Nature of Students' Research Projects at a Japanese National High School

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Abstract

There is a dearth of research that shows the nature of Japanese high school students' Project Research (課題研究) outputs. In this study, we determined the major recurring themes, issues addressed, research designs, and STEM competencies exhibited by the research projects made by students from a national high school in Ehime Prefecture, Japan. Using a text mining software and manual categorization, we found that the major themes set by the students for their research were concentrated on local issues familiar to them such as revitalization of local cultures and communities, and development, improvement, and utilization of technologies related to agriculture and disaster prevention. These themes aligned directly with the top Sustainable Development Goals issues that most of the students focused on: Sustainable Cities and Communities (SDG 11) and Industry, Innovation, and Infrastructure (SDG 9). For the design of their research, most of the students used non-experimental research design which included survey, field, and archival designs. This may have impacted the results that showed strong indications that students exhibited STEM skills like complex problem-solving, critical thinking, and mathematical thinking and reasoning skills, but quite low indications on skills such as knowledge integration, creativity and innovation, and engineering-design process skills. These results may imply that in guiding students' research, teachers must encourage students to innovate and solve more novel and globally relevant issues.

Keywords: students' project research; text mining analysis; SDGs; research designs; STEM competencies

INTRODUCTION

At a national high school in Ehime Prefecture, Japan, students are provided with a comprehensive academic system and a wide range of highly distinctive education, among which are cooperation initiatives with its affiliated university. A major feature of these cooperation initiatives is the subject offering called *Project Research* (課題研究). This subject offering was designed for students find local and global issues to work on according to their own interests and career aspirations. Moreover, a unique aspect of this subject's design is that students receive direct research guidance from the relevant faculty members of the school's affiliated university. Through this subject, students acquire the

qualities and skills to solve issues and problems pertinent to their society, thus playing a significant role in their communities.

Such design of Project Research subject aligns strongly with the reform of Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT) to promote inquiry-based learning. In the most recent revisions of the Japanese courses of study for science and mathematics for upper secondary schools, Science and Mathematics Inquiry course was established to train students to set their own problems, carry out the process of inquiry on their own initiative, and write reports on the results of their inquiry (MEXT, 2018). MEXT also highlights the similarities between its direction of the emphasis on inquiry-based learning with that of STEM education. In STEM education for supporting high-level cognition, the curriculum is organized such that it provides opportunities for students to creatively link between areas of science, technology, engineering, and mathematics subjects (Taber, 2018). Here, emphasis is placed on problem-solving and problem-based learning through the integration between areas of subject matter. Hence, students taking the Science and Mathematics Inquiry course not only immerse themselves in inquiry-based learning, but they also develop vital STEM skills such as complex problem-solving, 21st century skills, mathematical thinking and reasoning skills, and engineering-design process skills enhanced through problem-based learning (Ruamcharoen, Musor, & Loonjang, 2021).

While there had been recent studies that explored the effects of taking the Project Research course on students' agency (Matsubara, Sumida, Sato, Yoshimura, Kakuto, Onishi, Uwatoko, & Yagi, 2021) and achievement (Matsubara, et.al, 2022), the manner of implementation of the course at different senior high schools (Ichiryu, Muko, & Ikeda 2022), and STEM integration observed on high school students' project research (Sabong & Sumida, 2022), there is not enough evidence to show the nature of the students' research outputs. By exploring the nature of the students' research projects, we can reveal the qualities of their research outputs; whether these research outputs showed relevance to their local and global communities; and whether they exemplified vital competencies such as STEM-related competencies.

This present study is aimed at analyzing the research projects made by high school students from the target national high school in 2021. Specifically, we sought to answer the following questions:

1. What were the major recurring themes of the students' research projects?
2. What type of issues, local or global, or Sustainable Developmental Goals (SDGs) were addressed by the students' research projects?
3. What were the designs of the students' research projects?
4. Did the students' research projects show indication that they demonstrated STEM competencies during their research?

We believe that this study could provide insights on the measures for success of the implementation of the Project Research course at the target national high school and could potentially be a basis for enhancing research program initiatives at high schools.

RESEARCH METHOD

In school year 2021, 230 students from among the 2nd and 3rd grades of senior high school conducted research based on their interests and on relevant local and global issues. A total of 90 research projects were created by 90 diverse groups of students. We acquired a copy of the handbook that contains the summaries of the research outputs. To

further support our analysis, we also collected actual copies of the 90 research papers which are more detailed and made directly by the students themselves.

To understand the nature of these research projects, a text mining software called KH Coder was used to generate a word network of the students' research project titles. We loaded the complete titles of all the research projects to the software and limited the number of nodes to just 40 and the word-frequency up to 3. This was done to naturally drop irrelevant words or topics while surfacing the ones that would provide insights. By interpreting the results of the co-occurrence network, we could find major themes of the research titles from group of words which tend to appear together. From the word frequency list generated by the software as well, we could see whether the research projects addressed local or global issues. To get more precise results, we carefully examined the contents of each research paper and manually categorized them based on the type of issue that they addressed—whether local, global, or both. To determine the quality of the students' research outputs, we classified them based on the design of their research. While research project designs may be classified in multiple ways, we manually categorized them into experimental research, quasi-experimental research, survey research, field research, and archival research (Dane, 1990). Table 1 shows the description for each research design.

Table 1. Research designs and their description

Design	Description
Experimental	aims to establish causal relations between at least one independent and one dependent variable
Quasi-experimental	aims to establish causal relations between independent and one dependent variable/s but does not rely on random assignment
Survey	involves the use of questionnaires to obtain direct self-report information from participants
Field	includes any research applied to natural events—those not created, sustained, or discontinued solely for research purposes
Archival	includes any project in which existing documents or data are the units of observation

Lastly, to surface the STEM competencies exhibited by the students during their research, we adapted the list of STEM competencies by Ruamcharoen, Musor, and Loonjang (2021) and used them as criteria for manually rating each research project. These competencies were knowledge integration, 21st century skills (complex problem-solving, critical thinking, and creativity), mathematical thinking and reasoning skills, and engineering-design process skills. Table 2 shows the description for each criterion.

Table 2. STEM competencies criteria

Criterion	Description
Knowledge Integration	Research exhibited integration of knowledge of STEM (science, technology, engineering, and mathematics) or other disciplines
Complex problem-solving skill	Research showed evidence that students demonstrated the use of scientific method to solve a problem
Critical thinking	Research showed evidence that students demonstrated careful evaluation of the reliability of data given or gathered
Creativity / Innovation	Research showed evidence that students demonstrated ability to innovate and see new ways of doing things
Mathematical thinking and reasoning skills	Research showed evidence that students demonstrated making reasonable connections and predictions based on quantifiable data
Engineering-design process skill	Research showed evidence that students demonstrated ability to plan and design digital and mechanical systems to solve problems

RESULTS AND DISCUSSION

1. Major Themes of Students' Research Projects

By mere inspection of the handbook that contains the summaries of students' projects, the research projects can be organized according to the faculty that guided their research. Based on this, the students' research themes percentage are as follows: Faculty of Education (21%), Law and Letters (20%), Collaborative Regional Innovation (20%), Agriculture (14%), Engineering (11%), Science (7%), and Medicine (7%). However, categorizing the research projects this way did not clarify the nature of the students' research outputs. Using the text mining software called KH Coder, we were able to get a whole picture of the students' research projects. Figure 1.a shows the nodes which formed major topical groups as seen from the different colors that emerged, while Figure 1.b shows the centrality of each node with respect to other nodes.

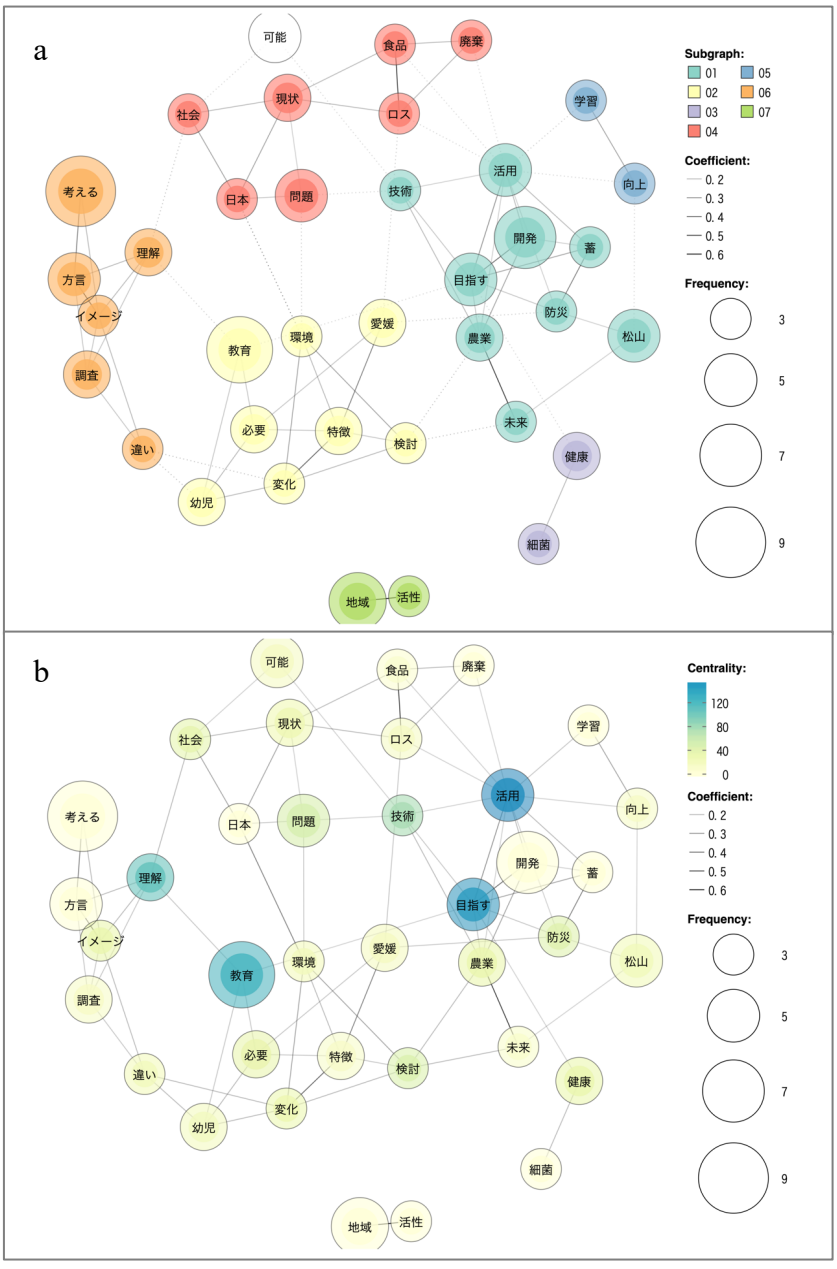

Figure 1. Text network of students' research projects (N=90)

Figure 1.a shows that the major topical groups were focused on the development, improvement, and utilization of technologies related to agriculture and disaster prevention (Subgraph 01); environmental change and education (Subgraph 02); and understanding the differences between certain dialects (Subgraph 06). From Figure 1.b, it can be observed that among the most frequently used words, the word "*utilization* (活用)" most frequently appeared next to the words "*technology* (技術)," "*aim* (目指す)," "*agriculture* (農業)," "*disaster prevention* (防災)," "*learning* (学習)," and "*improvement* (向上)." This word can be considered as the most influential node that is linked to different research topics. The network analysis further showed that many students focused on topics that dealt with revitalization of communities, health, improvement of learning, and food loss. The positive trend that emerged from the analysis was a strong focus on local issues as seen from the words "*Matsuyama* (松山)," "*Ehime* (愛媛)," and "*Japan* (日本)," which may indicate that students were able to process new information by connecting them with local contexts that are familiar to them.

2. Issues Addressed by the Students' Research Projects

Each research summary contained in the handbook included a list of sustainable development goals (SDGs) that are related with or addressed by the project. By mere inspection, it was found that the top issues addressed by the research projects were related to SDG 11 or Sustainable Cities and Communities (14%), SGD 4 or Quality Education (12%), SDG 3 or Good Health and Well-being (11%), and SGD 9 or Industry, Innovation, and Infrastructure (10%). Furthermore, 71% of the research projects addressed at least two SDG issues. For instance, the project "*Production of biodegradable plastics by marine bacteria: protect the richness of the sea with bacteria obtained from sun-dried salt*" addressed five SDGs (SDG 9, 12, 14, 15, and 17).

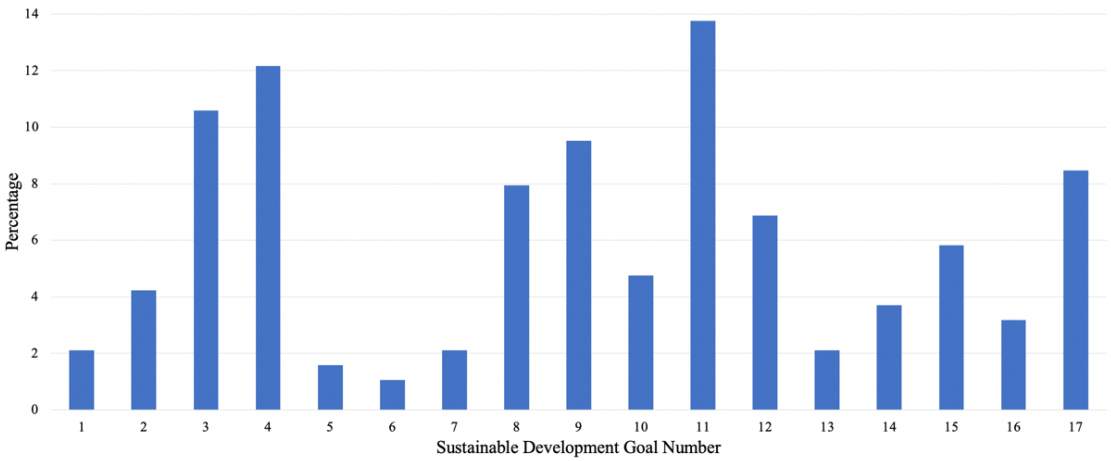

Figure 2. SDG issues addressed by students' research projects

To determine whether the research projects addressed local, global, or glocal (global + local) issues, we referred to the word frequency list produced by the software. Table 3 shows the top 60 words derived from the research titles of the projects that had the highest frequency (*f*). As seen from the table, the words "*Ehime*," "*Matsuyama*," "*Japan,*" "*Community,*" and "*Society*" appeared frequently, which may indicate that the research projects conducted by the students addressed issues that are contextualized to their local communities. We conducted manual categorization of the students' research projects to further clarify this result. Upon careful analysis of the students' research

papers, we found that 42% of them addressed local issues—half of which addressed issues contained in their region (e.g., Matsuyama, Ehime Prefecture) and the other half tackled national issues. This can be confirmed by the results of a recent study which revealed that the students chose research topics that are relevant to their everyday life and local community (Matsubara et.al, 2023). The projects that addressed global issues comprised 30% of the total number of research projects made.

Table 3. Top 60 words derived from the students' research titles

Word	English Translation	*f*	Word	English Translation	*f*	Word	English Translation	*f*
考える	Thinking	9	イメージ	Image	3	グルメ	Gourmet	2
教育	Education	8	マーケティング	Marketing	3	デバイス	Devices	2
開発	Development	7	ロス	Loss	3	プラスチック	Plastics	2
地域	Community	6	違い	Difference	3	プロ	Pro	2
可能	Possible	5	学習	Learning	3	リサイクル	Recycle	2
活用	Utilization	5	活性	Vitality	3	医療	Medical	2
松山	Matsuyama	5	環境	Environment	3	運動	Exercise	2
方言	Dialect	5	技術	Technology	3	映画	Film	2
目指す	Aim	5	検討	Consideration	3	英語	English	2
問題	Problem	5	向上	Improvement	3	音	Sound	2
愛媛	Ehime	4	細菌	Bacteria	3	改善	Improvement	2
健康	Health	4	社会	Society	3	学校	School	2
現状	Current Situation	4	食品	Food	3	楽器	Instrument	2
世界	World	4	蓄	Storage	3	関係	Relation	2
調査	Survey	4	日本	Japan	3	傾斜地	Slope	2
特徴	Features	4	廃棄	Disposal	3	啓発	Enlightenment	2
農業	Agriculture	4	変化	Change	3	景観	Landscape	2
必要	Necessary	4	防災	Disaster Prevention	3	血管	Blood vessels	2
幼児	Infant	4	未来	Future	3	減らす	Reduce	2
理解	Understanding	4	クスノキ	Camphor tree	2	語	Word	2

Interestingly, we found that 28% of the research projects addressed "glocal" issues, or issues that are familiar to students' local contexts but are also connected to global issues (Sumida, 2017). For instance, the research entitled, "*Kiwi x orange: Search for anti-allergic effects from food*" addressed a global issue on good health and well-being (SDG 3) while the students used local ingredients like kiwi and oranges that are very common in Ehime Prefecture upon conducting their research. The research project, "*Effective use of discarded purple cabbage: Let's reduce food loss*" tackled global issues on food shortage and responsible consumption, while the students used purple cabbage which are very commonly used as a salad ingredient in Japan. Lastly, the project entitled, *"Development of devices for smart agriculture Aiming for new agriculture utilizing advanced technology"* addressed the issues on climate action (SDG 13) and decreasing number of labor force in agriculture industry, while the students themselves conducted their research in their school which has a rich history of being an agricultural school.

3. Designs of Students' Research Projects

We categorized each of the 90 research projects according to their research designs by referring to their titles, abstracts, and methods (if present). As seen on Table 4, two-thirds of the research outputs produced by the students were non-experimental in nature, particularly, they had survey (28%), field (26%), and archival (12%) research designs. For instance, the students used open-ended survey questionnaires for their

research on "*The state of childcare support: Focus on the municipality's own policies*" for them to determine what the recipients of the local government's support wanted and needed. Another group of students also surveyed about 300 respondents to determine why Google continues to be used by people all over the world for their research on "*Google's magic: Power to be recognized by the world*." For their research project on "*The current situation and challenges on reducing food loss,*" the students did field research and interviewed convenience store workers and owners to determine how they are helping reduce food loss. For their research on "*Exploring English-specific expressions and sound changes characteristic to spoken language: Through the American movie 'Back to the Future'*," a group of students used archival research design by analyzing English phrases from a scene that they selected from the American movie *Back to the Future*.

Table 4. Research designs of the students' research projects (N = 90)

Design	No. of related research projects	Percentage
Experimental	20	22%
Quasi-experimental	11	12%
Survey	25	28%
Field	23	26%
Archival	11	12%
Total	90	100%

One-third of the total research projects were either experimental or quasi-experimental. Most of the students who conducted these research projects were guided by faculty members from the faculty of science, engineering, and agriculture. For instance, the research projects "*Deposition of impaired lignin upon acceptance of impaired stress in fern plants*," "*Examination of sterilization method based on low temperature plasma sterilization*," and "*Can sericulture waste be used as organic fertilizer?*" were experimental research designs guided by members of the faculty of science, engineering, and agriculture, respectively. For these research projects, the students stated on their research papers that they conducted multiple experiments and trial-and-error strategies to determine the causal relations between their identified dependent and independent variables.

4. STEM Competencies Observed on the Students' Research Projects

In our previous study (Sabong and Sumida, 2022), we observed the integration among STEAM (science, technology, engineering, arts, agriculture, and mathematics) disciplines in the students' research projects. While not all the research projects could be classified under these disciplines, we still found that 22% of the 90 research projects exemplified integration of at least two of the STEAM disciplines. This result was used to report the *Knowledge Integration* criterion percentage. Most of the research projects that showed disciplinal integration were an integration between science and agriculture disciplines. For instance, the research projects "*Water quality survey of familiar rivers: Difference between upstream and downstream*" and "*Accumulation and observation of soil microorganisms: Knowing the functions of living organisms in the soil*" were both guided by faculty members from the faculty of agriculture and tackled both agriculture and science discipline principles. The research project, "*Development of automatic ventilation system using Arduino board: Infectious disease control in school classroom*" demonstrated an integration between science, technology, and engineering disciplines.

Following the criteria that we set on determining whether the students' research projects exhibited STEM education competencies, we found that there is an overall indication that the research projects did show evidence of alignment with STEM education competencies. Table 5 shows the result of the manual rating that we did for the research projects. We found that 56% of the research projects aligned with the criteria that we set, indicating that most of the students exemplified vital STEM skills in the process of making their research projects. All the research projects showed evidence that the students demonstrated vital 21st century skills such as complex problem-solving, critical thinking, and creativity and innovation skills. About 78% of the research outputs showed evidence of students' complex problem-solving skill which means that the students used scientific method in solving the issues pointed out on their research paper. All the research outputs displayed evidence of students' critical thinking skills, which means that they paid careful evaluation of the reliability of data that they gathered during research. Lastly, 42% of the research outputs displayed students' creativity and innovation skills. This is evident in the novelty of the solutions, systems or methods, and technology that the students proposed or produced after the conduct of their research.

Table 5. Alignment of the students' research projects with STEM competencies (N = 90)

Criterion	No. of research outputs that exemplified the given criterion	Percentage
Knowledge Integration	20	22%
Complex problem-solving skill	70	78%
Critical thinking	90	100%
Creativity / Innovation	38	42%
Mathematical thinking & reasoning skills	67	74%
Engineering-design process skill	17	19%
Average	50	56%

The other skills that we identified as critical STEM skills are mathematical thinking and reasoning skills and engineering-design process skills. Mathematical thinking and reasoning skills were evident on 74% of the research projects as seen on the reasonable connections and predictions that the students indicated on the results and discussion and conclusion portions of their research papers. Finally, 19% of the research projects showed evidence that the students exemplified engineering-design process skills during their research. These were the research projects that showcased the students' ability to plan and design digital and mechanical systems to solve local or global problems. For instance, in the research project, "*Development of automatic ventilation system using Arduino board: Infectious disease control in school classroom,*" the students designed and developed an automatic ventilation system that addressed both coronavirus outbreak and heat stroke countermeasures. In the research project, "*Development of devices for smart agriculture: Toward a new agriculture using advanced technology,*" the students designed and developed blueprints of an automatic watering system for smart agriculture and planned to complete the programming and manufacturing of the actual system in the future. The results on the STEM skills exhibited by the students while conducting their research aligned strongly with the study of Matsubara et.al (2022) which confirmed that students strongly reported that they acquired abilities to solve problems independently, devise problem-solving methods on their own, and think logically and make decisions based on evidence.

CONCLUSION

The results of the text mining analysis and manual categorizations revealed to us a clearer picture of the nature of students' research projects. First, the text mining analysis revealed that the students focused on the following research themes: revitalization of communities; improvement of learning; environmental change and education; health; and development, improvement, and utilization of technologies for agriculture and disaster prevention. This result is further supported by the data that we gathered which revealed that the top issues addressed by the students' research projects were related to Sustainable Development Goals on Sustainable Cities and Communities (SDG 11), Quality Education (SDG 4), Good Health and Well-being (SDG 3), and Industry, Innovation, and Infrastructure (SDG 9). This may indicate a successful implementation of the Project Research course and SDG-related initiatives by the target institution during that academic year. These results could also potentially be a basis for enhancing research program initiatives at other high schools.

Further analyses also revealed that the students tended to choose research topics that are contextualized to their immediate local community. This suggests that the students were able to process new information or knowledge in such a way that it makes sense in their frame of reference (Hull, 1995). As guidance when setting the theme of the research project, it is important for teachers to help students to make strong connections between the contents that they learn academically and the actual real-world scenarios that they experience. Students initiated research projects that could subsequently benefit their local community. While there is nothing wrong with this, teachers and school administrations may help facilitate a broader scope of the students' research themes. This could mean exposing the students more into initiatives or curricular and extra-curricular activities that promote a globalized environment. This could potentially help them increase their global awareness and solve more complex global issues.

Based on the results of determining the design of research that the students conducted, most of the students used non-experimental research design which included survey, field, and archival designs. This may have also impacted the result that showed quite low indications that the students exhibited skills like knowledge integration, creativity and innovation, and engineering-design process skills. This can be a good opportunity for the school administration and teachers to assist students in exploring research topics that are globally relevant, innovative, programmatic, and scalable to have longer-lasting effects to them personally and to their community. Since students exhibited other important STEM skills such as critical thinking, complex problem-solving, and mathematical thinking, it is important for teachers and faculty members guiding the research to value the process of solving novel problems through collaboration with peers and enhance the logic and rationale of research through discussion with others, such as at mid-term presentations.

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