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Board 38: Student-led Curriculum Development: Incorporating Mechanics of Materials Students in the Design of Statics Curricula (Work in Progress)

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Student Led Curriculum Development: Incorporating Mechanics of Materials Students in the Design of Statics Curricula. A Work in Progress.

Abstract

Students are a valuable stakeholder in curriculum design, yet they are seldom involved in curricular design efforts. One of the main concerns inhibiting student involvement in curriculum development is their perceived lack of required knowledge and pedagogical training. However, what if the goals for including students in curriculum design were not exclusively focused on creating adoptable curricula?

The purpose of this study was to provide students enrolled in a summer term of mechanics of materials an opportunity to develop a learning activity or tool for statics. While the students were encouraged to develop something that might be adopted in future offerings of statics, the authors' main goals were for the students to enhance their own understanding of a statics concept through the curriculum development process and gain a deeper appreciation for the challenges of designing effective curricula.

At the beginning of a summer 2023 offering of mechanics of materials, five students were assigned a project to choose a statics concept that they previously struggled with and brainstorm ways they would want that concept taught to themselves knowing what they know now. The mechanics of materials instructor interviewed each student individually early in the term using a semi-structured interview format with the goal of helping the students brainstorm curricula for their chosen concept. The students then had the remainder of the six-week term to develop their curriculum and were interviewed individually again at the end of the term by the instructor using a semi-structured interview format. The students presented their curriculum during the second interview and were questioned on their lessons learned throughout the development process.

The five students in this study picked a variety of statics concepts and curricular activities. The quality of their developed curricula varied with some students putting more effort into this project than others, as was expected. All the students expressed enjoying the opportunity to develop curricula and thought this was an interesting project that should be continued. Each student also articulated the challenges they faced in their curriculum design, notably the iterative process, trying to accommodate different learning styles, and getting their curriculum to match their intention.

This study is a work in progress that will be continued and improved in future summer offerings of mechanics of materials. While students were able to ultimately develop some form of curriculum by the end of the summer term, the range in quality and effort was considerable for the small sample. Based on feedback from the students, the authors will be adding an additional

interview in the middle of the term during future offerings to help track and guide the students' progress. Ultimately, a statics instructor was interested in adopting three of the five students' developed curricula to some extent. The greater success of this project, however, was exposing students to their metacognition of statics and their gained appreciation for the challenges of curriculum design. The authors hope that similar projects will foster greater empathy from students towards their instructors that are developing and testing new curricular activities.

Introduction

The aim of this study was to explore mechanics of materials (MoM) students' experiences with an opportunity to develop their own learning activity or tool for statics. Students are rarely given opportunities to actively participate in curriculum design, mostly due to their lack of experience with curriculum design [1-2]. Students, however, are valuable stakeholders of curriculum design that can make valuable contributions given the opportunity [2-6]. Such an opportunity was provided to a group of five students enrolled in a 6-week summer term offering of MoM. Most of these students had taken statics for the first time immediately before in a preceding 6-week summer term. As part of the assessment for the MoM course, the students were given a project asking them to develop a learning activity or tool for a statics concept. The MoM students were interviewed by the instructor, who is also the lead author, at the beginning and end of the 6-week term with the goal of exploring the students' experience with and perspective on curriculum development. This study is a work in progress with the intent to offer similar curriculum design experiences for future summer MoM students. The initial findings from this group of five students echoed similar challenges that instructors have with curriculum development. It is the authors' hope that these challenges foster empathy from these students to their instructors that are developing and implementing new curricula. In the subsequent fall semester, a statics instructor adopted one of the students developed learning activity.

Background

Most opportunities for student involvement in curriculum design limits students to only providing feedback and suggestions, ultimately for educators to then decide how to use that feedback [8-9]. Rarely are students given the opportunity to create their own curricula [4,6-7,10-11]. Curriculum is a broad term that encompasses everything from the overall structure of an academic program down to the daily activities and tools used in the classroom. In the context of this study, we refer to curricula as the learning activities and tools used in a specific course. A learning activity could be something students are asked to do in or outside of the classroom while a tool could be something that aids a student in understanding a concept. Students have not been provided many opportunities to develop curricula at this level because they are perceived as not having the necessary expertise to do so [1-2]. This perspective, however, focuses entirely on students' ability to contribute something of worth to the curriculum without recognizing other potential benefits for students and instructors by simply providing students the opportunity to design curricula with no expectation of it actually being adopted.

It is well understood that we learn material better when we teach it to someone else [12]. Through the curriculum design process, the designer often thinks about what helps them understand the material well enough so that they can teach it to someone else, and this process facilitates a greater understanding of the material [2-5,7,10,12]. While designing curricula is not teaching, it does force the designer to consider how their curriculum will be implemented by teachers and received by students. Students may not be experienced curriculum designers, but they are experienced recipients of good and bad curricula, or at least what they perceive to be good and bad curricula. By providing students the opportunity to develop their own curricula, they can explore their opinions on curricula further and potentially gain appreciation for the challenges of curriculum design. Therefore, it was the authors' hopes that providing MoM students the opportunity to develop their own statics curricula, that the students would improve their understanding of a particular statics concept and develop empathy with their instructors for the challenges of curriculum design.

The context wherein this curriculum design opportunity was provided for these students was a 6-week summer MoM course that started immediately after a preceding 6-week summer statics course. Both courses met for two 3.5-hour class periods each of those 6 weeks to count as a 3-credit course. All five students in the MoM course took statics for their first or second time during the preceding 6-week summer term. MoM courses significantly build off of statics concepts. Most MoM problems require using statics to solve. While 6-week terms require an incredibly fast paced course for the amount of content covered in statics and MoM, the authors identified the summer MoM course as an ideal opportunity to provide this student-led statics curricular design opportunity because of the small class sizes that summer courses typically provide and the relative recent exposure the students had with statics. For comparison, at the institution where this study was conducted, MoM courses offered during spring semester typically have 20-30 students, and those students may have anywhere from 1-9 months between the end of their statics course and the beginning of their MoM course. The small class size in the summer offering enabled the instructor to provide more guidance for the students on their statics curriculum development, and the recency in which the students had taken statics likely made them more cognizant of statics concepts they would be interested in revisiting through their curriculum development.

The curriculum design experience was facilitated to the five MoM students as a term long project worth 10% of their MoM grade. Since the goal of a MoM course is not to assess a student's ability to design curricula, the project could not be worth a substantial portion of the final grade. 10% was chosen to provide a low stakes opportunity to the students, but still make it worthwhile for the students to participate. Assessment of the project was primarily participatory. Students had to participate in an interview with the instructor at the beginning and end of the term and submit a final project deliverable, their learning activity or tool, to receive the full 10%.

Methods

This study was conducted after receiving approval from the Institutional Review Board (IRB00006544) at the institution where the summer MoM course was offered. The student-led curriculum design project was first offered to the five students enrolled in the summer 2023 offering of MoM. The authors intend to continue offering this project to future summer MoM students to iteratively improve the facilitation of the project and collect data from more students. Information about the five students that participated in this first iteration is provided in Table 1.

Table 1. Student demographic information and their designed learning activity or tool.

Student	Female/ Male	ME/CE	Statics Attempts	Learning Activity/Tool
1	F	CE	Summer ‘23	Pegboard for visualizing moment direction
2	M	ME	Summer ‘23	Paired method of sections analysis of Steel Bridge Competition entry
3	M	CE	Fall ‘22 & Summer ‘23	Flipped classroom with YouTube videos on vector addition
4	F	ME	Summer ‘23	Checklist for solving 2D equilibrium
5	F	CE	Summer ‘23	Flowchart for solving moment equilibrium

On the first day of class, the students were presented with the project expectations and informed they had to complete their first interview within the first two weeks of the course. Students were told to prepare for the first interview by identifying statics concepts that they struggled with, or still struggle with, and curricular ideas for learning activities or tools that they think would be helpful for teaching and/or learning that concept. Students were provided a list of the statics concepts they covered in their summer statics course. The first interview was semi-structured and conducted by the course instructor with the goal of helping the students select a specific concept and learning activity or tool to begin designing. The students then had to complete their second interview before the last class. The second interview was also semi-structured and conducted by the course instructor. Students were required to bring their designed curriculum to the second interview to help facilitate the discussion of their curriculum. Students were informed that their designed curriculum did not have to be perfect or 100% complete, but that it needed to be far enough along to facilitate a meaningful discussion about their design process and lessons learned. Admittedly, the students did appear to struggle with the ambiguity of the deliverable expectations, which is discussed later in the paper.

Semi-structured interviews were chosen to ensure there were a set of consistent questions being asked of all students in the interviews while also allowing the interviewer to ask follow-up questions that were suitable for each individual student [13-14]. The interviews were audio-recorded with each student's consent and then transcribed by a third-party transcription service for later analysis. The decision to have the course instructor, who is also the lead author, conducting the interviews does elicit concerns of the reliability of the responses provided by the students because the students might provide inauthentic answers that they perceive their instructor will look favorably upon. Ultimately, the authors decided that the course instructor would have the most rapport with the students and unique insight into their curricular design experience through informal interactions in class and office hours to help inform their interviews and achieve the study goals of exploring and understanding the students' perspective of and experience with the curriculum design process [13,15].

Data analysis began with two undergraduate research assistants inductively coding the first interview transcripts on their own. The first author also inductively coded the first interviews and the authors met with the undergraduate research assistants to discuss any themes emerging and discuss different interpretations [16]. This process was repeated for the second interview transcripts. While this was both undergraduate research assistants' first experience with coding interview transcript data, their novel perspective was valuable in providing alternative interpretations of the data [17].

While inductive coding sought to identify themes across the five participants, the sample size is too small to make generalizable claims about student-led curriculum development. The authors intend for this to be an iterative research project wherein the curriculum design project is offered in future summer offerings of MoM with integrated lessons learned from previous offerings. Identifying themes from this first round of five participants and subsequent participants will help inform how to continuously improve implementing such a project with the goal that some of these lessons learned are informative for other educators wishing to offer student-led curriculum development projects in their engineering courses and contexts.

Results

As a work in progress, the plan is to continue collecting data from future MoM summer students to provide a richer description of the student experience with this project and to iteratively improve the implementation of the project based on lessons learned that may benefit other instructors wanting to implement similar student-led curriculum design activities. Therefore, the results portion for this paper will briefly describe what the five participants created, the metacognition expressed by the students during their design process and their gained appreciation for the challenges of curriculum design. Lastly, lessons learned and planned future changes to the implementation of the project based on student feedback in the interviews are presented.

Four of the five students submitted a text document deliverable, while one submitted a physical prototype of a learning tool they developed. Of the text documents, two could be described as learning activities and the other two could be described as learning tools. The deliverable expectations and instruction were left intentionally open-ended to not limit the students' creativity. During the first interview, the instructor and each student brainstormed and discussed what a deliverable could look like based on their curriculum design ideas so that the students had a better understanding of what was expected from them on the project.

The student that developed the physical prototype wanted to create a peg board to help with understanding moment directions. Her prototype is shown in Figure 1. Her intention was that a student could place the black circle peg in the board as a point of interest to sum moments about and use the force vector and moment pegs to help visualize moment direction by spinning the board about that point as a result of applying a force/moment in the direction of those pegs. Her motivation for creating her learning tool was expressed in her first interview:

> *I think it's kind of fun coming up with things that could help other students learn, knowing that we struggled with that too. I think for this course [MoM] specifically, it's helpful too because it's a refresher on statics, which is the basis of what we're learning.*
> *-Student 1*

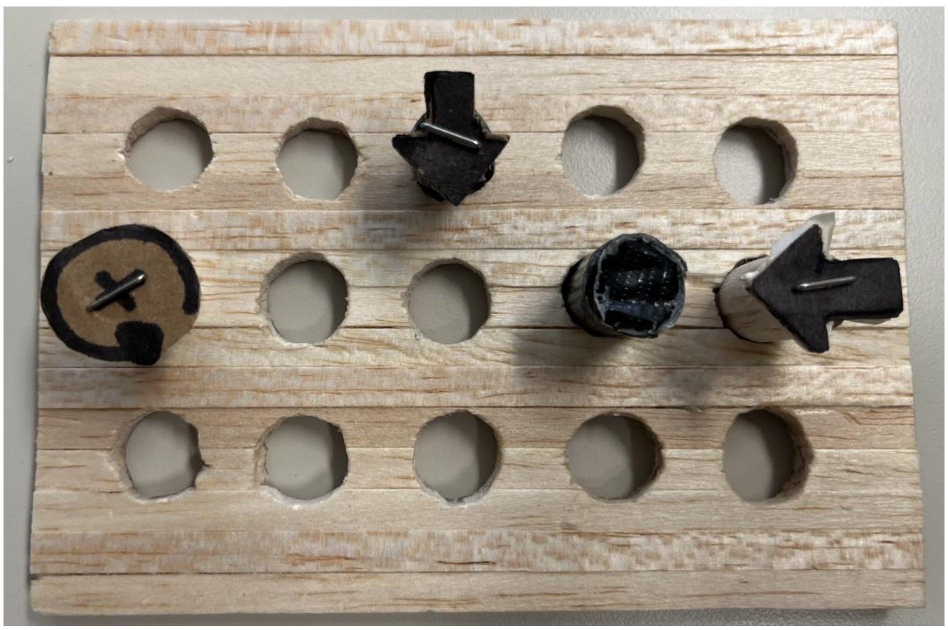

Figure 1. Student prototype of peg board for visualizing moment directions

The instructor's original idea for this project was for students to develop physical learning tools to help explain and understand statics concepts, but was concerned that requiring creating a physical model could be too restrictive for students that do not have the resources for such a task. Student 1 developed the peg board prototype using scrap material and tools available in the university makerspace at no personal cost, showing that it is feasible to create something physical without spending money.

The two learning activities submitted were explained in text documents. One essentially described a flipped classroom approach wherein students would be provided links to three YouTube videos explaining different ways to do vector addition. The student that created this activity envisioned that students would be expected to watch the videos outside of class on their own time and create a single page example/formula sheet based on the videos that they could then use on an in-class quiz with vector addition problems. This student expressed relying on YouTube to teach themselves concepts and also appreciated when instructors allowed example/formula sheets on exams. Incentivizing students to actually watch instructional videos (or read the textbook) outside of class by allowing them to create an example/formula sheet based on the content that they can use on a quiz could be a worthwhile approach in any flipped classroom. Providing multiple videos of different methods also provides students with options to choose which method/video they prefer to base their example/formula sheet on.

The other learning activity submitted as a text document leveraged a steel bridge model on display from a prior Student Steel Bridge Competition entry shown in Figure 2. Students would work in pairs to measure dimensions of one longitudinal side of the steel bridge to create a 2D-truss free body diagram. The instructor could randomly assign each pair of students with different point load magnitudes and/or locations to ensure all students had a different truss to solve. Each pair would be expected to solve for three internal members near mid-span by making a section cut through those members. One student would solve for the left side of the cut and the other student would solve for the right side of the cut. The student described their goal for this activity being that the students should get the same answer, but if they do not then they would have to work together to figure out where one or both went wrong:

> *But what it also does is if one guy got it wrong... Because they're interconnected. It's going to be cut at halfway. So, one has to line up with another group member. If they got it wrong, they both have to come back and talk it through, "oh, okay, you got this one wrong," or "it's my fault", or "I got it wrong" -Student 2*

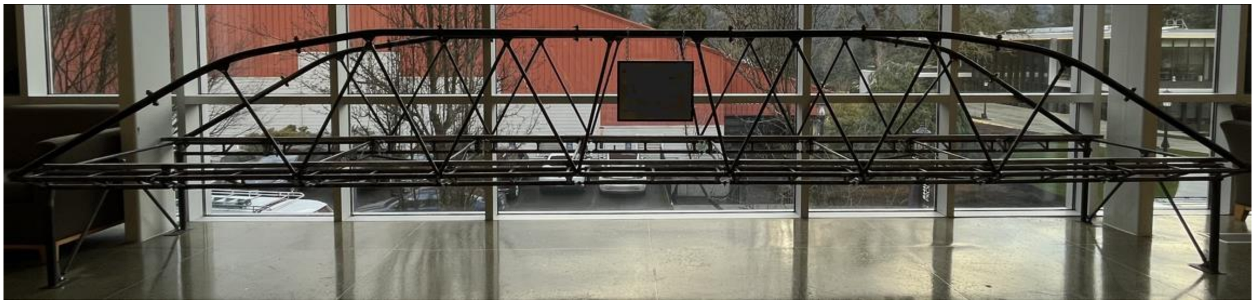

Figure 2. Steel bridge model for methods of section activity

The above three activities were of interest to a statics instructor to potentially adopt in the subsequent fall term. Ultimately, a statics instructor did adopt the steel bridge method of sections activity because they had noticed their students relying on method of joints and wanted an activity that could bolster their method of sections curriculum. The statics instructor also advices the ASCE Steel Bridge Competition team and hoped that this activity might inspire statics students to participate in future competitions.

The other two deliverables were text document learning tools. One was a flow chart for checking moment equilibrium and the other were checklists for 2D equilibrium, 3D equilibrium, and method of joint truss analysis. Both students wanted to create a document that would help them solve specific types of statics problems by delegating important procedural steps and checks to a flow chart or check list. The flow chart, however, was more of a checklist as it only had one diverging step. The checklist for 2D equilibrium was the most complete of the three checklists submitted by the other student. While these two students' deliverables appeared to have less effort put into them than the other three, both students still expressed valuable insight from their experience creating their deliverable.

For example, the student that developed the checklists, mentioned the following in her second interview about what she learned from her process of creating a checklist for method of joints:

> *It was also very interesting to just go through my own understanding of things, and so I enjoyed that part because for example, with the method of joints for the truss, that really helped me realize, I'm like, "Maybe I should try to better understand why certain methods are used for the truss problems instead of just automatically jumping to the one I want to do, which is the [method of] joints." I liked [this project] because it was a learning experience for me." -Student 4*

Even though this student's checklist deliverable for method of joints was not as well developed as her other checklist for 2D equilibrium, she still benefited from the process by realizing that she needed a better understanding of why method of joints or method of sections were better suited for different truss analysis problems.

The student who made the flowchart expressed her interest in maybe becoming a teacher or professor in her second interview and realizing the amount of work that goes into making a single learning tool:

> *…it's been a thought in the back of my mind of being a teacher or professor and seeing the actual work that goes into making not even a whole class plan, just one tiny aspect of it definitely opened my eyes to what it actually would look like. -Student 5*

This student mentioned putting several hours of work and multiple iterations into their flow chart, which is difficult to truly assess, but the above quote illustrates an increased awareness for the amount of work curriculum design can sometimes require. One improvement that could be made to this project to help assess the amount of effort students put into it would be to ask for an initial iteration deliverable at midterm to compare with their final deliverable and the progress made.

All the students expressed initially struggling with the open-endedness of this project and not having a clear understanding of what was expected of them. After the first interview, each student had more direction for what they wanted to design and what a final deliverable should look like, but more explicit instruction could have been given sooner as one student mentioned in their second interview:

> *So, the instructions you gave are detailed, but I don't think I came to these conclusions from the instructions. We had to talk. So maybe more detailed instructions. I wouldn't want students to find out what they're doing just because of the [first] interview -Student 2*

The instructor's initial instruction of the project was intentionally left vague to allow students the freedom to brainstorm several potential ideas before the first interview and then use the first interview to hone each students' project focus and deliverable. Future offerings could make use of these five students' deliverables as examples to provide clarity on expectations. Students could also be provided an approximate number of hours that the instructor expects them to spend on each phase of the project (e.g. 1-2 hours for brainstorming, 4-6 hours developing and testing, 3-4 hours for finalizing deliverable).

Some of the students also expressed that an additional interview or check-in at midterm would be helpful in guiding their curriculum design and maintaining progress. Student 5 mentioned in their second interview:

> *Maybe a check mark, check benchmark in the middle of it, sort of like, "Hey guys, maybe talk about how are you feeling about the project? Have you started? Where are you at?" -Student 5*

Based on this feedback the instructor plans to add an additional interview at midterm. To help facilitate that interview, students could also be required to do a brief 5-minute presentation to their classmates where they present an initial iteration of their deliverable and receive feedback from their peers. After the midterm presentations, each student would participate in their midterm interview with the instructor to discuss how they plan to incorporate their peer feedback and produce a final deliverable. Ultimately, the evolution of the design of this project could be used as an example for the students to show that curriculum design can require several iterations and not every modification ends up making the curriculum better, but it is difficult to know until we try it out.

Discussion

The results from this work in progress study demonstrate that students can develop potentially adoptable curricula, but that should not be the only goal, or even the main goal of providing students the opportunity to design their own curricula. Not all student-created curriculum will get adopted, but there is value in getting students involved in the curriculum design process [1,3-5,12]. Involving students in the curriculum design process can help foster greater motivation towards and awareness of their learning and improved understanding of concepts [2-5,10,12]. While we did not assess whether these five students improved their understanding of their chosen concepts, the interview data did allude to the students becoming more aware of the limitations in their understanding of their chosen concepts and hopefully motivated them to improve their understanding.

Another valuable aspect of including students in the curriculum design process is their increased appreciation for the challenges of curriculum design and a better understanding of educators' pedagogical decisions [7,10]. All five of the students expressed challenges with their curriculum design process, whether it be managing the time required, having sufficient understanding of their chosen concept, figuring out how to handle assessment, or dealing with different learning styles. The course instructor also developed greater empathy towards this group of five students as the interviews provided the instructor new insight into how the students perceived their engineering education and the challenges they hoped to address with their curriculum.

While the initial results from this study were positive, it should not be assumed that student led curriculum development projects are always positive [1] or appropriate for certain courses [2,4]. Engineering courses that build off content in preceding courses seem to have the most potential for a project like this, but additional contexts need to be considered. For example, the class size should be small enough for the instructor to be able to manage and help guide the project. Instructors need to be able to dedicate additional time to help prepare and guide students through their curriculum development [1-2,4]. In the case of this study, summer classes provided a nearly perfect opportunity to work with a small class size of students who had recently taken the prerequisite course. The downside of this context was the compressed 6-week term that limited the amount of time the students had for their curriculum design while also having to manage the workload of fast-paced MoM course. However, MoM or dynamics are probably the best suited courses to incorporate a statics curriculum design project due to their reliance on statics concepts and proximity to when statics is taken.

Conclusion

The purpose of this research was to provide summer MoM students a statics curriculum design project, interview those students to gain insight into their learned experience with curriculum design and gain feedback to improve the project in future summer MoM courses. While providing students with curriculum design opportunities within a fundamental technical engineering course can be challenging, their perspective as recipients of curriculum can provide valuable insight that may also result in improved curriculum. Interviewing the students at the beginning and end of their curriculum development project also revealed their increased awareness of their own understanding of the material and the challenges for curriculum design. Based on the feedback provided by the first cohort of students to receive this project, the next offering of the project will have students present a rough draft of their curriculum in class at midterm to receive feedback from their peers. Each student will then also participate in a midterm interview with the instructor to discuss how to incorporate that feedback in their final deliverable. The authors hope these changes will help students make further progress on their curriculum design, but also provide the students additional opportunities to reflect on and learn from the curriculum development process.

References

[1] A. Tuhkala, A. Ekonoja, and R. Hämäläinen, "Tensions of student voice in higher education: Involving students in degree programme curricula design," *Innovations in Education and Teaching International*, vol. 58, no. 4, pp. 451-461, 2021.

[2] C. Bovill, K. Morss, and C. Bulley, "Should students participate in curriculum design? Discussion arising from a first year curriculum design project and a literature review," *Pedagogical Research in Maximising Education*, vol. 3, no. 2, pp. 17-27, 2009.

[3] A. Fernandez, E. Delgado, Y. Montoya, R. Gonzalez, and M. Vaughn, "Student led curriculum development and instruction of introduction to engineering leadership course," in *IEEE 2015 Frontiers of Education Conference, El Paso, TX, USA, October 21-24, 2015,* IEEE, 2015, pp. 1-8.

[4] D.C. Bishop, "More than just listening: The role of student voice in higher education, an academic perspective," *IMPact: The University of Lincoln Journal of Higher Education Research*, vol. 1, no. 1, 2018.

[5] J. Bron and W. Veugelers, "Why we need to involve our students in curriculum design," *Curriculum and Teaching Dialogue*, vol. 16, no. 1 & 2, pp. 125-139, 2014.

[6] R. Hämäläinen, C. Kiili, and B. Smith, "Orchestrating 21st century learning in higher education: A perspective on student voice," *British Journal of Educational Technology,* vol. 48, no. 5, pp. 1106-1118, 2017.

[7] S. Brooman, S. Darwent, and A. Pimor, "The student voice in higher education curriculum design: is there value in listening?" *Innovations in Education and Teaching International,* vol. 52, no. 6, pp. 663-674, 2015.

[8] E. Blair and K.V. Noel, "Improving higher education practice through student evaluation systems: is the student voice being heard?" *Assessment & Evaluation in Higher Education,* vol. 39, no. 7, pp. 879-894, 2014.

[9] P. Carey, “Student as co-producer in a marketised higher education system: a case study of students’ experience of participation in curriculum design,” *Innovations in Education and Teaching International*, vol. 50, no. 3, pp. 250-260, 2013.

[10] C. Bovill, A. Cook-Sather, and P. Felten, “Students as co-creators of teaching approaches, course design, and curricula: Implications for academic developers,” *International Journal for Academic Development*, vol. 16, no. 2, pp. 133-145, 2011.

[11] J. Seale, “Doing student voice work in higher education: An exploration of the value of participatory methods,” *British Educational Research Journal*, vol. 36, no. 6, pp. 995-1015, 2010.

[12] X. Zhou, L. Chen, and C. Chen, “Collaborative learning by teaching: A pedagogy between learner-centered and learner-driven,” *Sustainability*, vol. 11, no. 4, 2019.

[13] B.L. Berg and H. Lune, *Qualitative Data: An Introduction to Coding and Analysis*. New York, NY: University Press, 2012.

[14] M.Q. Patton, *Qualitative Research and Evaluation Methods*, 2nd ed. Thousand Oaks, CA: Sage Publications, 2002.

[15] E.G. Guba and Y.S. Lincoln, *Fourth Generation Evaluation*, Newbury Park, CA: Sage Publications, Inc. 1989.

[16] M.B. Miles, A.M. Huberman, and J. Saldana, *Qualitative Data Analysis: A Methods Sourcebook,* 3rd ed. Thousand Oaks, CA: SAGE Publications, Inc. 2014.

[17] J. Walther, N.W. Sochacka, and N.N. Kellam, “Quality in interpretive engineering education research: Reflections on an example study,” *Journal of Engineering Education,* vol. 102, no. 4, pp. 626-659, 2013.