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Investigating Mechanical Engineering Learners' Satisfaction with a Revised *Monozukuri* MOOC

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Aside from providing instructional materials to the public, developing massive open online courses (MOOCs) can benefit institutions in different ways. Some examples include providing training opportunities for their students aspiring to work in the online learning space, strengthening its brand recognition through courses appealing to enthusiasts, and enabling online linkages with other universities. One such example is the *monozukuri* MOOC offered by the Tokyo Institute of Technology on edX, which initially presented the Japanese philosophy of making things in the context of a mechanical engineering course. In this paper, we describe the importance of involving a course development team with a diverse background. The *monozukuri* MOOC and its revision enabled us to showcase an otherwise distinctively Japanese topic (philosophy) as an intersection of various topics of interest to learners with an equally diverse background. The revision resulted in discussing *monozukuri* in a mechanical engineering lesson and how *monozukuri* is actively being practiced in the Japanese workplace and academic setting while juxtaposing it to the relatively Western concept of experiential learning. Aside from presenting the course with a broader perspective, the revision had been an

exercise for its team members on working in a multicultural environment within a Japanese institution, thus developing their project management and communication skills.

1 Introduction

Tokyo Institute of Technology (Tokyo Tech) is a top research-based national university in Japan dedicated to science and engineering higher education. Tokyo Tech has more than 140 years of history with approximately 10,500 students across its three campuses in Tokyo and Yokohama. To establish its place as one of the world's top institution in science and technology, Tokyo Tech started offering MOOCs on edX as TokyoTechX in 2015 [5]. Aside from serving as an outreach educational activity by providing course materials to the public on science and engineering, TokyoTechX's MOOCs serves as an ambassador by providing courses highlighting Japanese culture and values (e.g. modern Japanese Architecture, Science and Engineering Ethics, and Japanese Civil Law). TokyoTechX also aims to enhance the institute's brand image by introducing the concepts behind its cutting-edge research (e.g. deep earth science and Nobel prize winning research on autophagy) in a more accessible manner. On several occasions, MOOCs had enabled Tokyo Tech to strengthen its linkages with other universities both inside and outside Japan through organizing workshops and symposia on MOOCs [3] and the creation of joint flipped classroom via the Association of East Asian Research Universities – Summer Institute for Extended Flipped Education program [1]).

In 2016, Tokyo Tech started an education reform to strengthen its research capabilities [8] as shown in Figure 1. The reform promoted the "wedge-shaped education" where students can choose to be exposed to specialized courses or research activities if they wish to do so. Another important aspect of the education reform is the emphasis on liberal arts education to deepen the students' understanding of the social significance of science and engineering research, build their character with broader values, and foster creativity in the face of internationalization. The *monozukuri* MOOC is one such example of Tokyo Tech's aspiration of blending scientific theory with practice with a humanistic perspective.

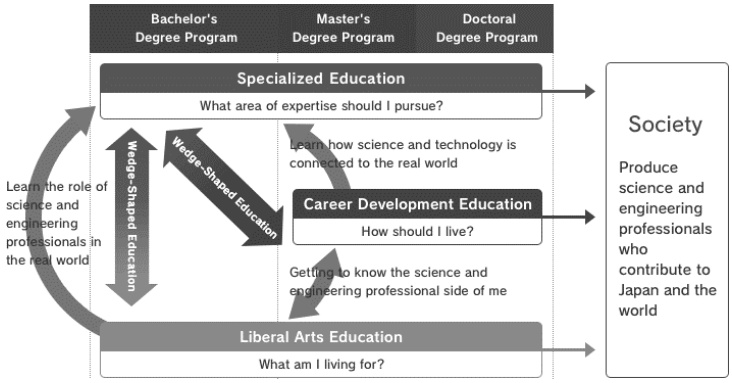

Figure 1: Tokyo Tech's Curriculum Design with Focus on Liberal Arts and Career Development Education [8]

2 Context

2.1 Original Monozukuri Course

Monozukuri (物作り or ものづくり), which is typically translated as "making things", is the Japanese philosophy generally applied to craftsmanship where a product is produced with the highest possible quality for the customer [9]. It is closely related to the concept *hitozukuri*, or character building, where an individual develops fortitude and craftmanship skills by, to some extent, surrendering themselves to the process of trial and error in order to improve quality (seeking excellence). An important aspect of *monozukuri* is dual-aspect monism, usually depicted as the necessary presence of both Yin and Yang. In *monozukuri*, Yang stands for theoretical knowledge while Yin for practical exercise.

TokyoTechX released its first *monozukuri* MOOC in September 2018 where the learners' goal is to create their own steam engine toy boat or pop-pop boat. Figure 2 shows the course map for the 2018 release. It is a four-week course covering the themes Principle, Design, Make, and Improve. In each week, the mechanical engineering theories behind a steam engine is discussed by Professor Hiroto Tanaka. This is followed by a workshop session where a teaching assistant, "Seiya" guides the learners in creating and finetuning their pop-pop boats. The learners can then invoke their experience in understanding the *monozukuri* lectures by Professor Masahiro Mori. Each week culminates with an interview with persons who have hands-on *monozukuri* experience.

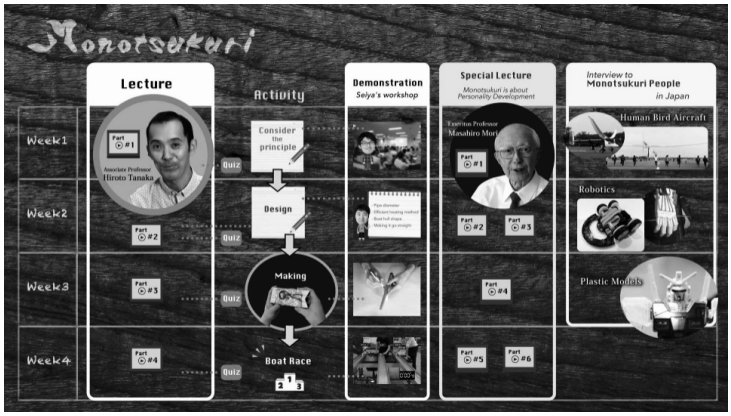

Figure 2: Course Map of the original *monozukuri* course called *Monotsukuri* (alternative Romanized spelling)

The rationale for touching on each of the four points mentioned above every week is to develop a broader view on the scientific theory while engaging the learners with a fun activity. However, each of these points appeared too distinct that several learners tended to focus more on a single point rather than taking the individual points as part of the bigger picture. As a consequence, the boat-making project took too long for those who focused on the thermodynamics part, the *monozukuri* message had not been as strong with some learners complaining that it sounded "cheesy", and there had been possibly not enough opportunities to showcase Tokyo Tech's *monozukuri* efforts as nobody mentioned about it.

2.2 Monozukuri Course Revision

TokyoTechX released an updated revision of the *monozukuri* MOOC in March 2020. Unfortunately, the original course development members, who are mostly Japanese, were no longer available for the revision efforts. The new course team was instead a mixture of students and faculty of various nationalities as shown in Table 1.

What was not heavily emphasized in the original *monozukuri* MOOC is at its core, *monozukuri* provides the philosophical substrate to Japan's manufacturing prowess mostly known as lean production and *Kaizen* or continuous improvement [10]. These concepts are not entirely new for a lot of people and is in fact one of Japan's manufacturing appealing factors. The international *monozukuri* revision team was made acutely aware of this not just through their experiences in their research laboratories but through their various levels of exposure to corporate

Japan. In the revised *monozukuri* course, not only is the importance of *monozukuri* in industries given emphasis, but also the notion that developing expertise as seen in Japan is a long learning process that can take a lifetime.

Table 1: Nationalities of the team members and their main roles in the course revision

Country of Nationality	Role
Tunisia	Course designer
Mexico	Content creator (pop-pop boat tutorial)
Mexico	Lead beta tester
Philippines	Content creator (experiential learning)
Philippines	Content creator (*monozukuri* in industries)
Greece	Graphics designer
Vietnam	Video editor
USA	Project manager

Another unique perspective that the international team was able to offer in the revised *monozukuri* MOOC is the relationship of *monozukuri* to the Western concept of experiential learning. The experiential learning theory defines learning as a process of transforming experiences into knowledge [7]. Without linking back to experiential learning, *monozukuri* may be misconstrued as the non-cognitive grit where an individual persists to achieve their goal. In reality, *monozukuri* is also a cognitive development process where the individual reflects on their experience to improve the quality of their work related to preparing a tangible object.

With the inputs from the international team, *monozukuri* is presented as a less esoteric concept in the revised MOOC. Table 2 shows the revised course outline. The *monozukuri* philosophy is first discussed in detail in Week 1. *Monozukuri* as seen in industries as well as in the academic setting is shown in Week 2. The learners are given the chance to experience *monozukuri* for themselves in Week 3. New tutorials were also added in Week 3 for creating pop-pop boats with alternative materials. Finally, Week 4 discusses how *monozukuri* affects all levels of a company and how it contributes to the continuous learning process. Each week is capped by a short showcase of *monozukuri* activities in Tokyo Tech. With the new course outline, the learners are given time to internalize each aspect of the course instead of jumping from one concept to another.

The entire course revision experience had been a first on several fronts. For instance, nobody in the team had created pop-pop boats in the past. The pop-pop boat introduced in the original course as seen in Figure 3 (a) requires materials (e.g. balsa wood, thick copper wire, etc.) not easily available and can be difficult to

Table 2: Revised *monozukuri* course outline

Week	Topic	Details
1	*Monozukuri* Philosophy	Introduction to *monozukuri* concept; *monozukuri* as dual-aspect monism; the process of learning and learning curves.
2	*Monozukuri* in Practice	*Monozukuri* in large, medium, and small corporations; *monozukuri* in education setting; learning styles, experiential learning, and reflection
3	Design Challenge	Physics and dynamics of the pop-pop boat; designing and prototyping the pop-pop boat; pop-pop boat tutorial
4	*Monozukuri* and Technology Transfer	Skill transfer through *monozukuri*; experiential learning in the workplace (individual and organizational learning); management learning

handle for younger learners. The team devised an alternative way to construct the pop-pop boat with more readily available and malleable materials (e.g. milk carton, aluminum can, sealing material, etc.). The team likewise applied the *monozukuri* concept in creating the boat shown in Figure 3 (b) to provide the learners with accurate instructions for creating their own pop-pop boats. These boats are showcased in Figure 3 (c) which served as the course banner page.

Figure 3: The pop-pop boat with balsa wood for the hull from the original course (a) and the pop-pop boat using milk carton (b) introduced in the revised course. These pop-pop boats inspired the course banner design (c).

A few members of the course team were working on course creation for the first time. Not everyone has knowledge on *monozukuri* at the start. Considering the extent of changes made, the consequent tasks had been too numerous for the team that it required everyone to develop project management skills. Some members have never worked in a Japanese setting yet outside their research laboratories; working on the *monozukuri* MOOC helped them calibrate their expectations for their future work. In a way, the team was teaching experiential learning while experiencing experiential learning for themselves.

3 Results and Discussions

3.1 Learner Data

Table 3 shows the learner data for the entire duration (from July 11, 2018 to March 3, 2020) of the original course and from March 4, 2020 to January 22, 2021 for the revised course. edX has made changes to its platform in December 2018 making the graded assessments inaccessible to those who are auditing the course for free [6]. All the assessments in both the original and revised courses are graded. In lieu of looking at completion rates, we looked at total enrollments, verified certificate enrollments, passing learners for those in the verified certificate track, and the responses in the post-course survey. Even for a shorter period of time (10 months against 20 months), the revised course has already attracted more learners both in the audit (free access) and verified certificate tracks, with higher percentage of verified learners having passed the course even before the course has ended. It should be noted the original course required the learners to prepare a pop-pop boat from wood and copper coil while preparing a pop-pop boat in the revised course became optional.

Table 3: TokyoTechX *monozukuri* MOOC learner data.

Description	Original Course	Revised Course
Total enrolled	4742	4005
Enrolled for verified certificate	39	91
Passing learners	16	45
Post-course survey responses	71	126

3.2 Learner Reception

We do not intend to change the learner workload required despite the drastic changes introduced to the course in the revision. Since the course requires considerable time outside the learner platform for the learners to create their pop-pop boats, we used the self-reported hours per week spent in the post-course survey. Figure 4 shows the density plot of the weekly hours for both the original and revised courses. The curves are approximately similar, and mean values for both values are about the same: 3.705 (standard deviation: 2.799) for the original course and 3.743 (standard deviation: 3.618) for the revised course. The values were also found to be not statistically different since the calculated p is larger than .05, which is traditionally taken to be the statistical significance cut-off (U : 3299, z-score: –0.08122, p = .936). Because the number of responses received is less than 200, the normal approximation for the two-tailed Mann-Whitney U test was used for evaluation.

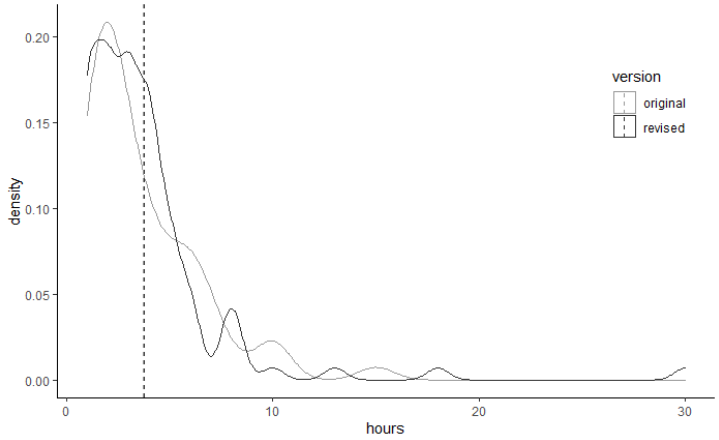

Figure 4: Density plots of the reported weekly hours spent for the original and revised courses with mean scores plotted as dashed lines.

The effort dedicated to creating a new tutorial for creating a pop-pop boat using alternative materials has proven to be fruitful. Several learners commented in the course's discussion forum that creating the pop-pop boat during some of the lockdown periods helped them in coping with the pandemic situation. Of the 97 learners who responded to our question about their favorite experience in the

course in our post-course survey, 29 mentioned that making the pop-pop boat is one of their favorites.

A technique that we had been using to determine learner satisfaction while a course is running is to conduct sentiment analysis on discussion board posts [4]. Figure 5 shows the density plot for the sentiment polarity values of the discussion board posts using Python's TextBlob library. We can see from here that the learners in the revised course had more positive sentiments (mean: 0.249, standard deviation: 0.292) than in the original course (mean: 0.202, standard deviation: 0.278). The statistical difference was similarly calculated, this time using the Welch's t test since there are considerably many samples (more than 200) for both original and revised courses. This resulted to a statistical difference with p = .013 (t = 2.485, df = 368, standard error of difference: 0.019). The Cohen's d was computed to be 0.559, which conventionally is medium effect size.

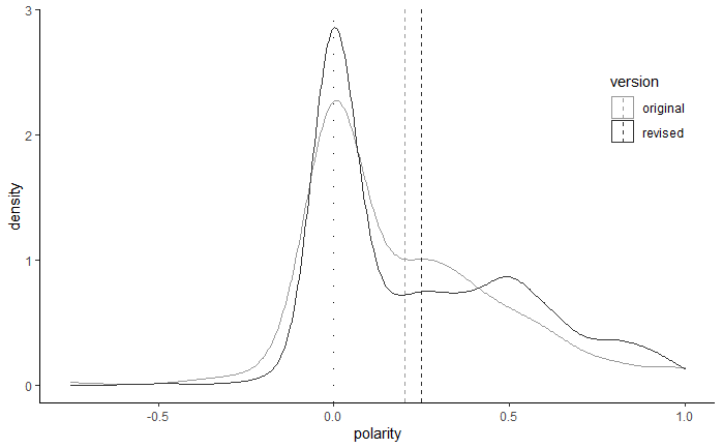

Figure 5: Density plots of the sentiment polarity scores for the original and revised courses with mean scores plotted as dashed lines and the neutral score with dotted line.

What the course team most appreciate are the learner testimonies in the revision's post-course survey. Several learners indicated that the revised course had a positive effect on them. Here are some of these positive testimonies:

- *All the people that were featured in the videos, their experience and advice is very valuable and very helpful.*

- *I agree a lot with the professor about learning from experience is one of the best approaches to master any processes. More important in actual industries when it is not allowed to commit mistakes in the final product.*
- *I truly enjoyed the videos, all of them. Amazing valuable interviews. Very happy with the broad information material provided on philosophy, learning styles, information on Tokyotech [sic] students club and the pop-pop boat. Every bit is so valuable. It did make me think a lot, very excited with the course and shared what I learned with my family. Re-reading and watching all. Monozukuri will be part of my whole life from now on.*
- *Learning from Emeritus Professor Masahiro Mori, the reading text about Emeritus Professor Shigeo Hirose, learning the engineering principles of pop-pop boat, learning the experience and wisdom of Professor Tanaka. I love learning from all those people I wish I could meet them.*

Nevertheless, there is still room for course improvement based on the learner's feedback. Some learners commented that the course is very text-heavy and will benefit more from more videos and exercises. Given the results of an existing study that most courses have more than 50% of its content based on word counts are presented in video format [2], this feedback from the learners is warranted. For the revised *monozukuri* course, less than 39% of the words were from video transcripts. Other related topics that the learners wanted to explore include Japan manufacturing philosophies such as *Kaizen* (continuous improvement) and *5S* (sort, set in order, shine, standardize, sustain). There are also several requests to have English audio for the Japanese lecture videos instead of closed-caption transcripts in English.

4 Conclusion

Tokyo Tech has utilized MOOCs to promote its educational reforms that aim to develop researchers with both technical and humanistic perspective. The *monozukuri* MOOC is an example of Tokyo Tech's brand of education focusing on knowledge with experience. Involving an international team in revising this distinctively Japanese course highlighted Japanese concepts such as lean production which is popular among learners outside Japan and linked foreign concepts such as experiential learning making *monozukuri* more accessible. Being involved in the *monozukuri* revision enabled to team to exploit aspects of *monozukuri* for themselves and has indeed been a learning-by-teaching encounter.

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