Online-Journals.org

iJEP International Journal of Engineering Pedagogy

iJEP | eISSN: 2192-4880 | Vol. 14 No. 2 (2024) | OPEN ACCESS

https://doi.org/10.3991/ijep.v14i2.42449

PAPER

Catalyzing Change in Engineering Pedagogy: The Role of Workshops, Modules, and Reflective Implementation

Peter Rillero[1](✉), **Hy Grant Rillero**[1,2]

[1]Arizona State University, Tempe, Arizona

[2]Crowne Iron Works, Minneapolis, Minnesota

rillero@asu.edu

ABSTRACT

This paper presents the implementation of a professional development program that aims at enhancing instructional practices to foster student-centered teaching approaches among engineering faculty at two universities in Pakistan. The program was guided by the theoretical perspective of enactivism and involved an initial three-day workshop, online modules, and reflective implementation assignments. The paper provides a detailed account of the program's framework, design, and evaluation. The research questions addressed are: What are the perceptions of faculty members regarding (a) the benefits of the program topics and (b) changes in their actions as a result of the program? Likert-item survey instruments with retrospective items were analyzed using descriptive statistics and paired t-tests. As the program moved from being required to voluntary, participation was declined. Faculty who participated in this engineering pedagogy project reported positive attitudes and significant growth in utilizing student-centered strategies. The three-day workshop was perceived as the most beneficial of the components. The module was perceived to be of the highest benefit when focused on writing effective questions for high-level thinking. All the pre-to-post retrospective items showed statistically significant increases, with the two largest being the use of student response systems (SRS) and the focus on big ideas in teaching. The combined approaches show promise for faculty who persist in long-term professional development projects, catalyzing changes in perceived value and the implementation of active learning techniques.

KEYWORDS

pedagogy, engineering education, student response systems, higher-level thinking, big ideas, question-asking, discrepant events, professional development

1 INTRODUCTION

In recent years, engineering programs have undergone significant curricular transformations to better align with the evolving needs of future engineers [1–3]. These changes go beyond mere content outlines, aiming to foster active learning among students. While tangible aspects such as syllabi, assignments, and readings

Rillero, P., Rillero, H.G. (2024). Catalyzing Change in Engineering Pedagogy: The Role of Workshops, Modules, and Reflective Implementation. *International Journal of Engineering Pedagogy (iJEP)*, 14(2), pp. 4–19. https://doi.org/10.3991/ijep.v14i2.42449

Article submitted 2023-06-19. Revision uploaded 2023-11-21. Final acceptance 2023-12-03.

© 2024 by the authors of this article. Published under CC-BY.

reflect these curricular revisions, their successful implementation relies on intangible factors, including the faculty's knowledge, abilities, and attitudes. Consequently, faculty professional development often focuses on these areas, aiming to optimize curricular enhancements. It is widely recognized that research-based curricular reforms, coupled with effective professional development, can greatly contribute to meeting the demands of future engineers.

Within the realm of university faculty professional development, there is a growing emphasis on fostering creativity through reflective, research-informed, and iterative practices. Published accounts that detail engineering curricular changes, along with evaluative research findings, can serve as valuable resources for other programs. Research and program descriptions suggest that active learning techniques (ALT) can improve student learning outcomes. However, there is a relative scarcity of published literature specifically addressing professional development programs designed to enhance pedagogical practices among engineering faculty. Engaging in scholarship related to the professional development of engineering faculty can help identify successful program components while promoting reflection and interactive improvements.

This paper aims to describe a professional development program implemented with engineering faculty at two universities in Pakistan. The primary objective of the program was to equip faculty members with student-centered pedagogical techniques that would enhance their implementation of revised curricula. The overall research question addressed is: What are the perceptions of faculty completers on (a) the benefits of the program topics and (b) changes in their actions as a result of the program? Descriptive statistics and paired t-tests of survey items address faculty completers' perceptions and changes in actions. The article provides an in-depth account of the program's design and implementation, along with a presentation and discussion of the collected data.

2 LITERATURE REVIEW

2.1 Active learning techniques in engineering education

Learning is an active process that requires both attention and critical thinking. While traditional lecture formats, supported by board notes or slide decks, can captivate student attention and foster thoughtful engagement, there is a diverse range of instructional methods specifically crafted for lecture classes that can further elevate student engagement, attention, and critical thinking [4–6]. These methods are part of the broader reform efforts in engineering education [7–8], driven by student-centered approaches and facilitated through the use of active learning techniques.

Rather than completely replacing lectures, an attainable objective is to supplement them with ALT, moving beyond the passive act of students merely listening and taking notes. These techniques encompass various approaches, such as facilitating brief dyad or small group discussions and incorporating student response systems (SRS). For the purposes of this research, ALT is operationally defined as methods used during a lecture to actively involve students in content-related tasks, surpassing traditional note-taking [9].

2.2 Benefits of active learning

Multiple studies have demonstrated the benefits of ALT over traditional lecture-based approaches in terms of student learning outcomes. A meta-analysis of 225 studies focusing on undergraduate STEM (science, technology, engineering, and mathematics) classes revealed that ALT implemented during scheduled lecture periods led to greater student engagement and achievement compared to lecture-only methods [10]. Further supporting evidence from Pascarella and Terenzini's [11] research underscores the impact of instructional approaches on student engagement and knowledge acquisition. Additionally, active learning tasks have been found to enhance positive student emotions [12].

Numerous methods contribute to student-centered approaches and active learning. Astin's research highlights that student-student and student-faculty interactions have the greatest impact on student academic and personal development, surpassing even curriculum factors [13]. This suggests that enhancing instructional techniques can amplify the benefits of curriculum development.

Active learning may benefit students by improving their attention span. Research indicates that the number of students taking notes declines as lectures progress [14], leading to decreased retention of information in the latter part of the lecture. Distractions such as clock-watching, texting, and unrelated homework further hinder student attention [15].

Lectures have been dominant in higher education [9], [16]. Lectures can be effective at introducing content to students [17]. Improving them doesn't mean removing them; faculty who teach through lectures are not necessarily luddites. Multiple approaches can be useful, and lectures can be effective at introducing concepts, providing appropriate levels of detail and context for courses, and motivating students [18].

2.3 Slow changes

In a survey of engineering department chairs, which may have favored higher perceptions of student-centered practices, disparities were observed between awareness and adoption rates [4]. While surveys indicated that 82% of faculty members were aware of ALT, only 47% had adopted it, and 29% did not practice any form of ALT. In a modest-sized study involving engineering educators at Canadian universities, nearly 95% of the surveyed instructors indicated that their primary instructional approach consists of delivering lectures [19].

The slow pace of change in adopting active learning techniques has prompted speculation. The topic can be divisive, with some faculty strongly advocating for alternatives to traditional teaching methods, while others view active learning as just another passing educational trend [5]. Specific concerns, such as covering course content, loss of control in large lecture halls, fixed desks, and student resistance, have been well-documented [20–22].

Despite the challenges, improving instructional practices may be more feasible to implement than curricular reform, as it often relies on individual professors' decisions. Promoting change may involve developing highly specific interventions that are perceived as manageable and not overly difficult to implement [10].

2.4 Professional development for engineering educators

Faculty practices are the most important means for potentially affecting changes in student learning and motivation [23]. Numerous professional development (PD) initiatives within university settings have been created to offer educators opportunities for enhancing their teaching techniques [24]. Although universities typically provide PD programs that address many disciplines and general teaching strategies, instructors have shown a preference for PD programs tailored to the specific requirements of their field [24]. More research in this area needs to be conducted for STEM faculty [25]. More specifically, engineering educators have indicated that they find non-targeted PD programs less directly relevant to their engineering-specific contexts. This has resulted in decreased participation in instructional development workshops and other educational growth opportunities [19]. Modules have been shown to be effective tools with engineering students [26–27], and engineering educators to promote reflection and changes in approaches [28].

Changes to student-centered teaching are not always straightforward and easy [29–30]. A complication for implementing instructional change is that university faculty frequently feel unprepared for their initial instructional roles [31–32], report that their graduate studies were not adequate in this regard [33], and beginning engineering instructors have even been described as "well-intentioned gifted amateurs" [34]. Faculty in "hard" sciences, such as engineering, frequently report using fewer active learning methods than those in other fields [35–36].

There are trends with engineering faculty spending more time understanding active learning, using more ALT in their teaching, and increasing active learning in their lectures [37], but the implementation percentages remain low [38]. Professional development efforts focused on increasing active student learning have had success. Attending a workshop on teaching had one of the strongest statistical correlations with implementing ALTs [39]. ALT did not replace lectures, but the practices were incorporated into a lecture-style teaching environment [40]. From their research, Borrego *et al.* [4] conclude that professional development that helps faculty members incrementally adopt ALT and describes how to gain student acceptance is more important than just describing the innovation and its benefits. Modules can streamline the professional development process, making it more efficient and consistent. Faculty members can access specific content and resources as needed and are generally viewed positively by faculty [41]. For many of these reasons, a report by the American Society for Engineering Education (ASEE) [28] recommends career-long professional development to facilitate effective learning environments. Combinations of lectures, research tasks, classroom interactions, and new assessment strategies may be key to transformative engineering education outcomes [42].

3 THEORETICAL BACKGROUND

Enactivism, a learning theory that emerged from several theories and philosophies, provides more robust insights into "how our lived experience, the embodied nature of knowing, shapes what we know or how we can come to know" [43, p. 108]. The theory moves past the limits of often unstated assumptions of "knowledge-as-object," where knowledge exists external to individuals and groups and can be stored and transferred as though it were a physical or virtual object. Definitions are a useful example of seeking an objectification of knowledge, yet useful definitions are those that seem to be agreed upon but are often subjective. Further, knowing is often tacit rather than explicit; it cannot be expressed or can only be expressed in limited ways. Thus, a more useful construct is "knowledge-as-action." Brown and Cole [44] describe this as performative "knowledge as doing," with equivalent words, which is also expressed as "doing is knowledge." Thus, in a professional development milieu, knowledge is linked to effective behavior.

As a full-sensory experience, learning is influenced by observations, emotions, actions, and culture [45]. In addition to cognition, our realities are created as selective observations. From this perspective, "the learner is shaped by the multitude of lived experiences from her history—she does not see the world as it is, she sees the world as she is, or rather as she has become. Consequently, this embodied understanding has the potential to shape, enable, or limit her learning" [43, p. 108].

Actions in the environment help to transform the individual, but these actions may transform the environment as well. This co-emergence can occur between interacting systems, such as humans, a culture, and an environment [45]. A conversation as a co-emergence analogy: We shape the conversation, but the conversation shapes us [46].

While the diverse aspects of enactivism can be chaotic, there are important applications for research professors and their teaching, where research competes with teaching for time, actions, and thoughts. Most engineering faculty have not received formal training in pedagogy as part of their doctoral work, and their pedagogical repertoire was obtained through action. Thus, their pedagogical knowledge is not knowledge as an object but knowledge as an action [47]. Based on their teaching experiences, interactions, and the culture of the department, their pedagogical knowledge may be unformulated, intuitive, or instinctive. Formulated knowledge from readings, peers, supervisors, and outside experts may catalyze change and be enacted. These changes in teaching change the learning environment. Selective and subjective observations of implemented changes by professors may have a cascading effect on evaluating the changes, with implications for cognitive knowledge, intuitive/unformulated knowledge, and emotions [48]. The interplay of experiences and current pressures leads to possible outcomes of accepting and improving the changes or rejecting of the changes. Although the system is complex and many aspects are unmeasurable, unraveling aspects can help us deepen our understanding of transforming instruction, according to research professors.

4 PROFESSIONAL DEVELOPMENT DESIGN

The professional development program, titled AIM (advancing instructional methods), consisted of three components (see Figure 1) that began at the start of the calendar year and ended in the summer of the subsequent year. There was an initial three-day workshop that was presented as a requirement by faculty supervisors. This was followed by optional online, interactive modules, which were complemented with reflective implementation assignments. An enactivism framework ran through the experiences. In the workshop, professors experienced the techniques as if they were students; the modules induced reflection and written responses on how techniques could be applied, and the assignments required implementation in their teaching.

The three-day workshop was designed for participants to experience ALT methods as first-year learners and then think about them as educators. The software Socrative was used as a classroom response system, and a variety of discrepant events were used to help them experience how they can be engaging, promote discussion, and enhance learning. The following topics were addressed:

- Less is more. The purpose of this topic was to shift the focus from presenting all the facts to an emphasis on big ideas, using the information, and engineering thinking. This is essential to helping faculty feel like they have time to implement ALT by presenting less. The faculty then worked together to consider big ideas for their courses.

- Higher-level thinking. This topic promoted discussions about using high-level questions to engage students and promote higher-level thinking. Faculty then worked together to generate questions.
- Questioning techniques. Methods to maximize student thinking and communication by all students when asking high-level questions were explored. The faculty in small groups practiced asking questions with adequate wait time and having multiple students respond before they did.
- Assessing and engaging. During previous topics, the use of classroom response systems with Socrative and Plickers was modeled with faculty engaging as students. The faculty were then led into the nuances of the approaches as instructed.
- Predict explain and test explain (PETE) method and discrepant events. During previous topics, the use of discrepant events with the predict, explain, test, and explain phases was molded for faculty. This led to discussions of alternate conceptions and discrepant events that could occur in engineering education.
- Scholarship for teaching and learning. This topic focused on how developing teaching methods can be used in presentations and publications. The idea is that improved teaching and research on the approach can be scholarly output. This is important as ALT can take time, but if it benefits both teaching and scholarship, more faculty may invest more time.

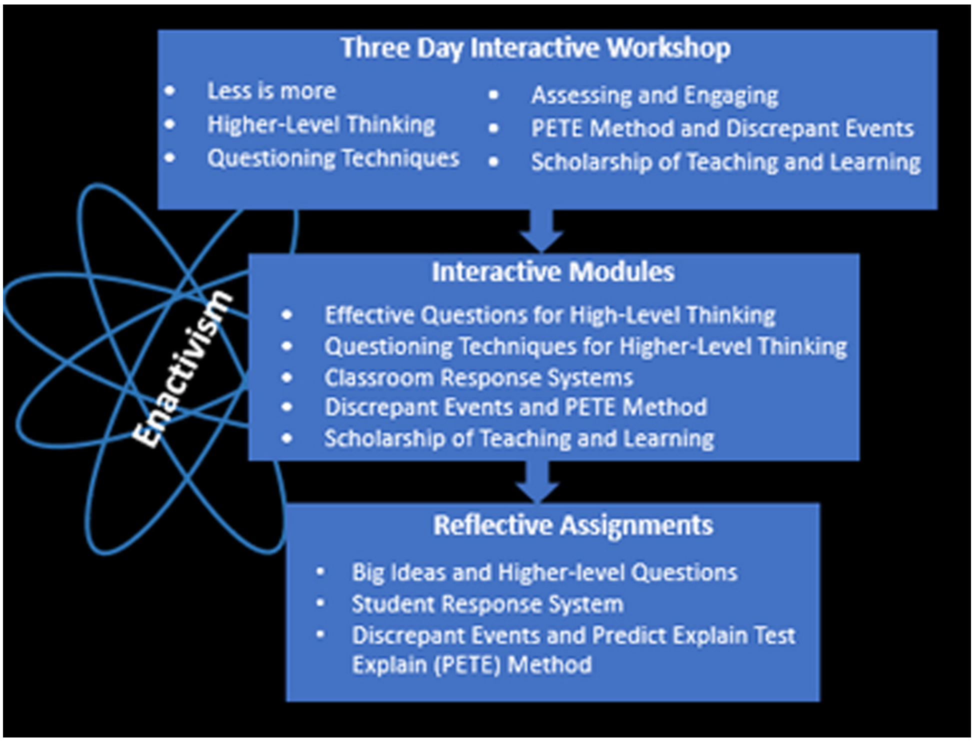

Fig. 1. The three components of the AIM Program

The interactive online modules, created with Articulate, were designed to deepen understanding of the three-day workshop topics. The five modules, each drawing from existing educational literature and research as its foundation, were as follows:
Writing Effective Questions for High-Level Thinking

- Questioning Techniques for Higher-Level Thinking
- Classroom Response Systems: Using Socratic

- PETE Method and Discrepant Events
- Scholarship for Teaching and Learning

There were three reflective assignments for the program.

- A document showing ten lectures, divided into five assignments, the big ideas in each lecture, and two higher-level questions designed to be incorporated into the lesson
- Student Response Systems Document showing questions incorporated into four lectures, along with student polling results and professor analysis
- Predict explain test explain method and discrepant events document with two professor scripts for demonstration, activity, or thought experiment using the PETE method.

5 METHODOLOGY

Engineering faculty from two research-intensive universities participated in this study. The first (University A) is consistently ranked by the Higher Education Commission (HEC) of Pakistan in the top three overall universities in Pakistan, and the second is smaller and lower ranked, but its engineering program is ranked by HEC in the top ten [49]. Participation was documented during the period of the program. This was assessed via attendance at the workshop and then via module and assignment completion. Participants who agreed to participate in the research completed a pre-survey with items from the Faculty Survey on Teaching, Learning, and Assessment [50], helped establish the needs and characteristics of the group. A mid-survey was completed after the three-day workshop regarding participants perspectives about the workshop. Participants completed a post-survey after the six-month implementation. The survey used Likert-items that ranged from strongly disagree (1) to strongly agree (5). Participants were also asked to evaluate the usefulness of the topics presented. Open-ended questions were provided for participants to elaborate on their responses and to delineate the program's strengths and areas in need of enhancement. To reduce response-shift bias—where participants overestimate knowledge, abilities, or behavior prior to an intervention—retrospective survey items were included [51]. Likert survey items were analyzed with descriptive statistics, and retrospective items were analyzed with paired t-tests, and thematic analysis was used on open-ended items.

6 RESULTS

6.1 Demographics and context

Eighteen faculty members completed the presurvey, establishing context for professional development and study. Seventeen listed their highest degree as a doctoral degree and one as a master's degree. 15 indicated they were male, and two indicated they were female. Table 1 shows the responses for the largest class taught and the smallest class taught within the last year. No class had more than 100 students, and only one had more than 51 students.

Table 1. Class sizes of participants

Within the last year...	Largest Class Taught		Smallest Class Taught	
Range	# of Responses	Percentage	# of Responses	Percentage
Less than 10 students	0	0%	6	33%
10–25 students	1	6%	7	39%
26–50 students	16	89%	5	28%
51–100 students	1	6%	0	0%
101-more students	0	0%	0	0%

Faculty responses to an item (regarding your own preferences, do your *interests* lie primarily in teaching or in research?) about teaching and research are presented in Table 2. Table 3 shows how the faculty self-report spending their time during a typical week during the semester.

Table 2. Teaching and research interests of participants

Items	# of Respondents	Percentage
Primarily in research	0	0%
In both, but leaning toward research	17	94%
In both, but leaning toward teaching	1	6%
Primarily in teaching	0	0%

Table 3. Faculty reports of time spent during a typical week

Items	1 Hour or Less	2–4 Hours	5–10 Hours	11–15 Hours	16 and More Hours
Teaching (including class time, grading, lab, preparing for class)	0%	0%	13%	38%	50%
Research (activities leading to a product)	6%	19%	25%	25%	25%
Scholarship/professional growth (expanding your knowledge of the field	13%	38%	31%	19%	0%
Institutional service (committees, administrative duties)	0%	19%	13%	38%	31%
External service (including professional organizations and civic projects)	38%	25%	19%	19%	0%
Professional consulting for pay	81%	13%	0%	6%	0%
Education committees (including thesis and examinations)	13%	31%	38%	19%	0%
Student advising	13%	0%	63%	19%	6%

6.2 Mid-survey

There were 33 participants in the workshop, 18 from one university and 12 from another. Three of the participants identified as female and 30 as male. The mid-survey was administered after the three-day workshop to obtain participants' perspectives about the workshop. It consisted of five responses, Likert items (1 = strongly disagree and 5 = strongly agree), and open-ended responses. 19 faculty members completed the survey, and the items are presented in Table 4.

Table 4. Participant perspectives of three-day workshop

Items	Avg	SD	% A or SA
Instructions given were consistent with stated objectives.	4.53	0.41	100%
Teaching methods were appropriate for subject matter.	4.58	0.77	94.74%
Contents of instruction were relevant and appropriate.	4.26	0.81	89.47%
The workshop met the stated objectives.	4.26	0.99	89.47%
The workshop enhanced my professional expertise.	4.32	1.00	89.47%
The learning outcome will be advantageous to my role.	4.42	0.96	94.74%

6.3 Levels of participation

The participation rates declined during the program period. There were 33 participants who attended all three days and completed the mid-survey. There were 22 professors who completed at least one module or assignment, with 13 completing at least half. The five big ideas and high-level question assignments had 100% completion by these 13 professors. The module on scholarship in teaching and learning and the PETE Sheet and Discrepant Events assignment had the lowest completion rate (77%). Nine participants completed all the assignments, attended the final online workshop, and answered the post-survey questions. Two faculty members were from University A and seven from University B.

6.4 Post-survey

The most valuable survey for this analysis was the post-survey, administered as an anonymous Google Form. The questions were composed of Likert items and were divided into the following three sections: (a) perceived benefit of PD topics; (b) perceived benefit of modules; and (c) retrospective pre- and post-test items to ascertain perceived changes as a result of the PD. There were open-ended questions for participants to explain their answers to (b) and to describe aspects of the program they perceived to be strong and where improvements could be made.

Table 5 shows the responses to the prompt, "How beneficial were each of the following for your professional development?" The responses ranged from "not beneficial at all" (scored as a 1) to "very beneficial" (4). The three-day workshop was viewed as the most valuable, followed by the online modules, while the SRS assignment was viewed as the least valuable.

Table 5. Perceived benefits of program components

Items	Avg	SD	% A or SA
Three-day workshop	3.89	0.30	100%
The online modules	3.67	0.45	94.74%
The PETE sheet assignment	3.33	0.77	89.47%
The Student Response System assignment	3.22	0.75	89.47%
The Big Ideas and Higher-Level Question Assignments]	3.67	0.46	89.47%

Participants were asked to identify modules that were most and least beneficial. They were able to select none, one, or more than one. For the most beneficial, all respondents selected at least one, with three respondents selecting more than one. For least beneficial, seven selected one item and two did not select any. The results are shown in Table 6. The least valuable topic was using discrepant events and the PETE method. The reason suggested for this being least valuable was that it was perceived that the discrepant events were best used with fundamental science concepts and not with advanced engineering concepts.

Table 6. Relative benefits of modules

Items	Number Selecting	
	Most Beneficial	Least Beneficial
Writing Effective Questions for High-Level Thinking	5	0
Classroom Response Systems	4	1
Questioning Techniques	3	1
Scholarship of Teaching and Learning	2	1
PETE Method and Discrepant Events	1	3

The most valuable module topic was writing effective questions. In the open-ended questions, the value was explained by two professors as follows:

> *"The writing effective questions for higher level thinking module helped me changing the pattern of my questions from simple recalling to analysis, evaluation and synthesis-based questions."*
>
> *"I observed that when I prepared lecture with BI [big ideas] and HLQs [high level questions], students remained focused and they tried to think of possible answers, which helped to deepen their understanding of the topic. In this way I could easily deliver the concept of the lecture."*

Retrospective pre- and post-test items were used to explore participants' perspectives of the changes that occurred. The items are matched, and means, standard deviations, mean differences, and T-values for paired T-tests are reported in Table 7. The final section of the post-survey had items that began with the stem: "As a result of my participation in AIM." Participants used this prompt to answer the items shown in Table 8.

Table 7. Two-tailed, paired t-test for retrospective items

Item	Mean	SD	Mean Diff *t-test, p =*
1a. Before AIM, how often did you focus on big ideas during your teaching?	1.44	0.47	MD = 2.89
1b. After AIM, how often did you focus on big ideas during your teaching?	4.33	0.45	$p < 0.000001$
2a. Before AIM, how often did you ask higher-level questions during lectures?	2.78	0.87	MD = 1.78
2b. After AIM, how often did you ask higher-level questions during lectures?	4.56	0.47	$P = 0.001224$

(Continued)

Table 7. Two-tailed, paired t-test for retrospective items *(Continued)*

Item	Mean	SD	Mean Diff *t-test, p =*
3a. Before AIM, how often did you use good question asking techniques when asking questions during lectures?	2.00	0.89	MD = 2.44
3b. After AIM, how often did you use good question asking techniques when asking questions during lectures?	4.44	0.47	$P = 0.00008$
4a. Before AIM, how often did you use a Student Response System such as Plickers or Socrative?	1.00	0	MD = 3.00
4b. After AIM, how often did you use a Student Response System such as Plickers or Socrative?	4.00	0.77	$P = 0.000006$
5a. Before AIM, how often did you have students make predictions in class?	2.44	1.11	MD = 1.56
5b. After AIM, how often did you have students make predictions in class?	4.00	0.63	$P = 0.000736$
4a. Before AIM, how often did you conduct activities that would lead to outputs in the Scholarship of Teaching and Learning?	2.22	0.75	MD = 0.78
4b. After AIM, how often did you conduct activities that would lead to outputs in the Scholarship of Teaching and Learning?	3.00	0.45	$P = 0.023197$

Notes: N = 9, degrees of freedom = 8, all mean differences are statistically significant.

Table 8. Respondent perspectives of participation outcomes

Items As a result of my participation in AIM, I think…	Avg	SD	% A or SA
I use more student-centered strategies.	4.56	0.50	100%
I find more joy in teaching.	4.44	0.50	100%
I'm a more innovative educator.	4.33	0.47	100%
My students like my classes more.	3.78	0.79	77.87%
Students are developing important abilities during my classes.	4.56	0.50	100%
Students are deepening their learning.	4.56	0.50	100%

7 DISCUSSION AND CONCLUSIONS

This study explored engineering faculty perspectives on the effects of a long-term professional development program promoting the use of active learning methods in their teaching. Acknowledging the inherent intricacy of student motivation and learning [52], it becomes apparent that the pedagogical expertise of engineering faculty, along with their integration of educational methodologies, is even more intricate [53–54]. Pedagogical knowledge is a component of this complex system that encompasses students, groups, classrooms, colleges, universities, communities, and cultures [55]. From the enactivism perspective, this knowledge evolves and is best understood through perceptions and actions within the teaching-learning environment. While direct instruction holds importance in engineering education, there are potential benefits for faculty exploring methods to enhance active learning [56].

Engineering faculty members who are involved in teaching, research, and service face significant time constraints. Among the respondents, 94% of faculty participants expressed interest in both teaching and research, but their research activities took priority and they had major service requirements. Implementing changes in teaching takes time [57] and thus can be an impediment to change.

Interpretation of the results of this study requires the understanding that the three-day workshop was required for faculty, while participation in the remainder of the program was not. The three-day workshop had 33 full attendees, with 13 professors completing the remainder of the program. There were no fiscal incentives for program participation or completion. To be sure, one limitation of the study might be that the program had a high attrition rate. The transition from a required to a voluntary program, however, created different circumstances that are beyond attrition. There is a long history of engineering faculty reluctance to participate in teaching workshops [58]. So, a positive interpretation is that about one-third of the faculty voluntarily opted into this long-term program.

These completers reported increases in using SRS, asking higher-level questions, using good techniques in question-answering, and having students make predictions. A perceived increase in focusing on big ideas may have helped them allocate time to ALT. An increased focus on the scholarship of teaching and learning may be a sustainable path for constant improvement and sharing.

The results align with the findings of Gormaz-Lobos *et al.* [59], suggesting that faculty develop positive attitudes towards workshops aimed at enhancing engineering pedagogy. Faculty members who persisted in this program likely possessed what Henderson *et al.* [60] refer to as an "impetus for change," driven by internal motivation. The assignments led to actions that influenced the teaching-learning environment, and the perceived relationships among variables were influenced by professors' past experiences. As faculty members reflected on their practices, they reported the most perceived growth in utilizing SRS, emphasizing big ideas, and employing effective question-asking techniques during lectures. Workshop topics highly valued by participants included writing effective questions for higher-level thinking and implementing classroom response systems. The use of discrepant events in engineering classes was not highly valued, possibly due to the limited academic work describing the utilization of phenomena in this manner within engineering courses.

All program completers agreed or strongly agreed that they were employing more student-centered strategies and experiencing greater joy in teaching as their students deepened their learning and developed important abilities. The positive emotion suggests that the professors felt in control and valued the implemented activities and the results [61]. These faculty may become what Middleton *et al.* [23] refer to as brokers, important in social networks and more powerful because they are in the same departments. Brokers "are largely considered critical for the diffusion of innovation, as they provide validation of the efficacy of new strategies independent of the school's administration or the faculty champions who may lead professional development" (p. 11).

Knowledge-as-action is an important tenet of enactivism. Faculty who implemented these techniques experienced significant growth in their perceived development. Enacted approaches change the teaching environment, and observations can reinforce the changes and catalyze more exploration. A minority of faculty leading a charge for change is consistent with other faculty development programs [23]. Perhaps these changes are best explored with highly committed faculty members who can iterate approaches and share them with more hesitant colleagues. Brickhouse [57] found positive effects of faculty collaboration on teaching practices.

Overall, this project suggests that experiences and actions can catalyze changes among engineering faculty in their perceived value and use of active learning techniques. The combination of face-to-face workshops, online modules, and reflective implementation practices shows promise and deserves further attention and support. Future research can explore these methods of producing knowledge-as-action and also explore how a minority of faculty brokers may influence departmental teaching cultures.

8 REFERENCES

[1] R. Graham, *The Global State of the Art in Engineering Education*. Cambridge: Massachusetts Institute of Technology, 2018.

[2] M. Valero, "Challenges, difficulties and barriers for engineering higher education," *Journal of Technology and Science Education*, vol. 12, no. 3, pp. 551–566, 2022. https://doi.org/10.3926/jotse.1696

[3] E. Cano (coord.), "Diseño del programa formativo 'Formación en Innovación Docente. Una nueva ingeniería para 2030'," *HEUMA-CORFO*, 2020.

[4] M. Borrego, J. E. Froyd, and T. S. Hall, "Diffusion of engineering education innovations: A survey of awareness and adoption rates in U.S. engineering departments," *Journal of Engineering Education*, vol. 99, no. 3, pp. 185–207, 2010. https://doi.org/10.1002/j.2168-9830.2010.tb01056.x

[5] National Research Council, *Discipline-Based Educational Research: Understanding and Improving Learning in Undergraduate Science and Engineering*. Washington, DC: National Academies Press, 2012.

[6] M. J. Prince and R. M. Felder, "Inductive teaching and learning methods: Definitions, comparisons, and research bases," *Journal of Engineering Education,* vol. 95, no. 2, pp. 123–138, 2006. https://doi.org/10.1002/j.2168-9830.2006.tb00884.x

[7] R. Lima, P. Andersson, and E. Saalman, "Active learning in engineering education: A (re)introduction," *European Journal of Engineering Education,* vol. 42, no. 1, pp. 1–4, 2017. https://doi.org/10.1080/03043797.2016.1254161

[8] A. A. Zaher, G. A. Hussain, and H. Altabbakh, "An active learning approach for applying STEAMeD-based education in engineering programs," *International Journal of Engineering Pedagogy (iJEP),* vol. 13, no. 3, pp. 4–26, 2023. https://doi.org/10.3991/ijep.v13i3.34819

[9] S. Proud, "If you build it, will they come?: A review of the evidence of barriers for active learning in university education," *Reire: Revista D'innovació i Recerca En Educacio*, vol. 15, no. 2, 2022. https://doi.org/10.1344/reire.38120

[10] M. Prince, "Does active learning work? A review of the research," *Journal of Engineering Education*, vol. 93, no. 3, pp. 223–231, 2004. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

[11] E. Pascarella and P. T. Terenzini, *How College Affects Students: A Third Decade of Research* (vol. 2). San Francisco, CA: Jossey-Bass, 2005.

[12] S. Hartikainen, L. Pylväs, and P. Nokelainen, "Engineering students' perceptions of teaching: Teacher-created atmosphere and teaching procedures as triggers of student emotions," *European Journal of Engineering Education,* vol. 47, no. 5, pp. 814–832, 2022. https://doi.org/10.1080/03043797.2022.2034750

[13] A. Astin, *What Matters in College? Four Critical Years Revisited.* San Francisco, CA: Jossey-Bass, 1993.

[14] J. Hartley and I. K. Davies, "Note taking: A critical review," *Innovations in Education and Training International*, vol. 15, no. 3, pp. 207–224, 1978. https://doi.org/10.1080/0033039780150305

[15] D. M. Bunce, E. A. Flens, and K. Y. Neiles, "How long can students pay attention in class? A study of student attention decline using clickers," *Journal of Chemical Education*, vol. 87, no. 12, pp. 1438–1443, 2010. https://doi.org/10.1021/ed100409p

[16] C. J. Asarta, R. G. Chambers, and C. Harter, "Teaching methods in undergraduate introductory economics courses: Results from a sixth national quinquennial survey," *The American Economist*, vol. 66, no. 1, pp. 18–28, 2021. https://doi.org/10.1177/0569434520974658

[17] D. A. Bligh, *What's the Use of Lectures?* San Francisco, CA: Jossey-Bass, 2000.

[18] N. A. Bradbury, "Attention span during lectures: 8 seconds, 10 minutes, or more?" *Advances in Physiology Education*, vol. 40, no. 4, pp. 509–513, 2016. https://doi.org/10.1152/advan.00109.2016

[19] N. Nelson and R. Brennan, "A snapshot of engineering education in Canada," in *Proceedings of the Canadian Engineering Education Association (CEEA)*, 2018. https://doi.org/10.24908/pceea.v0i0.13072

[20] M. M. Cooper, "Cooperative learning: An approach for large enrollment courses," *Journal of Chemical Education*, vol. 72, no. 2, pp. 162–164, 1995. https://doi.org/10.1021/ed072p162

[21] J. L. Cooper, J. MacGregor, K. A. Smith, and P. Robinson, "Implementing small-group instruction: Insights from successful practitioners," *New Directions for Teaching and Learning*, vol. 2000, no. 81, pp. 63–76, 2000. https://doi.org/10.1002/tl.8105

[22] A. B. Bennett, "A whole new learning space: Exploring classroom variability for teaching mathematics via active learning," *International Journal of Mathematical Education in Science and Technology*, vol. 53, no. 1, pp. 108–130, 2022. https://doi.org/10.1080/0020739X.2021.1961033

[23] J. A. Middleton *et al.*, "A social network analysis of engineering faculty connections: Their impact on faculty student-centered attitudes and practices," *Education Sciences*, vol. 12, no. 2, p. 108, 2022. https://doi.org/10.3390/educsci12020108

[24] A. Macphail, M. Ulvik, A. Guberman, G. Czerniawski, H. Oolbekkink Marchand, and Y. Bain, "The professional development of higher education-based teacher educators: Needs and realities," *Professional Development in Education*, vol. 45, pp. 1–14, 2018. https://doi.org/10.1080/19415257.2018.1529610

[25] C. Winberg *et al.*, "Learning to teach STEM disciplines in higher education: A critical review of the literature," *Teaching in Higher Education*, vol. 24, no. 8, pp. 930–947, 2018. https://doi.org/10.1080/13562517.2018.1517735

[26] C. Faber, R. Ellestad, and A. Walsh, "Information literacy modules for first-year engineering students," *Advances in Engineering Education*, vol. 10, no. 2, pp. 23–48, 2022. https://doi.org/10.18260/3-1-1153-36027

[27] A. S. Robberts and L. Van Ryneveld, "Design principles for introducing 21st century skills by means of game-based learning," *Industry and Higher Education*, vol. 36, no. 6, pp. 824–834, 2022. https://doi.org/10.1177/09504222221079210

[28] M. Kim *et al.*, "We learn things to solve real-life problems: Comprehending how engineering educators' beliefs regarding the nature of engineering influence the cultivation of pedagogical content knowledge in a modular engineering education professional development initiative," *Journal of University Teaching & Learning Practice*, vol. 20, no. 3, pp. 1–13, 2023. https://doi.org/10.53761/1.20.3.07

[29] E. Seymour, "Tracking the processes of change in US undergraduate education in science, mathematics, engineering, and technology," *Science Education,* vol. 86, no. 1, pp. 79–105, 2001. https://doi.org/10.1002/sce.1044

[30] A. Boklage, B. Coley, and N. Kellam, "Understanding engineering educators' pedagogical transformations through the Hero's Journey," *European Journal of Engineering Education*, vol. 44, no. 6, pp. 923–938, 2019. https://doi.org/10.1080/03043797.2018.1500999

[31] C. M. Golde and T. M. Dore, *At Cross Purposes: What the Experiences of Today's Doctoral Students Reveal about Doctoral Education*. Pew Charitable Trusts, 2001. Accessed Nov. 12, 2022. [Online]. Available: http://phd-survey.org/report%20final.pdf.

[32] K. Tanner and D. Allen, "Approaches to biology teaching and learning: On integrating pedagogical training into the graduate experiences of future science faculty," *CBE Life Sciences Education,* vol. 5, no. 1, pp. 1–6, 2006. https://doi.org/10.1187/cbe.05-12-0132

[33] G. D. Kuh, J. Kinzie, J. H. Schuh, and E. J. Whitt, *Student Success in College: Creating Conditions that Matter.* Hoboken, NJ: John Wiley & Sons, 2011.

[34] S. Lindblom-Ylanne, K. Trigwell, A. Nevgi, and P. Ashwin, "How approaches to teaching are affected by discipline and teaching context," *Studies in Higher Education*, vol. 31, no. 3, pp. 285–298, 2006. https://doi.org/10.1080/03075070600680539

[35] G. R. Lueddeke, "Professionalising teaching practice in higher education: A study of disciplinary variation and 'teaching-scholarship'," *Studies in Higher Education*, vol. 28, pp. 213–228, 2003. https://doi.org/10.1080/0307507032000058082

[36] T. F. Nelson-Laird, R. Shoup, G. D. Kuh, and M. J. Schwarz, "The effects of discipline on deep approaches to student learning and college outcomes," *Research in Higher Education,* vol. 49, no. 6, pp. 469–494, 2008. https://doi.org/10.1007/s11162-008-9088-5

[37] L. R. Lattuca, P. T. Terenzini, and J. F. Volkwein, *Engineering Change: A Study of the Impact of EC2000*. Baltimore, MD: ABET, 2006. https://doi.org/10.1109/FIE.2006.322520

[38] L. H. Jamieson and J. R. Lohmann, *Innovation with Impact: Creating a Culture for Scholarly and Systematic Innovation in Engineering Education.* Washington, DC: ASEE, 2012.

[39] L. R. Lattuca, I. Bergom, and D. B. Knight, "Professional development, departmental contexts, and use of instructional strategies," *Journal of Engineering Education*, vol. 103, no. 4, pp. 549–572, 2014. https://doi.org/10.1002/jee.20055

[40] D. Ebert-May, T. L. Derting, J. Hodder, J. L. Momsen, T. M. Long, and S. E. Jardeleza, "What we say is not what we do: Effective evaluation of faculty professional development programs," *BioScience*, vol. 61, no. 7, pp. 550–558, 2011. https://doi.org/10.1525/bio.2011.61.7.9

[41] M. A. Romarate, A. B. Aquino, E. J. Punongbayan, G. R. Quizon, L. A. Balilla, and N. P. Ramos, "Development of outcomes-based instructional materials in professional teacher education courses for a flexible set-up," *Journal of Education and e-Learning Research*, vol. 10, no. 1, pp. 61–67, 2023. https://doi.org/10.20448/jeelr.v10i1.4378

[42] R. Habash and N. M. Abdulkadir, "Video creation as a catalyst of value change in engineering education," in *2023 46th MIPRO ICT and Electronics Convention (MIPRO)*, Opatija, Croatia, 2023, pp. 1618–1623. https://doi.org/10.23919/MIPRO57284.2023.10159840

[43] S. Seymour, "Considering the learning theory enactivism to explore the development of socially conscious leaders," in *Strategies for Teaching Leadership: Proven Practices in Higher Education*, K. D. Kirstein, C. E. Schieber, K. A. Flores, and S. G. Olswang, Eds., Charleston, SC.: CreateSpace Independent Publishing, 2014.

[44] L. Brown and A. Coles, "Developing expertise: How enactivism re-frames mathematics teacher development," *ZDM Mathematics Education*, vol. 43, nos. 6–7, pp. 861–873, 2011. https://doi.org/10.1007/s11858-011-0343-4

[45] F. Varela, E. Thompson, and E. Rosch, *The Embodied Mind: Cognitive Science and Human Experience*, Cambridge MA: Massachusetts Institute of Technology, 1991. https://doi.org/10.7551/mitpress/6730.001.0001

[46] B. Davis and D. Sumara, "Cognition, complexity and teacher education," *Harvard Educational Review*, vol. 67, no. 1, pp. 105–125, 1997. https://doi.org/10.17763/haer.67.1.160w00j113t78042

[47] G. Bateson, *Steps to an Ecology of Mind.* New York: Ballentine Books, 1972.

[48] J. Mingers, *Self-Producing Systems: Implications and Applications of Autopoiesis*. New York: Plenum Press, 1995. https://doi.org/10.5962/bhl.title.111972

[49] Higher Education Commission of Pakistan, *5th Ranking of Pakistani Higher Education Institutions*, 2016. Accessed Oct. 10, 2022. [Online]. Available: https://www.hec.gov.pk/english/universities/Documents/Ranking_Doc%20(2015).pdf#search=ranking.

[50] E. L. Dey and S. Hurtado, *Faculty survey on teaching, learning and assessment*. Ann Arbor: University of Michigan, 2000.

[51] J. Klatt and E. Taylor-Powell, "Synthesis of literature relative to the retrospective pre-test design," in *Panel Presentation for 2005 Joint CES/AEA Conference*, Toronto, Canada, 2005.

[52] H. Ismail, A. Khelifi, and S. Harous, "A cognitive style based framework for usability evaluation of online lecturing platforms – a case study on zoom and teams," *International Journal of Engineering Pedagogy,* vol. 12, no. 1, pp. 104–122, 2022. https://doi.org/10.3991/ijep.v12i1.25295

[53] R. A. Cheville, "Engineering education today: Capturing the afterlife of Sisyphus in five snapshots," *Proceedings of the IEEE*, vol. 100, pp. 1361–1375, 2012. https://doi.org/10.1109/JPROC.2012.2190156

[54] T. Rüütmann and H. Kipper, "Rethinking effective teaching and learning for the design of efficient curriculum for technical teachers," *International Journal of Engineering Pedagogy*, vol. 3, no. 1, pp. 44–51, 2013. https://doi.org/10.3991/ijep.v3i1.2404

[55] D. L. Shreaves, Y. H. Ching, L. Uribe-Florez, and J. Trespalacios, "Faculty perceptions of online teaching at a midsized liberal arts university," *Online Learning*, vol. 24, no. 3, pp. 106–127, 2020. https://doi.org/10.24059/olj.v24i3.2199

[56] T. Rüütmann and H. Kipper, "Teaching strategies for direct and indirect instruction in teaching engineering," *International Journal of Engineering Pedagogy*, vol. 1, no. 3, pp. 37–44, 2011. https://doi.org/10.3991/ijep.v1i3.1805

[57] A. Brickhouse, "Sudden transition to online instruction for ESL instructors: A phenomenological study," *International Journal of Psychology and Educational Studies*, vol. 10, no. 1, pp. 196–208, 2023. https://doi.org/10.52380/ijpes.2023.10.1.967

[58] R. Brent and R. M. Felder, "A model for engineering faculty development," *International Journal of Engineering Education*, vol. 19, no. 2, pp. 234–240, 2003.

[59] D. Gormaz-Lobos, C. Galarce-Miranda, and S. Kersten, "Evaluation results of an online teacher training course specialized in engineering education," *International Journal of Engineering Pedagogy*, vol. 11, no. 5, pp. 54–69, 2021. https://doi.org/10.3991/ijep.v11i5.21981

[60] C. Henderson, A. Beach, and N. Finkelstein, "Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature," *Journal of Research in Science Teaching*, vol. 48, no. 8, pp. 952–984, 2011. https://doi.org/10.1002/tea.20439

[61] Z. Atiq and M. C. Loui, "A qualitative study of emotions experienced by first-year engineering students during programming tasks," in *ACM Transactions on Computing Education*, vol. 22, no. 3, 2022. https://doi.org/10.1145/3507696

9 AUTHORS

Peter Rillero, Arizona State University, Tempe, Arizona (E-mail: rillero@asu.edu).

Hy Grant Rillero, Arizona State University, Tempe, Arizona; Crowne Iron Works, Minneapolis, Minnesota.