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Board 75: Work-in-Progress: Instructor and Student Reflections on First-year Engineering Design

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Abstract

This work-in-progress paper summarizes how engineering faculty tried to make the better learning environment for the first-year engineering students by minimizing instructor involvement. In the introductory first-year course, Introduction to Engineering, the engineering design process was introduced with small practical exercises at major design steps, and discussion. Then, two different design projects were assigned to apply the engineering design process that they had learned. The learning experience as a team of 2-3 students through these projects is emphasized in this paper. The instructor provided a guideline for the design process, however, the instructor's direct inputs towards the problem-solving in the projects were minimized to encourage self-learning and learning while working together. These first-year engineering students as a team independently navigated to complete these two engineering projects. The survey data showed that majority of students felt that their projects were successful and mentioned that they had learned while working with their peers. The students were most satisfied with the projects when they met their own project goals. Even with limited data from one semester as well things to improve, the overall reflections on active learning experience under minimal instructor involvement was encouraging, which will lead us to conduct further in-depth research in the following upper-division engineering courses.

Introduction

Self-learning (or active-learning) is an essential skillset for lifelong learning and personal growth, as well as a recognition of taking control of one's education and professional development [1-3]. To promote such a learning environment, there has been a trend towards minimizing the involvement of instructors in the education process [4-9]. This shift is being driven by advances in technology, such as plenty of online resources with easy access, and an increasing emphasis on the benefits of self-learning [10]. For example, in our engineering program, there are freshman students who are already excellent on 3D CAD modeling as 3D printings are increasingly popular and cheaper. Many of them were found to study on their own using free online learning platforms or YouTube videos.

While this trend towards minimizing instructor involvement has its benefits, there are some potential drawbacks [11-14]. For instance, some students may struggle with self-learning, and potentially get behind the course flow. Especially, knowledge-based problem-solving courses might be difficult to implement this strategy. Some first-year engineering classes could also be challenging when students need to practice engineering skills, generally without possessing essential mathematical skills and science backgrounds yet [15-18]. However, it seemed to be less resistant to the active learning and consequently easy to perform various educational experiments, with a fresh mindset. That is why I chose this Introduction to Engineering to discover how students think of learning under minimizing instructor involvement. Another benefit from this course was that a significant portion of the contents was open-ended and required relatively a low level of mathematical and/or scientific knowledge, compared with other knowledge-based problem-solving course contents that require more knowledge and previous experience.

This introductory course aims to deliver an overview of the engineering profession and methodology of engineering design. This course invited professional industry engineers with practical engineering projects to let students obtain qualitative skillsets and mindsets for their future engineering careers. Also, social/economic impact of engineering designs and engineering ethics with several case studies were also discussed. In the second half of the semester, the engineering design process was practiced through the two engineering projects. All the students participated in the projects with a particular role, so that they could take responsibility in the team even under minimal instructor involvement.

Overall, this work-in progress paper focuses on the two engineering projects in the introductory engineering course to reflect the student-centered learning environment by minimizing the instructor's direct involvement towards the project activities. Most of the outcomes and presentations were assessed by students, while the instructor had a focus on providing a better learning environment and observing what they were learning. This paper summarizes perspectives from both students (Reflections) and instructor (Discussion).

Course Outline

There were 3 sections of 14-15 students with different instructors for this course (EGR-101 at Marian University). In this paper, we will have reflections on a particular section of the course with 14 students, where students' engineering-related experience varied from no experience to professional certificates and/or similar design project experience in their high schools. Course Objectives with ABET Student Outcomes (SOs) are followed. The last five COs are the ones related to the engineering projects in the course. Throughout the projects, students were expected to achieve the SOs 2, 3, and 5.

- Discuss various engineering disciplines and the role of engineers (SO4)
- Discuss engineering ethics and safety (SO4)
- Demonstrate teamwork for projects (SO5)
- Manage engineering project with effective communication (SO3)
- Implement engineering design process (SO2)
- Operate engineering software tools (SO2)
- Demonstrate engineering problem solving (SO2)

Design projects

The engineering design process was introduced prior to the first design project as shown in Figure 1. Examples, such as power transmission design [19] and good student projects from the instructor's previous courses, were provided to easily understand each step of the process. Also, some hands-on activities were conducted, such as generating multiple ideas as a team and decision-making using the design matrix. I encouraged the students to view the project outcomes from different aspects, such as economic, social, regulatory, or community-related views.

Two engineering projects were assigned as a team of 2-3 students in a period of 4-5 weeks per project. Each project made up 20% of their final grade. The first project was to build a cardboard chair without using any adhesives, which is widely used as a building activity [20, 21]. The purpose of the cardboard chair activity was to practice the engineering design process, rather than focusing on building. In the project, a virtual client asked them to build a customized chair made only of cardboard. This project was an open-ended project requiring significant creativity. However, because the material was limited, they had to make sure to design their chair components with minimal design flaws as possible before actual building. The second project was to build a car that can follow a track line and avoid obstacles. We used a pre-designed RC-car kit (Sport Car, Osoyoo) that provided all the hardware components and basic codes. Students had to repeat trial-and-errors to optimize sensors in their cars so that the cars don't lose control on the track. The second project provided less design flexibility, so we added another requirement creating any 3D-printed components to their cars [22].

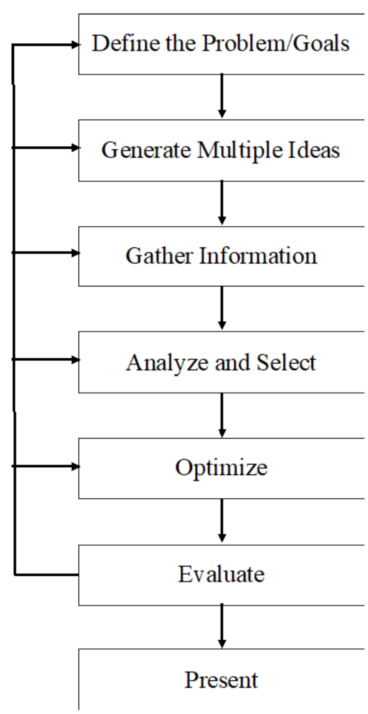

Figure 1. Engineering design process introduced in the class.

	Cardboard chair	RC car
Flexibility	• High flexibility for the design • Requires more creativity	• Low flexibility for the hardware and software change • Requires significant trial-and-errors for optimization
Restriction	• Limited materials and no adhesives • One-time prototype – design decision is important	• No change in mechanism, but other components were allowed to change using 3D printers

Table 1. Difference between two projects.

Students were required to establish their own design goals based on the given requirements. They were highly recommended to set up the project goals with plans to measure, quantitatively if possible. Table 2 shows an example proposed by one of the teams for the cardboard chair project. The first two design goals were to be quantified based on the requirements. However, there were other goals that did not specifically have measurable ways. We compared the project outcomes at the end of each project with their own design goals to assess completeness. Some groups had trouble to come up with measurable design goals.

Design requirements	Design goals	Note
Support a minimum of 200 lb for at least 5 min	Support 250 lb or more for 5 min	Considered margin of safety
Have a seat and back rest	Seat is at least 1.5' by 1.5' Backrest is at least 1.5' by 1.5'	Determined minimum dimensions
Be aesthetic	Be aesthetic	No specific goal and measurement provided
Be ergonomic	Be ergonomic	No specific goal and measurement provided
	Cardboard is used efficiently	Not from any requirement

Table 2. Example of design goals established by a team based on the given design requirements.

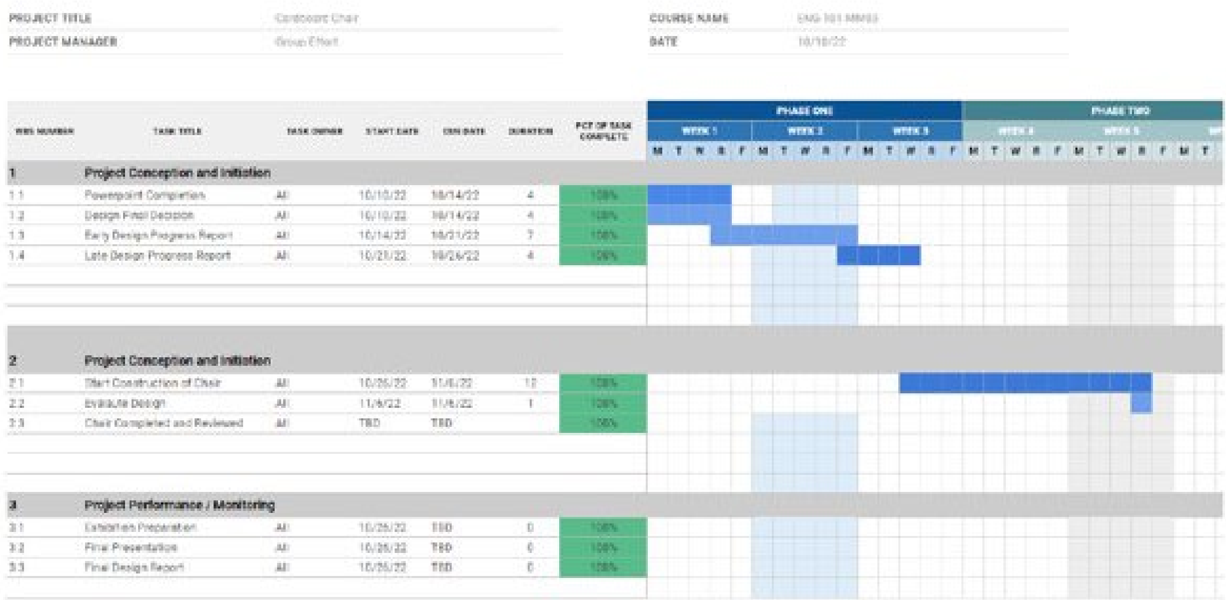

Figure 2. Example of Gantt Chart proposed for the cardboard chair project.

Although students had freedom to work outside the classroom even during the class hours, they were highly recommended to work as a team in the classroom with the instructor around. Their own Gantt Chart was presented in the Design Proposal presentation as shown in Figure 2. The subsequent two intermediate reports (presentations) were mandatory to make sure that they were making progress towards the goals. Students were guided that they could spend more time than planned to fix any time-consuming issues on their projects even if they were beyond the schedule. However, they had to speed up to demonstrate their outcomes on the final date. To practice active management of their projects, the instructor did not proactively check whether they were on time or give any heads-up according to their pre-set schedule.

Each project required a Design Proposal, Early Progress Presentation, Late Progress Presentation, and Final Presentation (with summary report). During the multiple presentations, students were expected to share their ideas and progress, provide any constructive feedback and comments to other teams, and potentially learn from others to improve their designs. Students freely exchanged their opinions and thoughts on ideas created by other teams during all presentations. The final presentation was an evaluation chance while there was still exchange of opinions and thoughts on the projects. The summary report was used to reflect the feedback and comments from the final presentation for suggesting future works as well as for recognizing unexpected aspects of the projects.

Assessment

Self-evaluation and peer-evaluation were primary assessment methods for the projects along with instructor's view on what they learned from the projects. This was based on the benefits of collaboration (part of active learning) by encouraging students to take responsibility for their own learning and managing projects [23, 24]. Self-evaluation was a survey form suggesting how many points they would deserve, specifically based on what criteria (why). This was performed at the end of each project. Peer-evaluation was performed during the final presentation of each project. All participants judged other teams' outcomes considering not only project completeness but also teamwork (communication) and assisting other groups.

Reflections

To avoid any confusion with less involvement of the instructor, the instructions and expectations were laid out at the beginning and the instructor tried to be around the students. Straightforward answers were given to questions, such as the project structures, plans on how to assess their outcomes, *etc*. However, the instructor tried not to answer directly to questions that might affect their designs and/or problem-solving in the projects. This way, students were forced to think about any problems independently and come up with their own solutions by communicating with others. After finishing the first project, students were asked how they felt about instructor minimizing the direct involvement for the project. Figure 3 shows that 88 % students liked to minimize instructor's direct involvement. They mentioned that they were able to manage their projects and make progress although they had some hiccups. Interestingly, one responder even said that he felt that he had received plenty of help from the instructor.

In the same survey, 75% of students responded that they had received feedback from other teams while sharing their design ideas, progress, and final outcomes as shown in Figure 4. However, half of the responses (37.5%: half of 75%) added that the feedback did not help. The other half mentioned that they had actually improved their designs thanks to the feedback from peers. Although this was encouraging, there is a room to improve to provide more students positive and constructive feedback. The negative response (37.5% - Received no feedback) might have attributed to some poor presentation of ideas and outcomes. Therefore, it would be beneficial to help students to deliver presentations in a more effective way and encourage the class to provide more positive and constructive comments and questions.

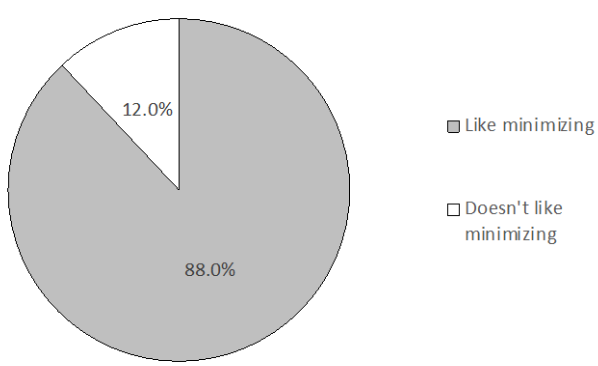

Figure 3. Students' preference on minimizing instructor's direct involvement.

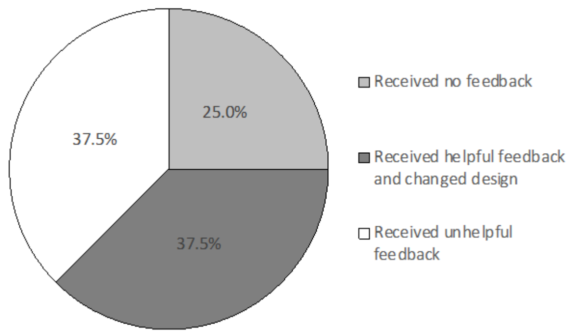

Figure 4. Students' response on the feedback.

This result led us to survey further about whether students consider that their projects were successful and why, at the end of each project. Figure 5 (A) shows that 90% and 85% of students think that their projects were successful with various reasons for the cardboard chair and the RC-car, respectively. Figure 5 (B) shows how they judged their projects regardless of their success. For the cardboard chair project, 40% of students stated that their projects were self-evaluated primarily by considering whether their final outcomes met the initial design goals. Other reasons were "*It was a good practice of engineering design process*," "*I learned about teamwork*," "*Our design process was good although the final product did not meet our design goals*," *etc*. It was interesting to observe that the response rate for "meeting the design goals" as a primary judging criterion increased to 80% in the RC-car. Although there were still 20% of other reasons like teamwork, learning, and communication, majority of the students judged their RC-car project by comparing their initial project goals with final outcomes (completeness).

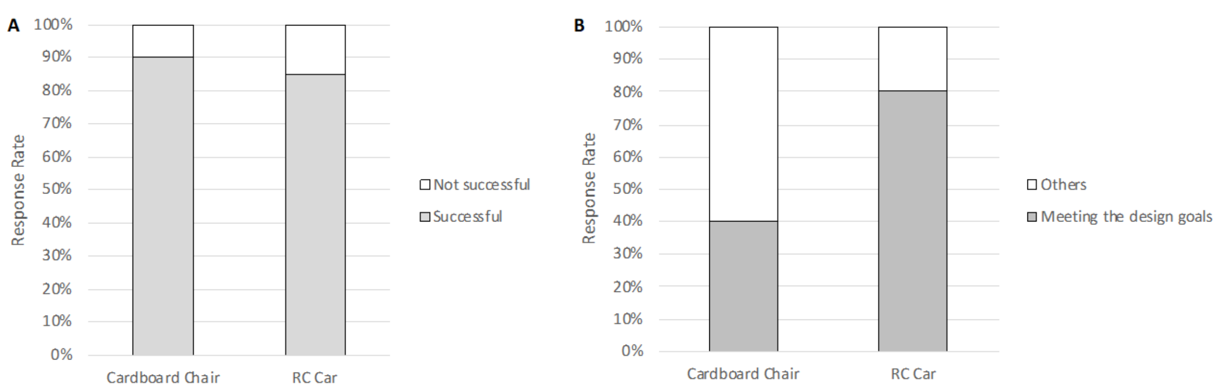

Figure 5. Students' response on (A) whether they think the projects were successful, (B) by what criterion they judged whether their projects were successful.

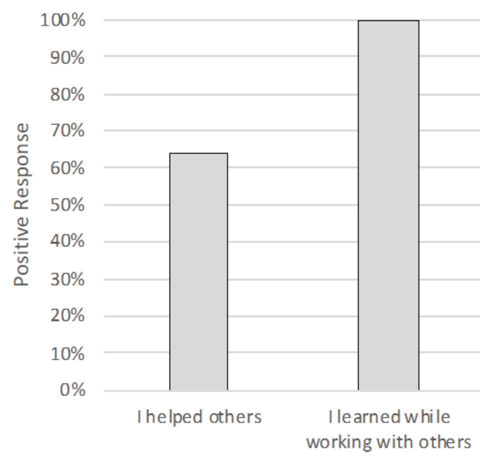

Figure 6. Survey result on helping and learning from each other.

Since significant portion of students who answered as their cardboard chair was successful due to teamwork, learning from others, and communication, further questions were asked to see what they think on helping and learning while working each other. Figure 6 shows that more than 60% of students responded that they helped not only their team members but also other teams to improve the project outcomes and to overcome some issues and/or struggles. It was also interesting to observe that all students found that they had learned while working with others, which means that a big portion of students shared their knowledge and skillsets, and also gained something else from others.

Figure 7 shows both self- and peer-evaluation results on the cardboard chair (A) and the RC car (B) projects. The initial expectation on this data before looking at, was significantly higher scores from self-evaluation compared to the scores from peer-evaluation. Although 80% of the teams scored higher in self-evaluation than peer-evaluation. However, Team 2 in the cardboard chair and Team 4 in the RC car showed even lower results from self-evaluation than from peer-evaluation.

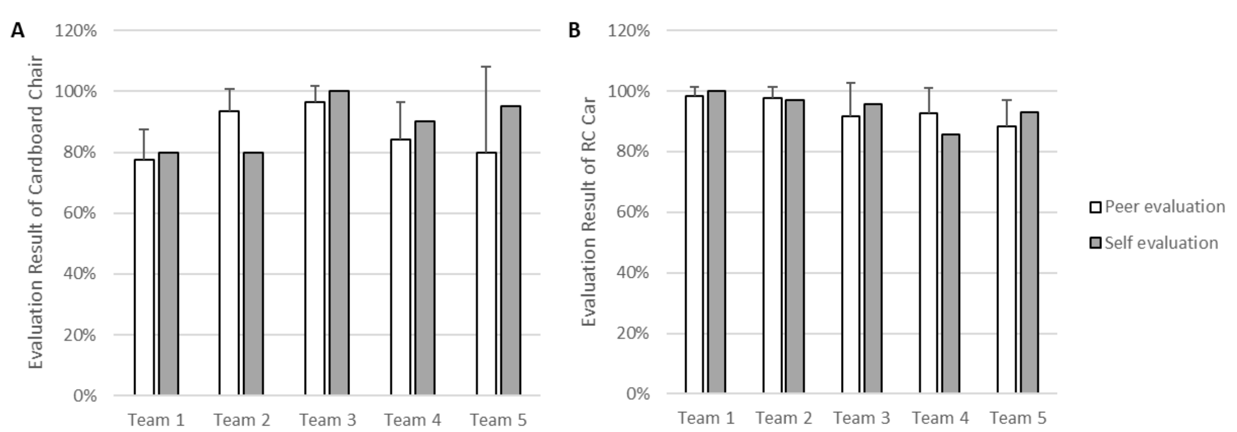

Figure 7. Evaluation results of (A) the cardboard chair and (B) the RC car projects.

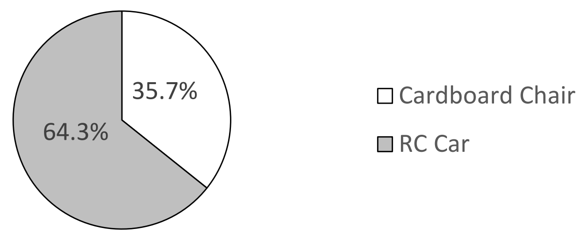

Figure 8. Response on preference for project.

The last survey data is about which project they liked more after experiencing both projects. Figure 8. indicates that 64.3% of students preferred the RC car project, while 35.7% of students liked the cardboard chair project. Majority of students who liked the RC car stated that it was because they saw their cars working as planned even with some hiccups. I think this result probably was in line with the higher response rate of "meeting the design goals" for judging their success in the RC car project in Figure 5 (B). Meanwhile, those who preferred the cardboard chair project mentioned having flexibility in design as the reason. Additionally, their final evaluation results might have influenced their preference. From Figure 7, we observed that the average final score was 86% for the cardboard chair, while they received the higher average final score (94%) for the RC car. This indicates that their sense of accomplishment and the evaluation results could be the primary contributors for the preference.

Discussion and Conclusion

The research goal was to provide overall reflections on active learning experiences, by surveying how first-year engineering students think of their learning experience. The active learning was cultivated while conducting two different engineering projects with minimal involvement of the instructor. These well-known engineering projects were inherently different in terms of design flexibility and restrictions. Therefore, different responses had been expected before the surveys were analyzed. As the results displayed, majority of the students thought that both of their projects went smoothly even with some hiccups, while the primary reason was varied. I tried to provide multiple opportunities to exchange their ideas and feedback in the class.

It was also intriguing to see the different learning experiences and project outcomes from the two different projects. We can't directly compare the results from the two projects due to the inherent differences, but it was meaningful to gain an insight into better approaches using the hands-on projects to practice the engineering design process in the next academic years. This will be applicable not only to first-year introductory engineering courses, but also to upper-division engineering courses containing the engineering design problems. For the upper-division engineering courses, adjustments should be made on projects, in terms of ways to study contents in advance, requirement, depth of analysis, team size, term, *etc*. As previous studied [25], promoting continuous teamwork competencies is believed to lead to higher academic performance in the further courses.

I, as the instructor of this course, enjoyed both projects a lot because I was able to observe the students working together to achieve their own project goals even in the situation where the instructor did not give straightforward help and solutions to their issues. It was obvious that this educational setting encouraged them to pursue self-learning and learning from other mates. Most of them testified that they enjoyed the projects and learned something new while working with their peers regardless of their completeness compared with their own project goals. Students mentioned that they had learned from small technical skillsets, such as how to use a voltmeter, to teamwork and communication skills. I don't believe that this single course can deliver a full range of learning opportunities on those skillsets up to the mastery level. However, this was considered as a good start for first-year engineering students to think about what skillsets they would need, where to learn from, and what to improve throughout the engineering program and beyond.

The biggest challenge was how to assess their learning achievement properly. I usually compare students' final outcomes with their initial project goals in other upper-division courses. However, I felt that this introductory course should be different considering students' capability, depth of engineering knowledge, and other teamwork experience. Therefore, I focused on what they had actually learned from the projects, such as technical skillsets, teamwork with communication, overcoming frustration, iteration process, *etc*. Additionally, I gave them multiple opportunities to think about not only other teams' progress, but also their own reflection through peer- and self-evaluation, respectively. The survey proved that they liked the idea of these evaluation methods at the end of the first project. However, it was unclear why it decreased at the end of the second project.

There are more things to improve to get better assessment data. First, the data in this work-in-progress paper was obtained from one class section in one semester. To see more accurate opinions for the active learning in first-year classes, there should be further research over the coming years with similar settings. Additionally, it would be great to follow up with the academic performance of these students over the next years, while assigning other types of engineering problems using more realistic examples (for curiosity), and in-depth engineering projects. Introducing a customer with certain needs will be a good way to incorporate the curriculum with an entrepreneurial mindset with a help of a needs-based design through consistent communication with the customer [26]. And we could let them think about connecting their design ideas with effects on other aspects in the society [27]. Second, we should utilize better-organized survey tools intentionally designed to assess the effect of minimizing the instructor's involvement for college education. This could provide a clearer correlation between a student-centered learning environment and the learning outcomes. Third, we could integrate this activity with either un-grading or mastery-based grading, so that students can focus more on learning through the projects, not on earning better scores. Lastly, we might have to consider effective strategies to reduce the student resistance to self-learning, which would potentially be observed when they get more challenging problems and/or are forced to think proactively [14, 28, 29]. With these improvements, the minimal instructor involvement will be more practical to other project-based engineering courses and will provide lifelong learning skills to students.

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