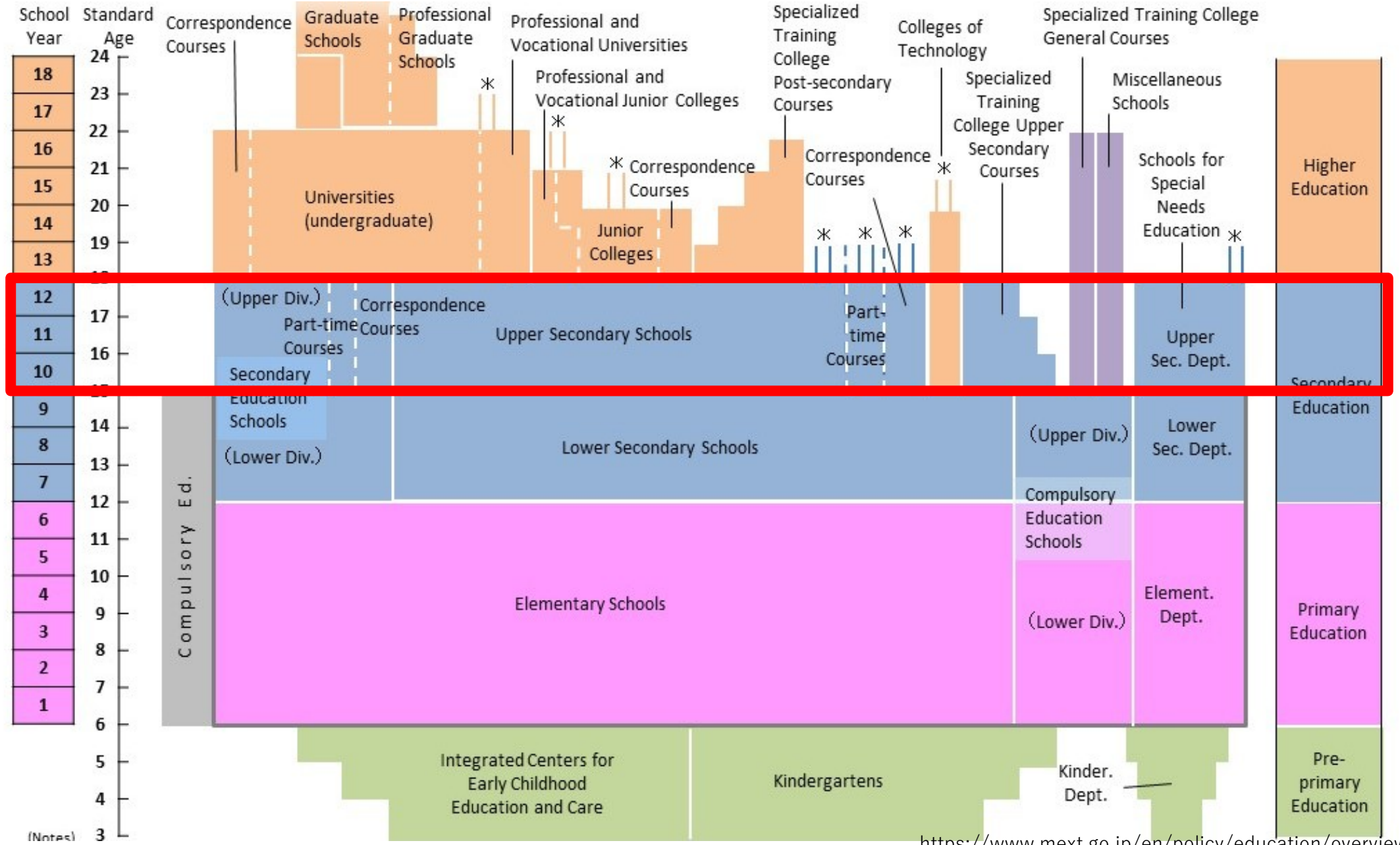
?

Student’s ability

Research Gap

Understanding these motivational factors is crucial for designing effective learning environments.

The Japanese School System and the Position of s-Labs



https://www.mext.go.jp/en/policy/education/overview/index.htm

Purpose of This Study

Ⅰ） **Student engagement** in FabLab activities: What **activities** do students undertake?

Ⅱ） **Independent Learning Development**: How does FabLab participation foster autonomy?

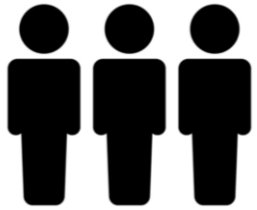
Ⅲ） **Inspirational Factors (IF)**: What motivates students to **participate** and **persist**?

By addressing these questions, we hope to gain insights that will inform the better design of FabLab-based learning environments. These insights will contribute to the design of effective FabLab-based learning environments.

Research Design & Methodology

We combine qualitative and quantitative methods to analyze student engagement.

interview



- Interview for three university students who previously participated in s-Lab activities.

Data Collection

- Activity Logs: Students recorded engagement in FabLab projects.
- Semi-Structured Interviews: Explored motivations and learning experiences.

Data Analysis

- Classification of Activity Types & Triggers.
- SCAT Qualitative Analysis: A four-step coding method extracting-key phrases, explanatory concepts, and theoretical constructs.

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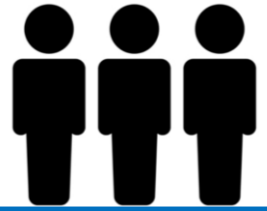

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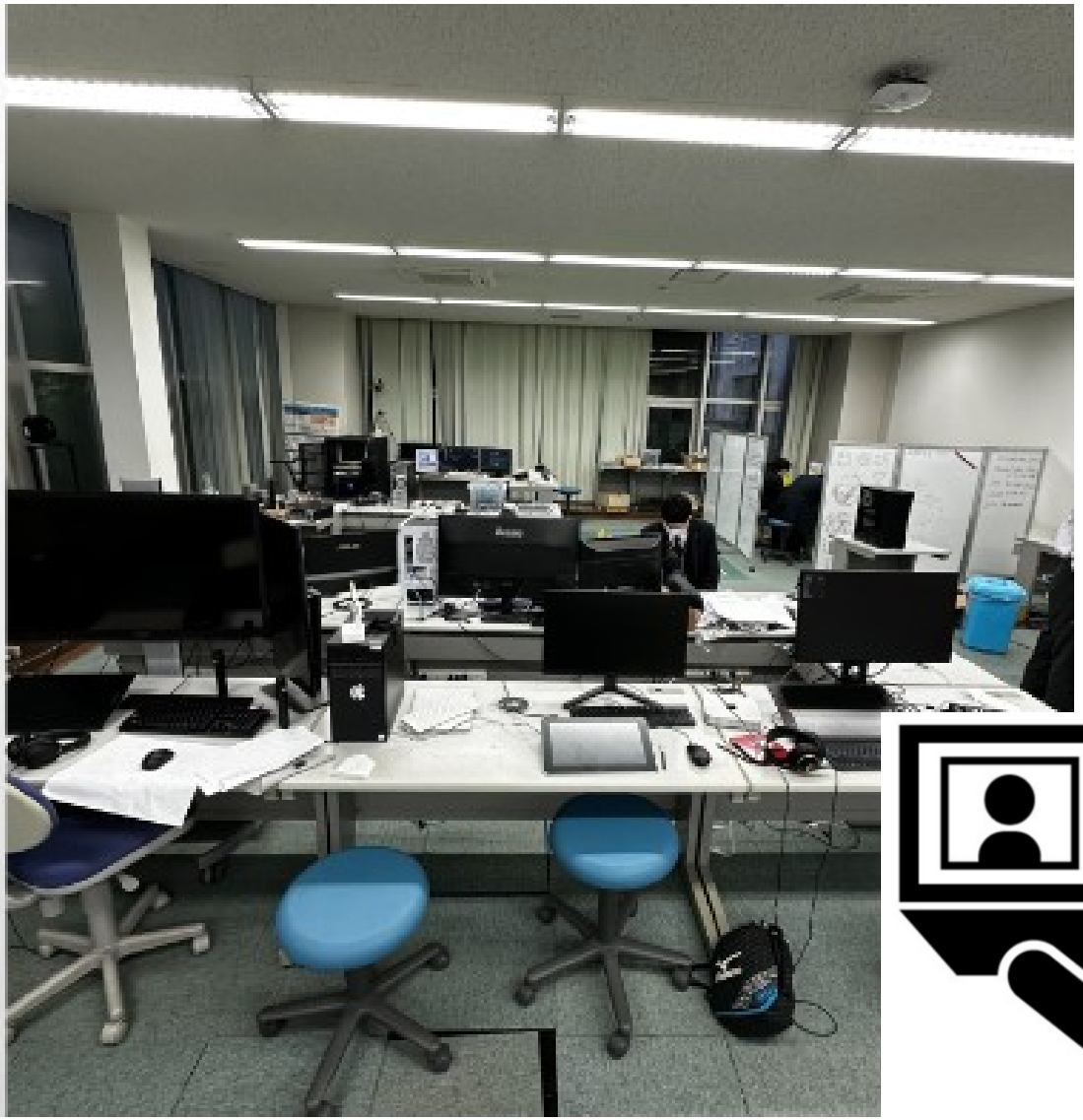
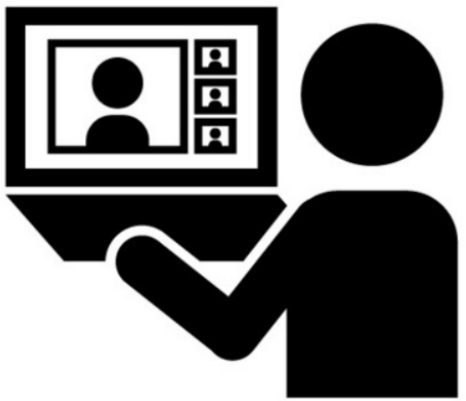
Following photos were presented to participants while the interview.





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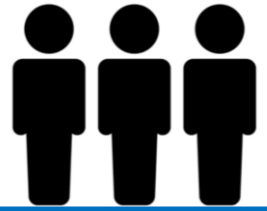

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Research Design & Methodology

Table Learning Activity Log while interview

学年	月	活動内容	活動の5カテゴリー	きっかけ	6カテゴリー
高1	春頃	数理研究同好会に所属	個人での活動	担任の先生にすすめられた	関係志向
		数理研究の他行とのオンライン交流会に参加	挑戦的な活動	顧問の意向	関係志向
					充実志向

Analyzed children's play behavior and categorized physical play Niwa et al. (1998)

Activity types categorized into:

1. Challenging Activities
2. Skill-Oriented Activities
3. Expectation-Driven Activities
4. Individual Activities
5. Team-Based Activities
6. Other (e.g., mentoring younger students)

Framework provides insight into how different forms of play affect motivation / skill development.

Learning Motivation (Ichikawa, 1998)

Top

Vertical Axis

Bottom

Fulfillment-Oriented Learning Learning for the enjoyment of the process itself.	**Training-Oriented Learning** Learning for mental discipline and self-improvement.	**Practical-Oriented Learning** Learning for application in work or daily life.
Relation-Oriented Learning Learning influenced by interactions with others.	**Self-Esteem-Oriented Learning** Learning driven by self-esteem and competition.	**Reward-Oriented Learning** Learning as a means to obtain external rewards.

Left ⟷ Right

Horizontal Axis

Two axes: importance of learning content and utilitarian vs. intrinsic motivation. Helps categorize student engagement triggers in FabLabs.

Created an instrument (Table Learning Activity Log) to be used in the interviews.

Research Design & Methodology

We combine qualitative and quantitative methods to analyze student engagement.

interview

Data Collection

Data Analysis

- Interview for three university students who previously participated in s-Lab activities.
- Activity Logs: Students recorded engagement in FabLab projects.
- Semi-Structured Interviews: Explored motivations and learning experiences.
- Classification of Activity Types & Triggers(inspired by Ichikawa, 1998).
- SCAT Qualitative Analysis: A four-step coding method extracting-key phrases, explanatory concepts, and theoretical constructs.

Research Design & Methodology

Study combine qualitative and quantitative methods to analyze student engagement.

A B C

Participants' score of activity log

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					卒業志向

Authors' check using rubric

Item	
1.Autonomy	✓
2.Proactive Engagement	
3.Execution Skill	✓
・ ・ ・	

Caluculate

Trigger Type	A	B	C
Fulfillment-Oriented Learning	11	2	7
Training-Oriented Learning	2	2	0
Practical-Oriented Learning	5	2	3
Relation-Oriented Learning	2	2	3
Self-Esteem-Oriented Learning	0	0	2
Reward-Oriented Learning	2	0	0

Activity Type	Observed Value
Challenging Activity	11
Skill-Oriented Activity	15
Expectation-Driven Activity	6
Team-Based Activity	5
Individual Activity	11
Other	4

We coded and quantified the descriptions and selected categories from the activity log obtained through interviews. These data were then analyzed statistically to understand student engagement patterns and learning motivations in s-Labs."

Research Design & Methodology

The conceptualization of the learners' prompts was conducted using Otani's (2022) Steps for Coding and Theorization (SCAT) qualitative analysis method, which consists of four steps:

(1)Key Phrases in the Text, **(2) Paraphrased Phrases**, **(3) Concepts Explaining the Phrases**, and **(4) Theme / Constructed Concept**.

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

Linking Research Objectives with Analysis Methods

To effectively present our results, I will explain how each research objective guided our analysis.

Objective I）Student engagement in FabLab activities: What activities do students undertake?

- Analysis Method: Classification of Activity Types (based on Ichikawa's Framework)
- Data Source: Activity Logs

Objective II）Independent Learning Development: How does FabLab participation foster autonomy?

- Analysis Method: Residual Analysis for Skill Development
- Data Source: Semi-Structured Interviews

Objective III）Inspirational Factors (IF): What motivates students to participate and persist?

- Analysis Method: Thematic Coding (based on SCAT Framework)
- Data Source: Semi-Structured Interviews

Result and Analysis[1/3] What Motivates Students to Engage?(1)

Table 2. Response Results for the Six Trigger Types

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

- Students are predominantly motivated by intrinsic enjoyment rather than external rewards.

Result and Analysis [2/3] What Motivates Students to Engage?(2)

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				

- Skill-Oriented Activity showed a significantly higher engagement ($p < 0.05$).
- Students engaged significantly more in skill-oriented activities, reinforcing the importance of hands-on learning in FabLabs.

Result and Analysis[3/3] How Does FabLab Engagement Impact Skills?

Key skills significantly developed:

- Autonomy (+6.09 residual)
- Execution Skill (+5.48residual)
- Execution & Technical Skills (+6.09 resid
- Questioning Skills (+5.18 residual)

- Students actively improve their technical expertise, problem-solving, and inquiry abilities in FabLabs.

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

Result and Analysis[1/2] What Inspires Long-Term Engagement? (1)

. Inspirational Factors and Their Role in Learning
: Analysis based on SCAT (Steps for Coding and Theorization)

Inspirational Factor	Mediation for Learning
Invitation	Being drawn into new activities by others who share their prior interests.
Instruction/ Advice	Receiving guidance from others to achieve one's goals.
Collaboration	Engaging in collaborative activities that connect to one's own learning.
Discovery	Being inspired by others' activities as a trigger for one's own.
Inevitability	Recognizing one's own activity status and engaging in activities autonomously.

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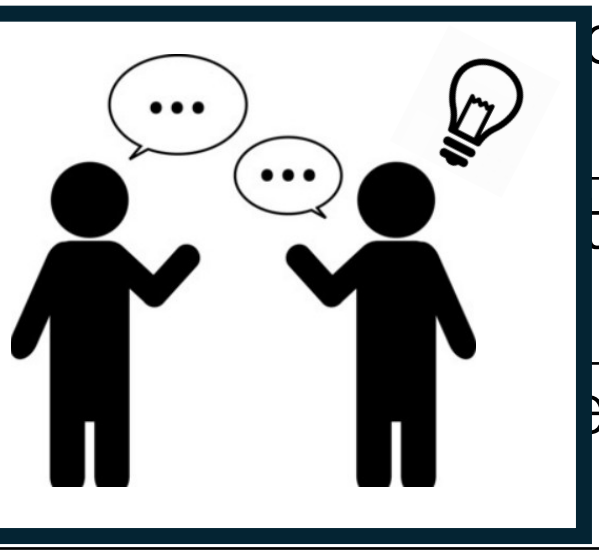

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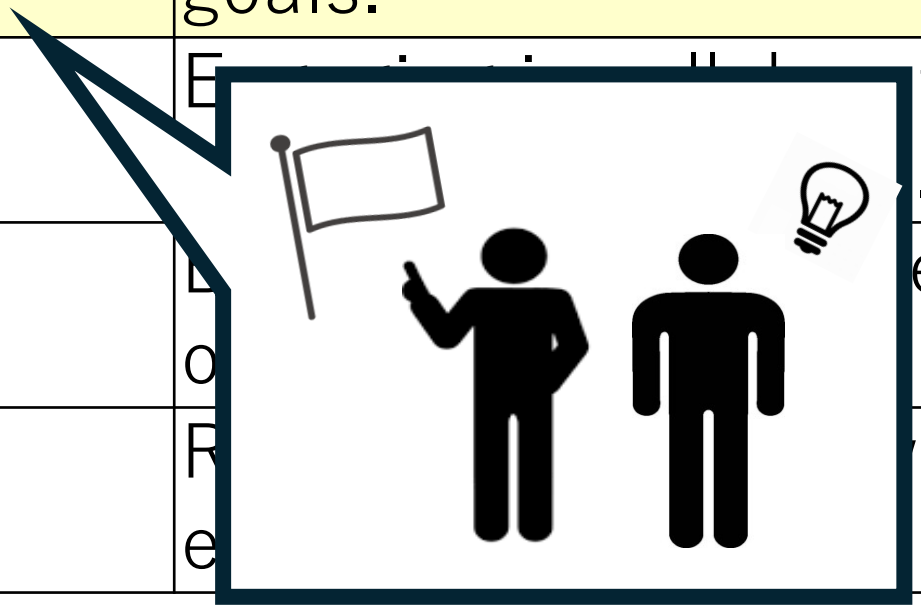

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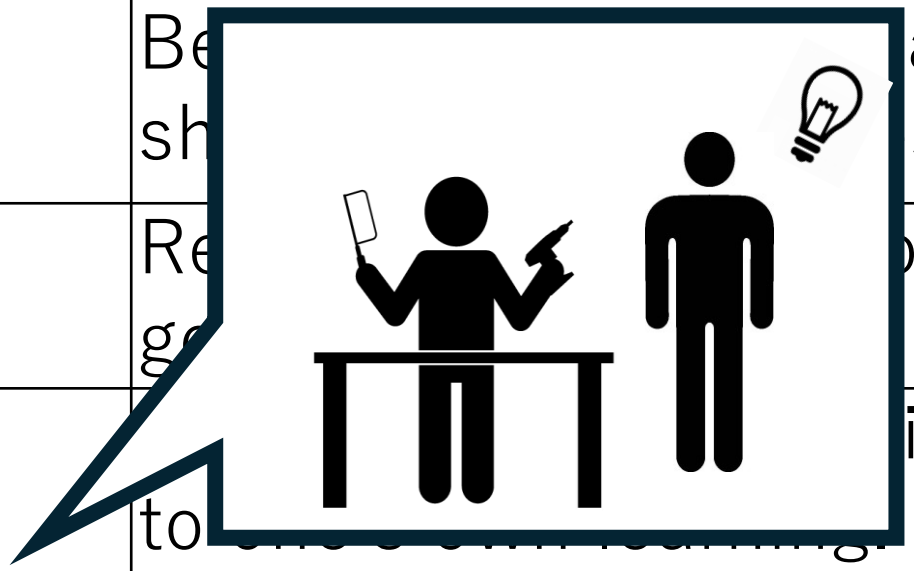

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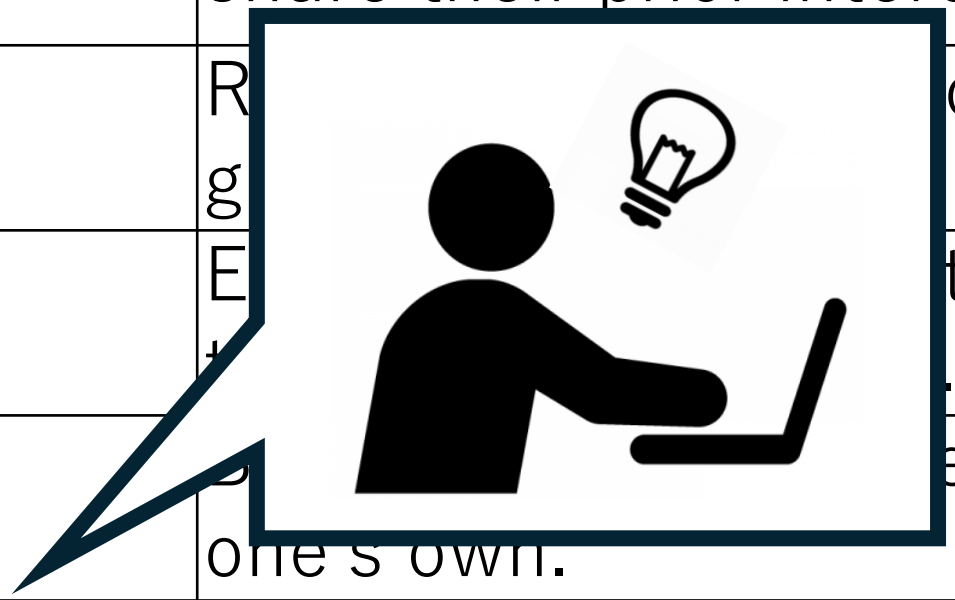

Result and Analysis[1/2] How Do Students Become Independent Learners?(2)

Table 8. Categories of Formed Subjectivity and Learning Actions: Analysis based on SCAT (Steps for Coding and Theorization)

Category	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)

FabLabs foster autonomy by encouraging students to take initiative in their learning environments.

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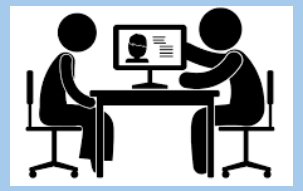
Environmental Management 	Expanding spaces to share one's intellectual curiosity and activities	"There are many people who are more interested in information-related topics. ICTLab, too. Also, it's not just that the shared space moved from the Mathematics Research Club to ICTLab, but rather, it was about broadening the space for activities." (3)
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Key Insights & Educational Implications

FabLabs foster self-directed learning through Inspirational Factors (IF), encouraging autonomy and skill-building. However, some challenges remain.

Key Strengths:

- Students develop independence and technical proficiency.
- Hands-on experiences reinforce intrinsic motivation.

Challenges & Educational Implications:

- Limited collaborative activities
  → Suggests the need for structured teamwork programs.
- Lack of stress management strategies
  → Highlights the opportunity to integrate resilience training.
- Variability in engagement levels
  → Calls for personalized support systems to sustain long-term participation.

Future Directions:

- Implement structured peer collaboration activities.
- Introduce stress-coping strategies to support student persistence.

Thank you for listening.

References

[1] Utsumi, S., & Nakamura, Y. “A Study on the Engineering Design Process (EDP) in STEM Teaching Materials at the Elementary Level in Tennessee, USA: Implications for Problem-Solving in Japanese Science Education,” *Journal of Science Education (Japan)*, Vol.64, No.3, 2024, pp.221–235.

[2] Fab Foundation. "Fab Charter," Online resource, 2025. https://fab.cba.mit.edu/about/charter/ (Accessed January 18, 2025.)

[3] FabLab Japan Network. "FabLab Japan Network," Online resource. http://fablabjapan.org/ (Accessed January 18, 2025.)

[4] Haramiishi, Y., Horiuchi, H., Ishida, K., Furuya, N., & Ouchi, H. "1A11: Rubric-based Educational Effects for Assessing Making Skills," *Proceedings of the 65th Annual Conference of the Japanese Society for Engineering Education*, Japan Society for Engineering Education, 2017, pp.20–21.

[5] Ichikawa, S., Horino, M., & Kubo, N. "Perspectives on and Motivations for Learning that Underlie Study Methods," In S. Ichikawa (Ed.), *Study Method Consultation and Guidance from the Perspective of Cognitive Counseling*, Brain Publishing, 1998, pp.186–203.

[6] Otani, T. (2008). "SCAT" a qualitative data analysis method by four-step coding: Easy startable and small scale data-applicable process of theorization. *Bulletin of the Graduate School of Education,* Nagoya University, 54(2), 27-44.

[7] Matsuura, R., Okabe, D., & Watanabe, Y. "Case Report on the Introduction of a FABLAB in Public High Schools: A Practical Study," *Japanese Journal of Educational Technology*, Vol.44, No.3, 2021, pp.325–333.

[8] Japan Society for STEM Education. Online resource, 2017. https://www.j-stem.jp/ (Accessed January 20, 2025.)

[9] Niwa, T. "Classification of Physical Play in Early Childhood," Dōhō Fukushi: Ningengaku Fukushi-hen, No.4, 1998, pp.46–36.

[10] Saito, M., Tokutake, K., & Sakuma, D. (2024)"Classification and Application of Feedback Prompt Requests for Generative AI in Self-Directed Programming Learning Among High School Students," *CIEC Spring Conference Proceedings*, Tokyo, Japan.

[11] Patton, M. Q. "Qualitative Research & Evaluation Methods: Integrating Theory and Practice," *Sage Publications*, Thousand Oaks, 2014.

[12] Watanabe, Y. (2013). *FabLab’s role in innovating manufacturing*. *Quarterly Journal of Public Policy & Management*, 25(1)–28(4). Mitsubishi UFJ Research & Consulting.

[13] Tokutake, K., & Sakuma, D. "Construction of a Learning Environment for Self-Sustaining Study in the School’s Fab Lab," *Proceedings of the CIEC Spring Conference (Web)*, Vol.14, 2023, pp.27–32.

Result and Analysis[1/2] What Inspires Long-Term Engagement? (1)

Inspirational Factors and Their Role in Learning
: Analysis based on SCAT (Steps for Coding and Theorization)

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.