Utilizing 3D-Printing Technology in Cross-Disciplinary STEAM Education

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INTRODUCTION

Globally, contemporary societies face severe sustainability-related difficulties. Thus, the United States initiated a national strategy to increase the number of Science, Technology, Engineering, and Mathematics (STEM) personnel in the future since the beginning of the 21st century (1). The drive to popularize STEM education to foster the growth of excellent professionals who can problem-solve sustainability-related issues has widened to include other nations. Museum exhibitions and events have also been arranged along its objective, and such experiences have contributed greatly to STEM education. The interactive exhibits recently installed in science museums and centers (e.g., hands-on displays and multitouch tabletops) allow the public to cultivate their scientific thinking and enjoy multisensory artistic experiences (2).

As universities collectively develop their education and research activities, their respective faculties and departments have largely concentrated on working toward a sustainable future. From this perspective, it seemed crucial to not only deepen respective discipline but also integrate multiple disciplines (3). One institution perfectly organized for cross-disciplinary activities with/through exhibitions and events is the university museum that not only bridges the fields of social education and school education but also possesses features of both formal and informal education. Especially Science, Technology, Engineering, Arts, and Mathematics (STEAM) education, which adds the Arts to STEM education, with its aim of fostering scientific thinking, an appreciation of multisensory art, and creativity (4, 5).

With the exception of a few universities, most Japanese universities usually only have one university museum. Japanese university museums dealing with contents attached to various discipline within institution function to connect between disciplines among parent universities.

This paper highlights the benefits of cross-disciplinary learning in STEAM within the context of a university museum: specifically, the case of a STEAM education project that was developed to afford a chance to collaboratively learn a certain subject (reconstruction of the microstructure within cells) with students majoring in different STEM disciplines. The author of this report was concerned with the minimal interaction between students in increasingly specialized and deepened faculties/departments, and wished to provide an opportunity for students to exchange their specific knowledge because the collaboration between activities of different disciplines is essential to problem-solving sustainability-related issues. Actually, student participants majoring in life science and computer science joined the project and worked interactively. To accomplish the project, students majoring in life science taught about cell functions and structures and students majoring in computer science reconstructed three-dimensional (3D) cell data. Together, the students created a detailed cell model which was able to combine knowledge and technology effectively.

PROCEDURE

Representation of cell structures

Eukaryotic cells possess various microstructures named organelles, including the nucleus, the Golgi apparatus, and mitochondria. While each organelle has its own independent and unique function, it can collaboratively interact with both similar and different organelles, a lot like a society. For example, the nucleus expresses genes, the endoplasmic reticulum and the Golgi apparatus synthesize and process proteins, and the mitochondrion and plastid generate energy inside the cells. As shown in Table 1, the student participants were recruited and asked to work in pairs with those majoring in different disciplines.

TABLE I
Process of the project

Process of the project	Step	Work contents	
		Life science	Computer science
Call for student participants	1	Recruitment of student participants was simultaneously announced on the museum website to their faculties (life science and computer science); "Create the hands-on cells! Let's utilize the knowledge and skills of both life science and computer science with one another, and experience the usefulness and importance of interdisciplinary cooperation." Consequently, 18 students, nine from each faculty, responded to participate in the project.	
Student exercise 1: representation of cell structures and modeling of 3D printed cells	2	The student participants gathered in the museum and introduced themselves to one another. After they received a detailed explanation of the project aim, they were divided into pairs with one student majoring in life science and one in computer science and commenced the respective work with lectures from university professors in the field of cell biology and mathematical engineering, respectively.	
	3	They learned how to reconstruct 3D data and model eukaryotic cell's object (OBJ) data with Blender, a software which creates 3D computer graphics from the students majoring in computer science.	They learned the microstructure within eukaryotic cells and the mechanism of homeostasis and environmental responses within the cells from the students majoring in life science.
	4	Small cell models with a diameter of 3 cm were test printed on a Mimaki 3DUJ-553 3D printer (Mimaki Engineering Co., Ltd.) based on the OBJ data. Tests were performed several times by the company engineers and the student participants to confirm the spatial positioning and to complete the colors of the printed intercellular organelles. A spherical eukaryotic cell was thus printed with each cell possessing a diam of 6 cm.	
Student exercise 2: holding the workshop for K-12 pupils	5	A science workshop for K-12 pupils was held in the museum. Recruitment of pupil participants was simultaneously announced on the museum website; "Let's learn of the microworld within cells with the student educators." Consequently, 20 pairs of pupils and parents offered to participate.	
	6	They narrated various functions and structures of the microworld within cells from yeast to plants and animals with models, living samples such as yeast, fishes, and leaves, and slides.	They described how to create 3D data for a 3D-printed model that briefly imitates a cell, and let the pupils experience printing smaller cell models with a versatile Value3D MagiX MF-2200D 3D printer (Mutoh Industries, Ltd.) and paint them.

Modeling of 3D printed cells

The organelles in eukaryotic cells were reconstructed as 3D data, and a model was created with a 3D printer. A problem, however, was that 3D-printed models generally tend to be monochromatic (e.g., white, blue, or red only). Although the surfaces of the 3D-printed models can be acrylic painted as necessary, it is not possible to paint inside the model and thus reconstruct the intercellular microstructure. To overcome it and print eukaryotic cells properly, a state-of-the-art technology was used with the help of the university and the company to print multicolored and transparent 3D-printed models.

Table 1 and Appendix S1 in the supplemental material (see Text S1) present the process and participants for the project, respectively. First, the author, a biology educator, provided an explanation of the project aim, whereas the university professors of cell biology and mathematical engineering presented the concept of the project contents.

Second, student participants majoring in life science taught cell functions and structures to their partners majoring in computer science and discussed reciprocally. Third, the students majoring in computer science reconstructed and modeled the 3D eukaryotic cells while capturing the opinions from their partners (Fig. 1). Finally, 3D-printed eukaryotic cells with a diameter of six centimeters were printed out through trial and error.

Holding the workshop for K-12 pupils

The project provided its elementary school student participants (pupil participants) the opportunity to utilize the 3D-printed models to teach designated topics in class or workshops. After the 3D eukaryotic cells were printed, the university professors and student participants examined other ways in which they could be employed as teaching material. To this end, they held discussions with university professors, schoolteachers, and parents. Parent-and-pupil
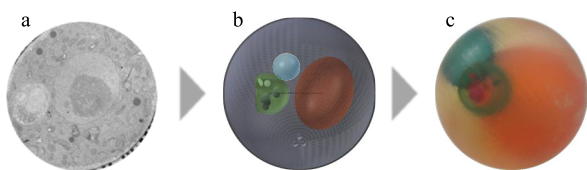
FIG 1. **3D-printed eukaryotic cell.** 3D data were reconstructed by students majoring in computer science on the basis of unrefined photographs observed and captured by students majoring in life science. a: an electromicroscopic photograph of a pollen cell; b: a reconstructed image of a pollen cell; c: a raw model printed on an advanced 3D printer.

groups were subsequently invited to organize a science workshop in which the microworld within cells could be explicated through 3D-printed eukaryotic cells using the example of a society. The student participants were required to prepare material to deliver lectures and answer questions that may be asked. The pupil participants took the miniaturized cell models home and painted them as they wished with the help of their parents.

Basically, all activities related to the project were achieved as extracurricular activities conducted every other Saturday during the autumn/winter semester (see Appendix S2 in Text S1). Hence, the participants proceeded with each step without disruption by their formal school curriculum (see Appendix S3 in Text S1).

CONCLUSION

This STEAM education project served students from different fields the opportunity to interact with each other. As such, the barriers existing between the different disciplines seemed to be overcome through student collaboration, which ranged from modeling the 3D-printed eukaryotic cells to holding the workshop for K-12 pupils. The pupils were allowed to view and hold the 3D-printed eukaryotic cells and looked entirely satisfied. Significantly, the students noted the significance of fruitful collaborations among different disciplines for problem-solving sustainability-related issues through informal discussions. For instance, they realized that personnel belonging to any singular discipline would not be able to develop advanced wearable health/medical monitoring devices and that the design of such products would require experts in life sciences, as well as computer science specialists. In congruence to the project, collaborations can be planned among different disciplines in various ways, and the significance of such associations will increase in the near future. Lastly, the author believes that such study can help develop the utility of a wide range of STEAM education programs available in common education sectors, including university museums, as well as help a greater number of children and youth to become innovators/leaders in their chosen field of STEM via both organic and dynamic academic interaction.

SUPPLEMENTAL MATERIALS

Supplemental material is available online only.

TEXT S1, DOCX file, 0.4 MB.

ACKNOWLEDGMENTS

REFERENCES

1. Bybee RW. 2010. What is STEM education? Science 329:996. https://doi.org/10.1126/science.1194998.
2. Mujtaba T, Lawrence M, Oliver M, Reiss MJ. 2018. Learning and engagement through natural history museums. Stud Sci Educ 54:41–67. https://doi.org/10.1080/03057267.2018.1442820.
3. Takeuchi MA, Sengupta P, Shanahan MC, Adams JD, Hachem M. 2020. Transdisciplinarity in STEM education: a critical review. Stud Sci Educ 2020:1–41. https://doi.org/10.1080/03057267.2020.1755802.
4. Rolling JH. 2016. Reinventing the STEAM engine for art + design education. Art Educ 69:4–7. https://doi.org/10.1080/00043125.2016.1176848.
5. Segarra VA, Natalizio B, Falkenberg CV, Pulford S, Holmes RM. 2018. STEAM: using the arts to train well-rounded and creative scientists. J Microbiol Biol Educ 19:1–7. https://doi.org/10.1128/jmbe.v19i1.1360.