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Exploring Engineering Faculty's Use of Active-learning Strategies in Their Teaching

Dr. Aliye Karabulut-Ilgu, Iowa State University

Dr. Aliye Karabulut-Ilgu is an assistant teaching professor in the Department of Civil, Construction, and Environmental Engineering at Iowa State University. Her background is in Curriculum and Instruction, and her research interests include online learning, hybrid learning, and technology integration in higher education.

Dana AlZoubi, Iowa State University

Dana AlZoubi is a PhD candidate, majoring in Educational technology and co-majoring in Human-Computer Interaction at Iowa State University. Her research interests include learning and teaching analytics, dashboards, online learning, self-regulation, student engagement, and reflective practices. Her current work aims to examine how instructors' teaching strategies and methodologies may be informed and improved by interpreting data visualizations (i.e., dashboards) in both in-class and online environments.

Dr. Evrim Baran, Iowa State University

Evrim Baran is an associate professor of educational technology in the School of Education and Human Computer Interaction at Iowa State University. She conducts research at the intersection of technology in teacher education, human-computer interaction, and learning sciences. Her research aims to establish effective strategies for the design of mobile, online, and flexible learning environments in teacher education, engineering education, and STEM learning contexts.

Exploring Engineering Faculty's Use of Active Learning Strategies in their Teaching

Abstract

Active learning approach, an umbrella term for a multitude of instructional methods that require students to actively participate in the learning process, has gained increasing popularity in engineering education. Based on the complexity and the time requirement, active learning can take many different forms from simply pausing a lecture and asking students to write a summary of what has been covered in the lecture to asking them to collaboratively work on real-world problems and projects. The effectiveness of active learning strategies compared to the traditional lecture approach, when implemented well, has been empirically validated and documented in engineering education literature. The purpose of this mixed-methods study was to explore engineering faculty's use of active learning strategies in their teaching in a Midwestern university's college of engineering context. Data sources included a survey about the faculty knowledge and use of active learning strategies and follow-up semi-structured interviews that aimed to gather an in-depth understanding of their implementation of active learning strategies in their classrooms. Results indicated that collaborative learning and problem-based learning were two most commonly used active learning strategies, while 1-minute paper and peer instruction were the least commonly used strategies. Participants agreed that active learning improved student learning outcomes, and motivated students to participate in the class, but required an increased workload during the development of activities. The results of this study may inform future faculty development efforts on adoption of active learning strategies in classrooms that were proven to improve student learning and retention in engineering education.

Introduction

Active learning approach has gained increasing popularity in engineering education. The effectiveness of active learning strategies compared to the traditional lecture approach, when implemented well, has been empirically validated and documented in engineering education literature [1-3]. Engineering instructors are required to go beyond a traditional approach and integrate learning activities that would create various opportunities for students to practice professional skills. Active learning strategies that engage students in creating solutions to real-world problems hold promises to produce well-rounded future engineers. Despite the ample evidence of the effectiveness of active learning strategies in improving student learning and engagement in engineering classrooms, the translation to actual classroom practice has been substantially slow [4]. To facilitate change and future adoption of active learning strategies, we need to understand instructor's current status and beliefs about active learning strategies. The goal of this study was to identify the level of implementation of active learning strategies, explore the factors that influenced engineering instructors' perspectives on the effectiveness of active learning, and identify barriers to effective implementation as well as the factors contributing to the adoption of various active learning strategies. Findings from this study would inform future faculty development activities to prepare engineering faculty for the integration of evidence-based active learning strategies into their teaching.

Review of the Literature

Active learning is an umbrella term that is generally defined as any instructional method that requires students to actively participate in the learning process activities besides passively listening to the instructor [1]. As the name suggests, active learning requires students to actually do things (e.g. write, read, discuss, solve) either individually or as a group and reflect on what they do. Active learning can take many different forms from simply pausing a lecture and asking students to write a summary of what has been covered in the lecture to asking them to collaboratively work on real-world problems and projects. Active learning strategies chosen for this study were based on a previous study conducted by Borrego, et al., [5] on research-based strategies, and are defined as following (p. 449):

- *Collaborative Learning*: Asking students to work together in small groups toward a common goal during class
- *Problem-Based Learning*: Acting primarily as a facilitator and placing students in self-directed teams to solve open-ended problems that require significant learning of new course material
- *Inquiry Learning*: Introducing a lesson by presenting students with questions, problems or a set of observations and using this to drive the desired learning
- *Concept Tests*: Asking multiple-choice conceptual questions with distractors (incorrect responses) that reflect common student misconceptions
- *Think-Pair-Share*: Posing a problem or question, having students work on it individually for a short time and then forming pairs and reconciling their solutions. After that calling students to share their responses
- *Cooperative Learning*: A structured form of group work where students pursue common goals while being assessed individually
- *Case-Based Teaching*: Asking students to analyze case studies of historical or hypothetical situations that involve solving problems and/or making decisions
- *Peer Instruction*: A specific way of using concept tests in which the instructor poses the conceptual question in class and then shares the distribution of responses with the class (possibly using a classroom response system. Students form pairs, discuss their answers, and then vote again
- *1 Minute Paper*: Asking students to take one minute to reflect on the day's lesson and provide feedback to the instructor

Active learning has been extensively studied in engineering education. For example, surveying the existing research examining various forms of active learning (i.e. introducing activities into lectures, collaborative learning, cooperative learning, and problem-based learning), Prince [1] found evidence for all the forms of active learning included in the study promoted academic achievement and positive student attitudes. Similarly, Freeman et al. [2] conducted a meta-analysis of 225 studies that reported data on student scores on assessments and failure rates in both traditional and active learning sections. They found that average exam scores improved 6% in active learning sections while students in the traditional sections were 1.5 times more likely to fail than their counterparts in active learning sections. Furthermore, students in active learning sections performed better on concept inventories which were designed to assess higher level cognitive skills than course examinations that emphasize content mastery. In a particularly recent study, Deslauriers et al. ([3] indicated that students engaging in active learning learned more than they think they had learned. Despite all this compelling evidence for the effectiveness and affordances of active learning, large scale adoption of active learning strategies has been slow [4].

In an attempt to understand the slow pace in adoption of active learning strategies in engineering education, some researchers investigated what might be hindering the use of active learning. Barriers to effective implementation of active learning included student characteristics (e.g. student expectations and resistance), instructor-related concerns (e.g. preparation time, beliefs about effectiveness of these strategies), and pedagogical concerns (e.g. nature of the content; difficulty of implementation in large enrollment courses) [6-8]. Understanding what contributes or hinders engineering faculty members' perspective is the key to success in any professional development that aims to teach active learning strategies to engineering instructors. In this study, we examine engineering faculty members' beliefs, knowledge, and level of use of active learning. Specifically, the following research questions were examined:

1. What are engineering instructors' perspectives on active learning?
2. To what extent do engineering instructors know and use active learning strategies?
3. How frequently do engineering instructor implement various active learning strategies in their teaching?

Method

A mixed method approach, combining quantitative and qualitative data, was adopted in this study. Quantitative data included a survey adapted from Borrego at al., [5] including four parts. The first part asks participants to rate their level of agreement on a 5-point scale (strongly agree to strongly disagree) on their beliefs about active learning. The second part asks participants to indicate their level of knowledge about each of the listed active learning strategies listed above (e.g., collaborative learning, problem-based learning, inquiry learning, etc.). Definitions of each active learning strategy was provided to ensure the participants interpret had the same understanding of active learning as different titles might be used in various contexts. The third part included the same list of active learning strategies and asked the participants to indicate the frequency of their implementation of each strategy. Finally, the last part included background questions such as demographic characteristics, teaching experience, and if they participated in any professional development for teaching, and in particular on the use of active learning. This quantitative data were analyzed using descriptive statistics. Percentages, measures of central tendency, such as the mean, median and mode were examined as well as demographic distributions.

Qualitative data included semi-structured interviews with participants, and aimed to delve further into how engineering instructors learned about various active learning strategies, why they decided to implement them in their course(s), what kinds of support they received as well as any challenges they had, and how they overcome those challenges. This qualitative data was analyzed following a recursive and spiral pattern to code for recurring themes and categories [9]. Periodic peer debriefing sessions were conducted to determine agreed-upon principles for data analysis that included inductive analysis of the common themes emerged from the interviews, discussion of discrepancies, mutual and exclusive definition and refinement of the themes through discussion and negotiation.

Qualitative and quantitative data were linked in a purposeful way to allow researchers to view the active learning phenomena through diverse research lenses. The mixed method approach allowed a better understanding of the connections between both data sources by enriching the evidence from the quantitative data and allowing further specific questions about active learning to be answered more deeply.

Participants

The study was conducted in the college of engineering at a large mid-western university. The college has twelve ABET accredited programs providing undergraduate and graduate education. Out of total 257 faculty members who were invited to participate in the study, 53 completed the online survey, and 11 of them provided their contact information to participate in the follow-up interviews. Out of 11, four instructors participated in the interviews. Table 1 displays the background information for participants.

Table 1. Background information for the participants

Gender (N=43)*	Male				Female		
	65%				35%		
Age (N=42)*	Younger than 30	30-39	40-49	50-59	Above 60		
	2%	29%	33%	21%	14%		
Ethnicity (N=42)*	White	Hispanic or Latino	Asian	Other			
	83%	2%	10%	5%			
Academic ranking (N=43)*	Assistant Professor	Associate Professor	Full Professor	Assistant Teaching Professor	Associate teaching professor	Full teaching professor	Other
	21%	19%	21%	6%	15%	2%	6%

*Missing data

Results

The analysis of the quantitative and qualitative data is presented in three categories based on the research questions listed in the previous section: (a) perspectives on active learning, (b) knowledge and use of active learning, and (c) frequency of active learning implementation.

Perspectives on Active Learning

Understanding faculty members' beliefs and perspectives on active learning would help explain the reasons behind their use or rejection of active learning. Four items in the survey specifically asked faculty members' perspectives on the contribution of active learning to student learning (Figure 1). A very high percentage responded positively that active learning improves student learning outcomes (80%), increases student engagement (83%), motivates students to participate in class (82%). In the follow-up interviews, participants' perspectives aligned with the survey responses and extended them with further explanation. For instance, interview participants also indicated that they were able to bring in experience and real-world applications to their instructions via active learning strategies while highlighting that this would not have been possible in a traditional lecture classroom. For the item asking if active learning is more effective than traditional learning, though, the responses were a little more dispersed with 52% positive, 21 % neutral, and 17% negative rating.

Three items in the survey asked faculty perspectives on barriers to the implementation of active learning based on previous literature. Only 20% of the participants opined that active learning took too much class time to let them cover the syllabus while 48% disagreed with the statement. Majority of the participants were neutral with regard to increased preparation time (40%) and there were almost equal percentages for positive and negative ratings. The interview participants also highlighted *time* as a potential barrier because the initial time investment during the development of in-class activities might be high, yet they all agreed that it was worth the effort. Also, because the activities are usually open-ended, and do not necessarily have one right answer, they can easily be reused in subsequent semesters. That way, faculty members can focus on student learning rather than preparing new materials. A similar percentage (42%) of participants remained neutral in terms of students' negative reaction to active learning. However, only 8% stated that students reacted negatively, while the percentage of people disagreeing with student resistance was 51%.

The interview participants stated that, in general, when using active learning in classrooms, they received positive reactions from their students even though they would have a few students that would resist against working in groups, or completing their preparation work before class. However, one participant stated that student evaluations usually were lower when they implemented a team-based approach. Team-based learning is a more structured active learning approach that requires students to be always prepared, and take the responsibility for their own learning. This comment confirmed the negative reactions that some faculty may face when they try to implement such approaches. However, the interview participants who might be considered as successful implementers of active learning, underscored that they explain the course structure, expectations from students, and how each class would be structured on the first day of class, which helps them set the stage. Collecting feedback from students during the semester, as opposed to waiting until the end of semester, helped that faculty member to address any concerns students had.

Finally, participants were asked about the peer and administrative support that might influence their decisions to implement active learning. More than half of the participants (57%) indicated that their peers used active learning, and 51% indicated that their administrators encouraged them to use active learning. Interview participants perceived that their efforts in teaching were recognized. For instance, some of them indicated that they were nominated for teaching awards, and others revealed that their peers approached them for help in designing active learning exercises. Even though the administration seemed to be encouraging the use of active learning, responses to whether the participants thought they were provided with the resources to support their implementation were more dispersed (41% negative, 37% neutral, and 23% positive). Similarly, 42% of the participants were neutral in terms of whether their administration values the implementation of active learning. However, it is worth noting that the negative rating was quite low (14%), while the positive rating was close to the neutral rating (46%).

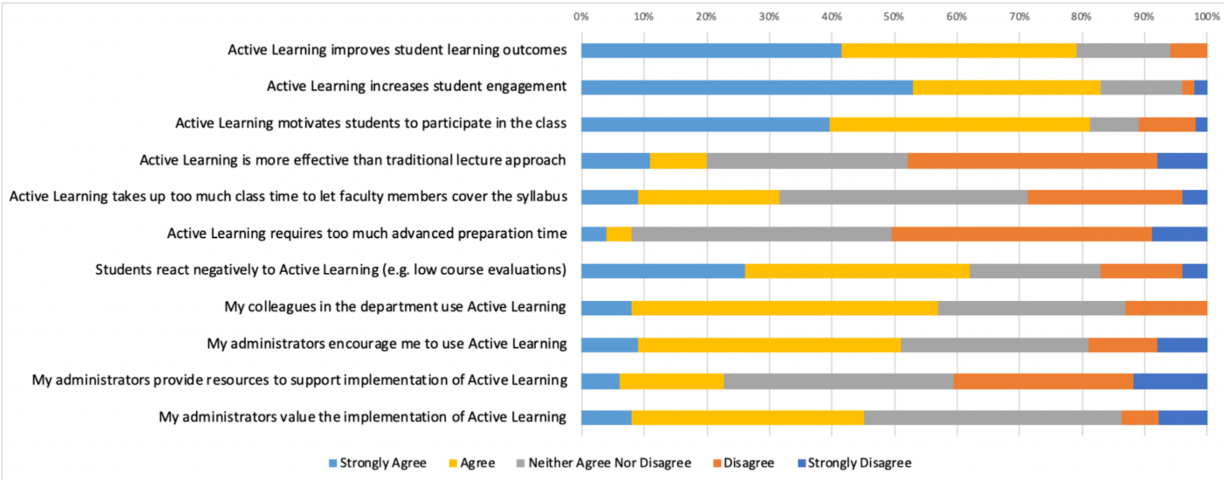

Figure 1. Perspectives on active learning (N=53)

Knowledge and Use of Active Learning

Participants were asked to indicate their level of knowledge for various active learning strategies that are listed as evidence-based strategies in the literature [5]. Figure 2 displays participants' self-reported knowledge and use of each of the active learning strategies. Findings indicated that collaborative learning and problem-based learning seemed to be the most commonly used strategies followed by cooperative learning and concept tests. Interestingly, concept tests, peer instruction, and 1-minute paper were three strategies about which the participants had the least knowledge.

In the follow-up interviews, participants indicated that they mostly learned the aforementioned used active learning strategies through the university level workshops they attended. One of the participants was a teaching assistant for a professor who was the pioneers of active learning engineering during their graduate studies, and that impacted their teaching career in the long run. Being able to observe an effective implementation of active learning produced a long-term effect on this faculty member, and motivated them not only to enhance their teaching skills through active learning but also to develop interest in engineering education research.

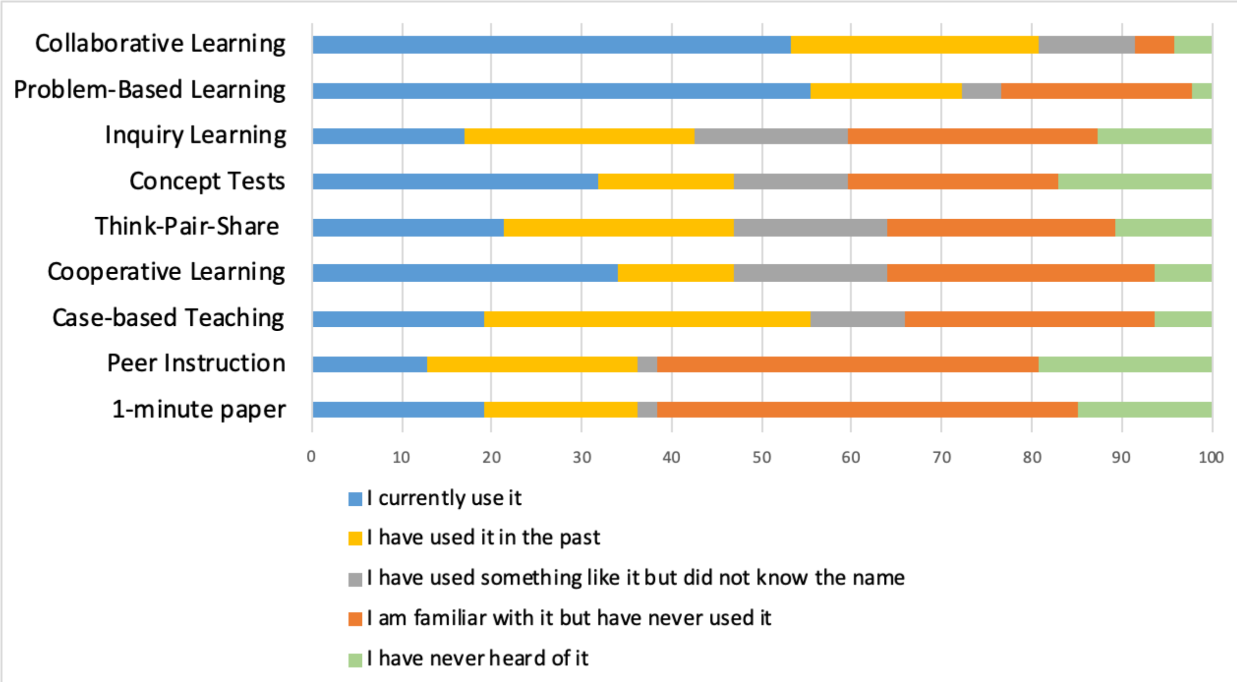

Figure 2. Level of knowledge and use of active learning strategies

Participants were also asked if they had received any training on teaching. Out of the 43 respondents, 81% indicated that they received training on teaching which included department level workshops (49%), college level workshops (37%), university level workshops and learning communities (97%), workshops offered through professional societies such as (60%), courses on teaching during graduate education (31%), and online training such as webinars, courses, and seminars (54%). It needs to be noted here that one respondent might have participated in more than one training activity. However, it seems like almost all participants joined a workshop or training provided by the Center for Excellence in Learning and Teaching –a university level support unit. Out of 35 participants who indicated that they had received training on teaching, 66% stated that their training had a focus on active learning, while 29% stated their training had a focus on active learning to some extent, while six percent indicated that their training had no focus on active learning.

Frequency of Active Learning Implementation

Figure 3 displays the frequency of the implementation of active learning strategies. Similar to the results of the use of active learning strategies, the frequency of implementation of collaborative learning and problem-based learning was the highest. Approximately 25% of the participants indicated that they used collaborative learning and problem-based learning nearly every class period. The least commonly used strategies were 1-minute paper and peer instruction.

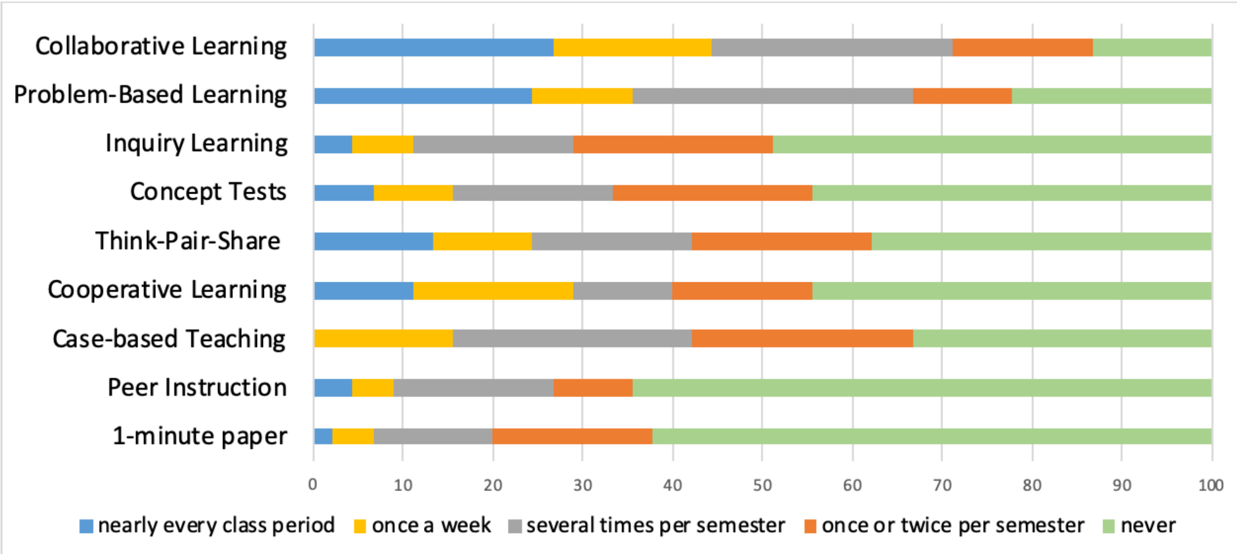

Figure 3. Frequency of implementation of active learning strategies

In the follow-up interviews, participants indicated that they mostly used team-based learning and problem-based learning while implementing active learning strategies. However, it is worth noting that depending on their course requirements, objectives and structure, the same faculty indicated that they may be able to implement team-based learning in one classroom while not in the other.

Discussion

Despite the increasing volume of research supporting the effectiveness of active learning strategies, the actual implementation seems to be very limited in engineering classrooms. Rather, the traditional lecture approach that fails to engage students in the learning process [10], seems to be dominating the practice of teaching engineering. This study aimed to identify the current use of active learning in the college of engineering at a large research university, and explore the contextual factors that might support or hinder its implementation.

The results of this study indicated that faculty members' perspectives on the effectiveness of active learning were in line with the previous studies that active learning improves learning outcomes, increases student engagement, and motivates students to participate in the learning process [2], [11-13]. To increase the number of faculty members using active learning strategies, these faculty members could play an important role in acting as opinion leaders, mentors, and advocates of active learning by sharing their experiences and findings from their classes in terms of student learning gain and motivation.

Faculty members who used active learning strategies seemed to learn these teaching strategies through university-level workshops, which underscores the importance of availability of professional development opportunities for enhancement of teaching [14]. Majority of the professional development activities at the university under investigation, focused on specific active learning strategies such as team-based learning which is a very structured collaborative activity which requires significant time investment at the development stage. The fact that collaborative learning and problem-based learning were the most commonly used approaches indicated that at least some engineering faculty embraced the role of collaborative learning. Easier activities such as 1-minute paper, think-pair-share were not as frequently used. Professional development activities that focus on taking incremental steps to make the courses more active would be beneficial for novice faculty members who might feel overwhelmed by some strategies that require a lot of planning, resources and time allocation.

Implications for Practice

Results from this study clearly indicated that faculty members who integrate active learning into their teaching believed that active learning improved students and increased student engagement and motivation. As pedagogical beliefs have been proven to be significantly impacting teaching behavior [15], faculty professional developments could focus on changing instructor beliefs about active learning. Once convinced about the effectiveness of alternative approaches to traditional teaching, faculty members would be more open to trying various active learning strategies.

The fact that collaborative learning and problem-based learning were the most commonly used approaches and the university-level workshops emphasis on these specific approaches implied that increasing awareness and knowledge of faculty members on various active learning strategies would positively impact their adoption of active learning. Additional active learning strategies could be integrated into faculty development efforts. Additionally, faculty members who could be regarded as pioneers of active learning in their departments, could play a major role in facilitating professional development activities and sharing their experiences.

Finally, administrators could accelerate the adoption of active learning by providing resources, acknowledging the extra effort instructors devote in developing activities, and using alternative evaluations for teaching since student evaluations may not necessarily reflect the quality of instruction because of extraneous factors.

Limitations and Implications for Future Research

As with any research, this study has some limitations to take into consideration while interpreting the findings. First, it is likely that only instructors who are somehow interested in active learning might have taken the survey as the invitation to participate explicitly included a statement on active learning. Therefore, findings may not represent the entire college population. It would be interesting to identify people who are skeptical about active learning and find more about their perceptions in particular. It would also be worth investigating if faculty rank makes a difference in terms of how active learning is perceived so that more targeted professional development opportunities could be developed. The same survey can be distributed every semester to see if there are any changes both in terms of beliefs about active learning but also the implementation. Additionally, classroom observations might provide additional data with regard to how faculty members implement active learning.

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