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Integrating Active Pedagogy into Engineering Education: Perspectives from the SPARK-ENG Professional Learning Program

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ABSTRACT

The need to shift from traditional to active pedagogy in higher engineering education has garnered significant attention. In response to institutional demand for supporting our engineering educators, we developed SPARK-ENG (Scholarship of Pedagogy and Application of Research Knowledge in Engineering), a modular professional learning program at a major Canadian university. This study explored how engineering educators integrate active pedagogy into their teaching practices through their engagement with the program. Using situated learning theory and the model of teacher change as theoretical frameworks, along with thematic analysis for data interpretation, we found that participants employed a variety of strategies to understand and integrate active pedagogy in post-secondary engineering courses, and student learning, which positively influenced their professional growth. This study captures what active pedagogy looks like in the context of engineering educators' engagement with the SPARK-ENG program, providing an example for empowering educators to integrate active pedagogy into their teaching practices.

Keywords: Active Pedagogy, Professional Learning, Engineering Educator, Teacher Change

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1. Introduction

There has been growing recognition of the shift from traditional teaching methods to a more student-centered approach in higher engineering education (Dewsbury et al., 2022; Hartikainen et al., 2019; Leupín, 2016) and post-secondary education more broadly (Thompson et al., 2003; Wright, 2011). Active learning is increasingly viewed as a key response to this shift (Fields et al., 2021). Classrooms that implement active learning have been shown to improve student motivation, knowledge retention, and their ability to transfer content (Michael, 2006; Norman & Schmidt, 1992; Vosniadou et al., 2001, as cited in Cattaneo, 2017). These approaches are part of a broader framework of active pedagogy (AP) that emphasizes student-centered learning (Leupín, 2016) and encompasses active engagement in learning (Dewsbury et al., 2022). Researchers and practitioners have shifted their focus towards AP, emphasizing a more integrated approach that promotes deeper engagement and critical thinking among students (Leupin, 2016). However, these pedagogical practices have not penetrated engineering classrooms as deeply as their proponents had hoped (Dewsbury et al., 2022). The majority of engineering instruction in higher education continues to be dominated by didactic lecturing (Hadad et al., 2020; Dewsbury et al., 2022). This presents an even greater challenge for engineering educators, as many lack the experiences when they were students and the training required to effectively implement AP in their teaching (Sukackė et al., 2022).

The imperative to support engineering educators in understanding and implementing AP cannot be overstated (Hartikainen et al., 2019). In response to institutional demands, we developed a modular professional learning program at a major Canadian university to assist engineering educators in this

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effort. In this study, AP refers to instructional approaches that actively engage engineering students in the learning process—promoting critical thinking, collaboration, and problem-solving through participatory activities. We intentionally examined engineering educators' experiences integrating AP into their teaching practices while participating in the professional learning program.

2. Research Purpose

The professional learning program we created, titled Scholarship of Pedagogy and Application of Research Knowledge in Engineering (SPARK-ENG), consists of 12 modules: *Philosophy of Teaching and Learning* (Nature of Learners, Nature of Learning, Equity, Diversity and Inclusion in Teaching); *Fostering Learning Opportunities* (Interactive Lectures, Classroom Discourse, Empowering Students to Learn); *Designing Courses for Learning* (Problem-based Learning, Team-based Learning, Assessment Practices); and *Scholarship of Teaching and Learning* (SoTL) (Forming an Identity as an Educator, Professional Learning Communities, Researching Educational Practices in Engineering). This study specifically addressed the following research questions: (1) How did engineering educators integrate AP into their teaching practices while participating in SPARK-ENG? and 2) What did AP look like in practice within the context of this integration?

3. Conceptual Frameworks

3.1. Situated Learning

Teacher professional learning has increasingly been conceptualized through the lens of situated learning, moving away from the traditional model of linear knowledge acquisition that has long dominated teacher education (Pitsoe & Maila, 2013). Lave and Wenger (1991) describe situated learning as "a set of relations among persons, activity, and world," emphasizing that "a community of practice is an intrinsic condition for the existence of knowledge, not least because it provides the interpretive support necessary for making sense of its heritage" (p. 98). Building on this, several distinctive features of situated learning are noteworthy: knowledge is constructed through social interactions (Julien, 1997); learning is an enculturation process that occurs within a Community of Practice (CoP), where social interactions facilitate the learning of specific practices (Vermunt, 2015); understanding learning requires consideration of both environmental factors and individual contributions (Johri & Olds, 2013); and learning involves drawing on both internal and external resources to solve problems (Newstetter & Svinicki, 2014). These features emphasize the importance of understanding teacher learning through "a holistic, emergent, and multi-level mutual-causality perspective" (Pitsoe & Maila, 2013, p. 214). The most impactful learning within a professional learning community occurs when it is closely tied to social interactions grounded in authentic practice (Lave & Wenger, 1991). Consequently, emphasizing the situated nature of knowing and learning highlights the importance that teachers' own teaching practices serve as vital contexts for their professional learning (Pitsoe & Maila, 2013).

3.2. The Model of Teacher Change

Even though professional learning has been regarded as essential for teaching improvement, most programs don't achieve effective results (Cohen & Hill, 1998, 2000; Kennedy, 1998; Wang et al., 1999, as cited in Guskey, 2002). This may be due to two key factors: a lack of motivation among teachers to engage in professional learning, and the vagueness of the learning process that leads to changes in teaching (Guskey, 1986, cited in Guskey, 2002). These issues were intentionally addressed by our SPARK-ENG program through engineering-focused learning modules, instructional coaching, and CoP facilitation (see Figure 1). The program also supported participants in designing teaching materials, observing classroom teaching, and providing feedback or suggestions. To explore participants' experiences with AP in their teaching practices, we adopted Guskey's (2002) model of teacher change to highlight the key impacts of the program: changes in teachers' classroom teaching, shifts in their beliefs and attitudes, and improvements in student learning. In light of our program

features, we further developed the model into a conceptual framework (see Figure 1) to structure our investigation of participants' experiences with AP while engaging with SPARK-ENG, as well as the impact of these experiences on their professional growth.

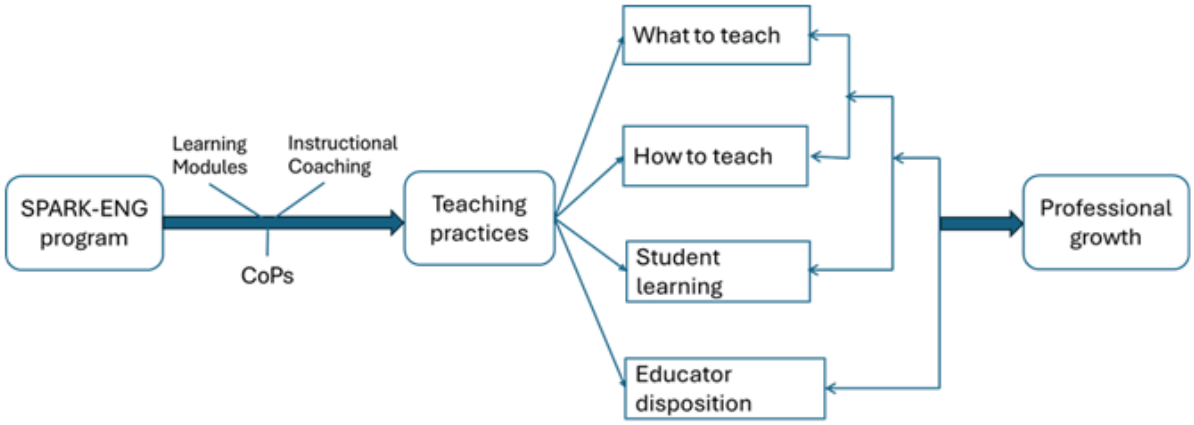

Figure 1. The Conceptual Framework of the SPARK-ENG Program

The framework highlights the interaction among the factors that both demonstrate and impact teacher change. For instance, preparing engaging teaching materials (what to teach) could facilitate learners' development of conceptual understanding and problem-solving skills in engineering (how to teach), which could enhance learners' engagement and achievement in engineering (student learning). Moreover, these experiences could strengthen educators' pedagogy and foster their attitudes, beliefs, or passion for AP (educator disposition). In turn, developing positive educator disposition could motivate educators to continue adopting AP to improve students' learning experiences in engineering. This framework enabled us to situate our interpretation of engineering educators' experiences integrating AP within the context of their engagement with the SPARK-ENG program and to examine the process by which they integrate AP and its impact.

Overall, our conceptual frameworks guided us in interpreting participants' experiences integrating AP into their teaching practices from a holistic, contextual, interactional, and situational perspective.

4. Methodology

In SPARK-ENG, each module was implemented over four weeks. In the first week, participants explored a case study and readings that introduced a pedagogical concept, followed by a workshop with an instructional coach. During weeks two and three, participants engaged with additional resources related to the concept—such as podcasts and videos—while the coach conducted classroom observations and provided one-on-one mentoring to support their application of the concept in teaching practice. In the final week, participants met as a CoP to reflect on and discuss the module's content and its application to their teaching practices.

4.1. Participants

The SPARK-ENG program has been implemented in the Faculty of Engineering for two years, with three cohorts of participants so far. These participants included professors and instructors (referred to as educators in this study) from various engineering fields, such as Chemical and Materials, Electrical, Mechanical, Civil, Environmental, and Biomedical Engineering. Each cohort participated in 11 or 12 CoP sessions during their time in the program. A total of 12 educator participants took part in this study.

4.2. Data Collection

We conducted participant interviews at two points: during their participation in the program and at the end of each year of participation. We also collected their reflections and recorded their CoP meetings. Both the interviews and CoP recordings were transcribed, and participants were invited to review the transcriptions for accuracy and to raise any concerns. Participants were assigned identifiers from P1 to P12.

4.3. Data Analysis

We adopted thematic analysis to analyze the data. Thematic analysis is a method used to identify, analyze, and present patterns (themes) that emerge from data (Braun & Clarke, 2006). Both explicit and implicit ideas from the data can be identified and described thoroughly through thematic analysis; codes are typically created to represent these themes and are associated with the raw data to act as summary indicators for subsequent analysis (Guest et al., 2012). We employed thematic analysis for its effectiveness in capturing nuanced meanings within textual data (Guest et al., 2012) and its strength in organizing and richly describing the dataset (Braun & Clarke, 2006).

We conducted our data analysis following Braun and Clarke's (2006) thematic analysis framework. First, to get to *know our data*, research team members attended CoPs, conducted interviews, and reviewed participants' personal reflections, taking detailed notes throughout these activities. These notes were shared and discussed in biweekly research meetings to ensure a comprehensive, shared understanding of the dataset. Next, we *generated initial codes* by reviewing these notes, conversations, and discussions, identifying key ideas related to developing an understanding of AP, strategies for integrating AP into teaching practices, and the impact of AP engagement on participants' professional growth. These initial codes served as the first level of coding and helped us identify broader patterns across the dataset.

We then *searched for subthemes* under the initial codes through manual coding—annotating all the transcripts from audio-recorded data, color-coding potential subthemes, and selecting representative quotes as evidence. This process yielded refined subthemes, which served as the second level of coding. Further, we *reviewed and contextualized* the initial codes and their corresponding subthemes within the dataset. In research meetings, the team discussed salient data quotes to develop agreement on the participants' meanings. After reaching team consensus, we *defined and named the codes* as two-level themes, organizing them into a coherent thematic map (see Table 1). Finally, we *wrote up the analysis*, synthesizing the data with supporting quotes and presenting the finalized results. The final phase enabled us to consolidate our understanding of the data to make connections across the codes.

Table 1. The Codes for the Thematic Map

Level 1 Codes	Level 2 Codes	Descriptions
Developing an Understanding of AP	Building Foundational Pedagogical Knowledge	The program's learning content enhanced participants' understanding of AP, equipping them with the foundational knowledge needed to implement these pedagogies.
	Unpacking the "Why" and "How" of Teaching through Interaction	Participants gained an understanding of teaching approaches and the underlying rationales through their interactions and conversations.
	Understanding Effective Learning Environments for Students	Participants emphasized the importance of creating a positive learning environment that encourages feedback, communication, active participation, and inclusion.
Integrating AP into Teaching Practices	Teaching Materials	Participants developed teaching content or materials to promote the integration of AP into their teaching and enhance their teaching.
	Teaching Approaches	Participants tried various strategies for integrating AP.
	Student Learning	The integration of AP into teaching practices positively impacted student learning.
	Instructional Coaching	Participants appreciated the various forms of support provided by the instructional coach in integrating AP.
The Impact of Integrating AP on Educators' Professional Growth	Enhancing Educator Disposition	The experiences of integrating AP enhanced participants' dispositions toward continuous professional growth.
	Embracing SoTL's Role	Participants came to recognize the role of SoTL in integrating AP for continuous teaching improvement.

To advance the trustworthiness and credibility of this study, our research team employed the following three approaches: data triangulation (Zellermayer & Margolin, 2005), investigator triangulation (Krefting, 1991, as cited in Elfarargy et al., 2022), and low inference descriptors (Johnson, 1997). Specifically, for data triangulation, we collected data from three sources: CoPs, interviews, and reflections. For investigator triangulation, the emerging themes and subthemes were reviewed and validated by one member of our research team, and then reviewed and confirmed by the other three members. Investigator triangulation is an effective qualitative research technique that helps reduce bias. It is especially beneficial when the researchers come from diverse backgrounds (Krefting, 1991, as cited in Elfarargy et al., 2022), as is the case in our study. Additionally, we employed low inference descriptors, which refer to the descriptions or interpretations that closely align with participants' accounts (Johnson, 1997). We deliberately used verbatim quotes from CoPs, interviews, and reflections as evidence to illustrate the themes that emerged from the data.

5. Results

Through data analysis, we uncovered the strategies participants used to understand and integrate AP into their teaching practices, facilitated by the learning opportunities that emerged from their engagement with the program. We also examined the impact of these efforts on participants' continuous professional growth. Viewed holistically, the findings illustrate what AP looked like in the context of engineering educators' engagement with SPARK-ENG, providing insights into how to empower educators on their path toward AP to improve their teaching practices. Certainly, these insights can also serve as references for educators across higher education, as our interpretations were guided by literature that speaks to educators more broadly (Carvalho et al., 2021).

5.1. Developing an Understanding of AP

Teacher education has increasingly emphasized the need to enhance support for teachers in effectively applying knowledge to practice (Parker et al., 2016). Professional learning programs are a key pathway for providing relevant necessary support in helping educators understand AP and its application (Herbert & Bragg, 2021). Engaging with SPARK-ENG provided participants with opportunities to develop an understanding of AP, particularly for those who lacked the necessary pedagogical knowledge of it. As P5 reflected, "Everything actually was in this program was focused

on the why behind the teaching. In fact, I cannot answer this at the beginning." Various pathways, as well as a commitment to developing an understanding of AP, emerged from participants' engagement with the program.

5.1.1 Building Foundational Pedagogical Knowledge

Participants recognized the significance of the learning materials in the program for their learning. They highlighted the role of engaging with the learning content and its impact on their teaching practice. As P1 indicated, "I think the readings…as part of the beginning of each module, those are very effective, …influenced me." The related learning helped them build foundational pedagogical knowledge for adopting AP in their teaching, as P6 experienced:

> I've been exposed to a lot of things that I had no familiarity with, like right from the beginning, talking about different learning styles and things like that and how to incorporate different methods of teaching so that you can try and address multiple learning styles and get students to be thinking about things from different angles, a little bit more interactive and getting a little bit more of that active learning happening. I mean, I've learned about all these things in a somewhat formal method for the first time through this program. So that has been very, very beneficial. I think having just some background knowledge in all of this is crucial in order to be an effective teacher.

Participants learned about effective teaching by reviewing literature and research that offers both theoretical support and empirical evidence. This boosted educators' confidence in implementing AP, as P5 noted: "Once you start to see that those theories and those strategies are already out there and published, you feel more confident about doing it and implementing it." Participants felt supported after learning about evidence of effective teaching from the literature, as P9 indicated:

> As you go to prepare [for teaching], there's…what is the literature saying about what I have intuitively seen as good teaching. And now found evidence that backs that up, and…my experience has been very positive. …. it's encouraging, and I felt motivated to do more…

5.1.2 Unpacking the "Why" and "How" of Teaching through Interaction

Participating in CoPs encouraged participants to discuss the rationales behind teaching practices and enabled them to explore how to teach more effectively. For instance, P4 acknowledged the discussion of the "why" behind teaching through CoPs:

> What pops into mind first would be our community of practice like when we all got together to discuss. That probably helped me make that connection [the "why" behind the teaching suggestion or teaching practice] better than I would have maybe not make it at all on my own. So, the get-together and the chat with my colleagues was probably the best part of that.

P2 valued the opportunity to collaborate with CoPs to discuss strategies for teaching more effectively:

> Because, and why that is so for me is that just being able to get together in a room with other teachers, with other colleagues and sit down and discuss about teaching style and also look at ways to improve my teaching….it's so valuable that we are able to come in. … talking about an experience or talking about a way the person probably implemented something.

Participants also gained an understanding of AP by learning from their colleagues' experiences in integrating it. This served as a powerful catalyst for participants to innovate their own teaching practices. Through the insights shared by experienced educators, such as those highlighted by P5, participants were able to learn about effective AP integration:

> Sharing knowledge between instructors, that's something that I learned and implemented during the last year that I started to share things about my course with other instructors and see what you do in your course…We know those things theoretically, or we know them by heart, but we don't do them. That was the key that how can we create that culture that we don't just go to the class, teach the lesson, and leave, and that's it. It doesn't end by the end of the lesson. There is more. There is more for us to share experience with each other.

5.1.3 Understanding Effective Learning Environments for Students

By learning more about AP, participants advocated for cultivating an effective learning environment that fosters constructive feedback, open communication, active participation, and inclusion. As P2 reflected:

> I think one thing that … it's important to create that atmosphere that allows for constructive feedback. So that atmosphere between instructors and students where instructors understand where the issues might be in terms of learning for students. And also students understand exactly what the instructor wants, what the learning objectives are.

Participants highlighted the significance of inclusive environments for student learning and stressed the necessity to offer a variety of ways to engage every student in the learning process. This is essential across higher education, particularly for engineering students, who are widely recognized as diverse learners with unique abilities, skills, and strengths (Holvikivi, 2007). As P7 noted:

> We need to definitely consider students have different education background, cultural background, or they even have different brain functions that can identify or really even understand the problem. So, we need to provide different explanations that may enhance students that could understand the problem so they [are] able to link to what they have learned in the class to really tackle the problem that we [assign] to them.

5.2. Integrating AP into Teaching Practices

Having an understanding of AP prepared participants to integrate it into their teaching practices. They then explored various strategies for its integration, including changes to teaching content and materials, teaching approaches, and student learning. Throughout the process, instructional coaching played an essential role in facilitating this integration.

5.2.1 Teaching Materials

AP depends greatly on student involvement and experience; without supportive lesson content or materials, the full advantages of these methods cannot be achieved (Ayoobi et al., 2018; Mizrachi et al., 2010). The need to adapt or create lesson plans, learning materials, and questioning strategies is crucial for integrating AP effectively (Ginsburg, 2010). Our participants intentionally sought to develop teaching content and materials to integrate AP into their lessons, such as designing a lesson "hook," incorporating authentic or real-world problems, effective questioning, crafting engaging lesson materials, and restructuring assessment activities.

To begin with, participants considered designing a lesson "hook" to engage students. An effective lesson "hook" can serve as a pedagogical tool to improve students' overall experiences (Niemi, 2016). However, teachers often rely on their expertise or familiar pedagogical theories to manage their teaching, which can lead them to overlook the crucial role of engaging students at the start of their lessons (Allchin, 2015). Our participants were encouraged to consider the lesson "hook" and subsequently employed a variety of strategies to create a captivating hook for learning, as demonstrated by P10:

> At the beginning of each lecture, I started by telling students about (a) the suggested readings from the recommended text as they relate to the current topic, (b) the importance of the topic in the real world, and (c) outlining the learning objectives.

Explicitly sharing learning objectives at the beginning of class was a new approach for many participants. Some participants explored a more interactive "hook" to engage students. For instance, P12 designed an image-sharing activity in which students shared water images as a starter for each class:

> First day…I wasn't really sure how to implement [interactive lectures]. I'm teaching about advanced water course and finished kind of the introduction, kind of like the motivators and what are some of the barriers to clean water or things like this are. [To engage students, I

> designed an activity where they shared images of water]. We've been looking at all these images of water that [students] submitted over the semester…at the beginning of each class I kind of include that… just like kind of to have them discuss sort of that.

When students shared their water images, they also recounted related stories, such as how water from their hometowns nourished their growth, provided energy, and brought evoked feelings of contentment. These connections not only encouraged students to engage with the learning activities but also broadened their perspectives on water as they viewed the images and listened to the stories they conveyed.

In addition, participants came to understand that incorporating authentic, real-world problems is crucial for achieving AP integration. Such problems create opportunities for students to develop critical thinking and problem-solving skills (Lowell & Moore, 2020). Our participants recognized the value of incorporating these types of problems into their coursework and contextualizing the related subject matter. As P10 revealed, "It was imperative to integrate real-world examples into the course delivery to enhance student engagement and comprehension." They further employed numerous approaches to this integration. For instance, P7 directly adopted a real-world question provided by a company for the class:

> For [the topic of] mine economics, we just finished the class today, and we actually have a question designed by Suncor, which is the biggest oil company in Canada, about their fleet optimization problem, whether they want to replace or just overhaul the current fleet or just using a contract, you buy a company like Tag, or they can buy the new fleet which is running electrical vehicles which will lead to less carbon emissions, and we also include carbon tax.

Furthermore, participants recognized that effective questioning is essential for successful AP integration, as it plays a pivotal role in engaging students in critical thinking and problem-solving (Jacques et al., 2020). Educators need to ask questions thoughtfully (Oliveira, 2010), as crafting well-thought-out questions is both challenging and rewarding. This requires careful consideration of students' responses, as P4 noted:

> I would focus on…thinking about…how to set up…questions…and probably the most challenging aspect was, well don't just ask the question, think about what the answer – what kind of answers you're going to get…. You can't just ask the question and then just hope that they get where you are going with it, right?…since it's the most challenging, and also the most rewarding….What's surprising was how well [student] can answer,…that's exactly what I want to use.

Another important way participants integrated AP into their teaching materials was by intentionally designing engaging lesson activities to enhance their teaching practices. These activities can provide students with meaningful learning opportunities (Wang et al., 2021). Participants explored different ways to develop lesson materials to enhance their teaching practices, including creating communication exercises and smoothing the flow of ideas, as P4 revealed:

> There was the communication exercise for [one course] and that was great. That was a LEGO exercise….put together the prevention through design—just clarifying ideas and the flow of—sometimes it's hard when you know something so well to try and make it flow properly for people who are learning the material for the first time. What does that look like? What's the thought process? And sometimes it's hard to break down those thoughts into bite sized pieces, and so that's been very helpful.

That being said, it is worth noting that restructuring assessment captured participants' attention as they developed their assessment materials. Assessment is a critical component of teaching and learning, particularly in engineering education (Olds et al., 2005). However, educators, particularly in engineering education, often lack sufficient experience in assessing student performance and providing effective feedback (Subheesh & Sethy, 2020). The SPARK-ENG program provided participants with support and opportunities to learn about assessment, apply their knowledge of assessment to teaching practice, and develop their perceptions of assessment in engineering teaching. Participants explored a range of strategies to restructure assessment activities and shift from passive

assessment to a more engaging and dynamic approach. For instance, P4 restructured the assessment activities by providing students with time and opportunities to work on the targeted task, ask questions, and receive support. This fostered a more interactive and productive learning experience:

> I gave [students] about an hour to work, and they really appreciated that. I heard in the feedback that they appreciated that because not only did it give them time to work on their material, they could ask questions, right? And I was there to answer their questions. So, rather than struggling with their questions for the whole hour, they could work on it a little bit and then ask me and then go back and work on it some more. So, I think it really facilitated their learning to have kind of a workshop or kind of structure.

Participants also designed assessments that gathered evidence of student learning in a low-pressure environment, fostering a supportive atmosphere that encouraged students to engage freely without fear of being judged. As P10 noted:

> Considering the course's nature, I ensured that the assessments were relatable to the students. For instance, one of our in-class quizzes involved applying knowledge of water quality to understand and interpret daily water quality reports from Edmonton, as reported on the EPCOR website. This exercise helped students grasp the hardness of the water we receive in our homes. I had to redesign my assessments. The new focus was on gathering evidence of students' understanding of course content and their ability to meet learning outcomes without pressure. I found this approach beneficial as it created a no-judgment zone where students felt comfortable providing answers, even if they were incorrect.

However, participants encountered difficulties in restructuring assessment, including a lack of necessary knowledge, expertise, or skills, as P6 shared:

> The biggest one was working on…designing my exams….I don't feel that I have enough skill or expertise or knowledge and how to do that properly so that I can tie that in a little bit more to maybe Bloom's Taxonomy and have different levels of knowledge that I can sort of assess with different questions or with different parts of each problem or something like that.

5.2.2 Teaching Approaches

Higher education institutions are increasingly tailoring their educational programs toward AP (Carvalho et al., 2021; Aparicio-Gómez et al., 2024); however, these approaches have been adopted slowly in classrooms, particularly within engineering education (Van den Beemt et al., 2023). Integrating AP is the main emphasis of our program. Participants engaged in a range of AP in their teaching, including getting to know students, encouraging students' self-reflection, incorporating interactive tools, adopting team-based learning and Think-Pair-Share, cultivating students' professional competencies, and enhancing student participation.

In the first module of SPARK-ENG, the central concept developed is the importance of educators getting to know their students. This concept encourages participants to explore various methods for gaining a deeper understanding of their students' needs, backgrounds, and learning styles. Participants explored diverse ways to get to know their students. By observing interactions in class, holding office hours, and addressing conflicts, they created a supportive learning environment that fostered a deeper understanding of their students. As P10 shared about the strategies they employed:

> I started trying to learn about each of the students in the class through various means—when they asked questions in class, came for office hours, or when a conflict arose in class, etc. …Through conflict resolution and interacting with affected students, I came to appreciate the importance of [getting to know students].

Another teaching approach participants tried to incorporate was self-reflection assignments, which enabled students to critically review their experiences and challenges, promoting deeper engagement and insights into their learning processes. As P8 revealed:

> I feel like there's …a good opportunity [for] a self-reflection piece to add in. [This can] give students an opportunity like what would you do differently or better at this point? What concept was the most troubling for…it can be a lot of grading depending on what you're doing, but that kind of like a self-reflective piece. Because I did that in [one course], a self-reflective final assignment. It was actually really cool to hear the students. … Students really got into it if they could self-reflect on, given the opportunity to chat about their group, what went wrong? What they should do differently.

Participants also creatively integrated interactive tools, such as online platforms, to promote active participation and foster an engaging learning environment. For instance, P6 incorporated an online platform and other sort of active learning tools:

> For me, the biggest thing was just incorporating [an online interactive platform] and other sort of active learning sort of things. I mean, that made a huge difference in the engagement in the class and in how well I felt like I knew my students and then how comfortable I felt like they were in interacting with me.

Additionally, as part of our program, participants learned that Team-Based Learning (TBL) promotes active learning and fosters student collaboration. Participants were encouraged to explore and adopt TBL strategies in their teaching practices. As P10 noted, they made efforts to incorporate TBL into their teaching to create a more interactive and engaging learning environment:

> A portion of [one] course is laboratory-based.…Through this team-based approach, students can network with their peers, collaborate during lab sessions, and extend their cooperation beyond the lab for research and the development of their lab reports,…encourag[ing] student collaboration and active learning.

Educators were introduced to a discussion protocol, Think-Pair-Share, as a strategy for engaging students in participation—students "have time to think individually, talk with each other in pairs, and finally share responses with the larger group" (McTighe & Lyman, 1988, p. 19). Some participants experimented with Think-Pair-Share in their teaching practices, as P9 indicated:

> Some quick hits – using Think-Pair-Share frequently, and well structured to provide clarity in the lecture space. I've colour-coded "participation" slides so students know what is expected. I then use these to drive classroom discourse.

Many of the features of active learning are reflected in professional engineering competencies students are expected to develop in their courses, such as investigation, design, and use of engineering tools (Engineers Canada, 2008). As such, participants acknowledged the importance of cultivating students' professional competencies, particularly in light of the increasingly complex and multifaceted challenges facing engineering education (Diaz Lantada et al., 2014). Our participants sought various pathways to develop students' competencies through, as demonstrated by P7:

> I'm restructuring the two courses of teaching, which is solid mechanics, [in] which a lot of linear algebra is inside of it, and they need to do a lot of matrix transformation. I would just let them just code using Python to solve those problems and also use softwares to really visualize the problem. Because the most difficult [part] in solving mechanics will be visualization. So, I would think as now really we're more and more access to—now I think knowledge becomes even more easier and easier to get access to. But [what] is really important is the skill sets.

What's more, participants recognized that enhancing student participation in the learning process is crucial for successful AP integration (Rodriguez-Largacha et al., 2015). To foster this, participants worked to create a supportive atmosphere that would motivate students' active learning. As P10 indicated:

> While teaching…, one thing I did regularly was provide opportunities for students to give feedback during the course. I used this approach to ensure that my teaching practice was flexible, fair, and equitable for all or most of the students. …I also tried to create a welcoming environment that encouraged respect, collaboration, and active participation from all students.

5.2.3 Student Learning

The development of teaching content and materials, along with the adoption of effective pedagogies, aims to enhance student learning (Ross et al., 2024). Professional learning programs that lead to changes in practice but do not yield discernible improvements in student learning should not be considered effective (Guskey, 2002, as cited in Guskey, 2021). However, there are few studies on how professional learning programs impact student learning, particularly in engineering education (Felder et al., 2011). Our program not only effectively encouraged participants to adopt AP but also positively impacted student learning, as reflected in participants' observations of improved attendance, engagement, and achievement. While direct data on student learning was not gathered, it remains valuable to explore how participants' integration of AP into their teaching may have influenced student learning.

Student attendance was identified as a critical issue by our participants. As P4 shared, "[students] think they don't need to show up to learn the material. It's a struggle, to be sure. All they're doing is taking the slides we post online, and they're not showing up to class." Through experimentation, participants found that interactive learning tools positively influenced student attendance, as P6 shared:

> I felt like I had a very good culture in my classroom this semester. And part of that, I think, is certainly because I was doing things like [interactive tools] this semester that I wasn't doing last semester. Whereas last semester, I felt like I didn't have as much engagement from the students…two-thirds of them who were in class most days. But I had much greater attendance this semester. I felt like I knew a lot more of the students better than I did last semester and had really good interactions with them.

In addition, student engagement was also recognized as a key concern by participants, as they noticed that it often fell short of expectations. Encouragingly, participants observed an increase in student engagement after adopting active learning strategies, as P6 indicated:

> For me, the biggest thing was just incorporating…active learning sort of things. I mean, that made a huge difference in the engagement in the class and in how well I felt like I knew my students and then how comfortable I felt like they were in interacting with me.

On top of that, enhancing students' achievement (e.g., performance and experiences) was regarded as a primary goal by participants as they aimed to integrate AP. They explored various strategies to achieve this goal. For instance, students responded better to assignments when provided with clear rubrics and structured support, as P4 shared:

> I found being very specific with the marking rubrics really helps [my students] to determine what they need to provide in their report. [For instance, in one course,] I gave them…two group assignments, one individual assignment. I gave them specific rubrics for each one, and they did a very good job—way better than the time before when I taught the [same]course, [but] I didn't have rubrics.

Incorporating clear rubrics enabled students to actively engage in assessment tasks that supported them in making their learning more apparent to their educators and thus impacted their achievement.

5.2.4 Instructional Coaching

Participants did not achieve the integration of AP on their own; the support from the instructional coach was essential in helping them incorporate AP into their teaching. By observing lessons and providing constructive feedback, the coach helped participants identify strengths and areas for growth, as P2 experienced:

> [The instructional coach] went to my classroom two times. One for soil mechanics and the other for mine economics. And [they] gave me the feedback, one-page feedback, for how I actually could improve in the class and what actually I already did well in the class. I think that is really helpful.

Furthermore, participants appreciated the specific help provide by the instructional coach with issues that emerged from their teaching, such as how to design exam, as P6 shared:

> I've had direct conversations with [the coach] about…my first exam last semester, for my midterm last semester, I hadn't designed it with a rubric in mind and I just sort of discussed how I could go about grading it with [them] at that time. And then we met specifically to discuss designing a rubric so that I had that prepared for my final exam… .So discussing those sorts of practices with [them] was very valuable.

5.3. The Impact of Integrating AP on Educators' Professional Growth

The impact of professional learning programs on participants' professional growth has been a key factor in evaluating their effectiveness (Felder et al., 2011). In our study, the adoption of AP in teaching practices, supported by participants' engagement with the program, positively influenced their professional growth. However, we recognize that such impact takes time to fully manifest; thus, the findings presented here represent only an emergent beginning. This impact included enhancing educator disposition and fostering an appreciation for SoTL.

5.3.1 Enhancing Educator Disposition

Knowledge, skills, and disposition are essential components of teacher quality; however, disposition is often overlooked in teacher education (Thornton, 2006). AP is viewed as both the disposition to learn and the means to facilitate this process in higher education (Drew & Mackie, 2011). Our participants' experiences integrating AP fostered a positive disposition toward continuous professional growth. They became confident in exploring AP, eager to share their experiences to inspire others, committed to apply their learning from the program to their teaching practices, open to embracing innovation, and mindful of continuously improving their teaching methods.

Initially, participants expressed a lack of confidence in exploring new pedagogies or integrating AP into their teaching practices, citing the pressure to cover curriculum content as a key contributing factor. As P11 shared, "I can't solve curriculum questions. I am just a cog in the wheel. I am nobody. I am surviving." This lack of confidence was also partly rooted in the fear of receiving negative feedback if they tried new approaches to teaching, as P4 explained:

> I find it's a little more daunting to take that leap in teaching rather than in research, because really the only one you impact on research is you. If it's teaching, not, you're impacting the students, and then you hear about it. If something didn't go well, in your feedback at the end of the semester, you will hear about it.

However, developing an understanding of AP and experiencing its integration positively helped participants gain confidence in improving their teaching practices. For instance, P1 moved away from traditional lecture styles toward more interactive, student-centered approaches, empowering them to create more engaging learning environments where students were actively engaged:

> I've learned a lot, and I've been able to apply it in my different classes…it's been a wonderful experience, and it's really given me the license and the confidence to do things better. Because there's all these traditional lecture styles, and you think you have to do it that way because that's how everyone else has done it for the past 250 years, right? But I can tell when my students are engaged and when they're not. And so, it gave me the confidence as well as the knowledge to do things differently. So, it's been amazing that way.

After incorporating new approaches or strategies into their teaching practices, many participants became enthusiastic to share their experiences. As P4 noted regarding active learning approaches:

> And I'm also excited to tell [my colleagues] about the different things like for [one course] for example, what we've implemented in the course to help the students like the design projects and the communication activity, the active learning exercises, I think, have been really good for the students.

Through their experience with AP, participants appeared to shift their perspective on professionalism in their roles as educators. Initially, many viewed professionalism as a static concept—once a course was "figured out," they believed it required no further updates. As P9 reflected: “I’ve figured it out once, and I’m good with the course; I’m done. I’m not going to change it or touch my overhead slides for the next 50 years. I will recycle and recycle.” However, through their engagement with AP and a deeper commitment to student-centered teaching, their understanding of professionalism evolved. They began to embrace continuous improvement—a shift exemplified by P2, who became more mindful of continually improving their teaching:

> And I think more importantly, it has just shown that it is important for us to keep developing our pedagogy. To keep developing our teaching styles. I think that's what is even most important, just to create that awareness that it's important to keep improving, to keep introducing new skills or new styles that would improve the teaching and learning process.

5.3.2 Embracing the Role of the Scholarship of Teaching and Learning (SoTL)

One pathway to continuously improving teaching is SoTL, which emphasizes the importance of systematic research in teaching and learning (Boyer, 1990, as cited in Miller-Young & Chick, 2024). SoTL has been regarded as an effective tool for enhancing teaching in higher education, as it often helps educators address practical issues arising from their teaching practices (Wright et al., 2011). Our program has encouraged and supported participants to explore SoTL. Throughout the program, they came to recognize the role of SoTL in integrating AP by analyzing key indicators—such as student engagement and feedback—to evaluate the achievement of learning objectives. This approach not only informed teaching strategies but also fostered a culture of continuous improvement, allowing educators to adapt and refine their methods based on concrete evidence of student learning. For instance, P6 was motivated to use SoTL as a pathway to improve teaching practices:

> It's good to already be motivated to do some of this stuff [SoTL] just to improve your teaching, but I mean, as researchers, we're all – as soon as we can try…some of that stuff, we tend to be very data-hungry. So as soon as we can try…some of it and see how well it's working and share that with others, it makes it even more exciting.

However, participants found it challenging to utilize SoTL to enhance their teaching practices, as they often lacked the necessary skills and resources for educational research (Ortea, 2015), such as navigating ethics approval processes. As P9 noted:

> I developed a survey with a colleague for their course after they implemented a new wind tunnel into an aerodynamics course. We surveyed the students and I’m in the process of putting together the paper right now! I’ve learned a lot about ethics approval and the way this research perhaps differs from what I’ve done in the past, and it is a steep learning curve.

Overall, the enhanced educator disposition, combined with the recognition of SoTL as a pathway to improving teaching, empowered participants to develop their own approaches and strategies for integrating AP. This fostered a sense of independence, enabling them to apply their learning effectively and confidently, while also equipping them to navigate challenges in their own ways. As P4 stated:

> [The learning process] helped me, now I can do it better. Now I have a process for doing that. [It] doesn’t need to help me every time now. …and now I can do it on my own, or I can do most of it on my own. I can get 80 percent of the way there.

6. Discussion

To support engineering educators, our program was designed to provide comprehensive AP learning materials and resources (e.g., readings, videos, and broadcasts) along with structured opportunities for participant reflection and collaboration. These supports included prompts for reflecting on understanding, encouragement to design lessons and activities that integrate AP, discussions within CoPs about their experiences and insights, and one-on-one coaching from the instructional coach.

This approach combined both theoretical and empirical evidence to help engineering educators understand and integrate AP into their teaching practice, aiming to meet their needs. Such a holistic approach is essential for fostering effective professional learning among engineering educators (Felder et al., 2011), and more broadly in higher education (Nicholls, 2001). As trained scientists who regularly engage in critical thinking, engineering educators are particularly discerning. If they are presented with a program consisting solely of strategies and tips without solid theoretical or empirical backing, they will likely be reluctant to change their pedagogy (Felder et al., 2011). Conversely, if they are provided only with broad theories and educational research findings and are left to adapt these to specific topics, such as fluid dynamics or microprocessor design, on their own, then meaningful change is also unlikely to occur (Stigmar, 2010).

Teacher change is inherently complex and cannot be achieved through a single action. Educators face significant challenges in making changes and developing their teaching practices without institutional and systemic support (Sancar et al., 2021), especially in higher education (Hénard & Roseveare, 2012; Fernández Díaz et al., 2010). This is evident in the challenges our participants faced, such as a lack of expertise and confidence in adopting AP. However, by understanding and experiencing AP in their teaching practices, our participants were able to build the motivation and confidence needed for integration, ultimately overcoming these obstacles and fostering professional growth. It is also noteworthy that educators need to see how their practices impact student learning in order to continue using these approaches (Bechtel & O'Sullivan, 2006), because the positive effects on student learning can enhance participants' confidence, disposition, and passion for continuing AP integration. As P6 experienced, "[Upon receiving] the positive feedback on [the interactive tool] after the midterm, I was willing to put more effort into that." Additionally, ongoing support and follow-up are crucial for educators' professional development (Bechtel & O'Sullivan, 2006), and the successful integration of AP requires a collective effort (Ryoo et al., 2015). These insights were echoed by our participants, who acknowledged that SPARK-ENG's support significantly enhanced their ability to integrate AP. Thus, our research is relevant not only to engineering educators but also to educators across higher education more broadly.

For educators adopting AP, an effective starting point could be targeted implementation by integrating a single AP approach (e.g., getting to know students) into one lesson, then refining it based on student feedback. We encourage interaction among peers through CoPs to adapt AP to specific disciplines and address implementation challenges. Educators can emphasize evidence-based practice by piloting the AP approach, observing or analyzing student learning, and using feedback to inform iterative improvements. Accessing instructional coaching or expert mentorship can provide personalized support, while reflection on student engagement and educator disposition helps sustain growth. These recommendations—informed by our experience in designing and implementing SPARK-ENG, as well as by participants' engagement—can foster educators' sustainable pedagogical growth.

7. Conclusions

Participants in SPARK-ENG developed an understanding of AP and experienced its integration into their teaching practices through their engagement with the program. These understandings and experiences allowed us to understand what AP looked like within the context of engineering educators' engagement with SPARK-ENG. This lead to actionable outcomes for our participants, including: a) Understanding AP, including foundational pedagogical knowledge, unpacking the rationales behind teaching methods, and advocating for effective learning environments for students; b) Developing teaching materials to center students in the learning process, including designing a lesson "hook", incorporating authentic problems, questioning effectively, crafting engaging learning activities, and restructuring assessment activities; c) Adopting various teaching approaches to engage students, including getting to know students, encouraging students' self-reflection, integrating interactive tools, fostering teamwork, adopting Think-Pair-Share, cultivating students' professional competencies, and enhancing participation; d) Exerting a significant impact on student learning, including promoting student attendance, engagement, and achievement; e) Fostering a positive educator disposition toward continuous professional growth, including increased confidence in integrating AP, eagerness to share experiences, a commitment to improving teaching practices,

openness to embracing innovation, and a mindfulness of continuous improvement; and f) Embracing the role of SoTL in catalyzing continuous teaching improvement. These experiences illustrated engineering educators' growth on the path to integrating AP, from becoming aware of students at the center of learning, to developing an understanding of AP, committing to embracing AP, experiencing AP in practice, promoting student learning, enhancing their disposition toward AP, and developing their own pathways for continuous professional growth. These experiences empowered engineering educators to enhance their teaching practices by adopting student-centred approaches. As P4 reflected, "My whole approach is different now... what I did was awesome... I was able to really engage with the students better, and I think they engaged with the material better."

In addition, situated learning theory helped us understand participants' experiences with AP within the contexts of their teaching practices (O'Connor & Glenberg, 2006) and within collective learning environments (Fields et al., 2021; Newstetter & Svinicki, 2014). It also allowed us to uncover the learning opportunities that arose within participants' engagement in professional learning about pedagogy—through interactions among participants, with the instructional coach, with learning resources, with CoPs, and with SoTL—which facilitated changes in their teaching practices, particularly in relation to AP. These learning opportunities make the growth of our participants as engineering educators possible on the path to integrating AP. Certainly, we recognize that not every individual participant reached the same milestone on the path. The growth we have illustrated primarily reflects the emergence of our participants' collective experiences in integrating AP through a variety of learning opportunities.

Overall, our interpretation of AP in engineering teaching practices—based on the experiences of our participants as engineering educators within the context of their engagement with the SPARK-ENG program—can serve as a valuable conceptual framework or a reference for empowering educators on their path toward AP, enhancing their teaching practices. Although SPARK-ENG is situated within engineering education, the support it provides, the emergent learning opportunities, and the participants' engagement experiences also offer valuable insights for educators across many disciplines in higher education.

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Contributions

All authors contributed to the study conception and design.

Ethics Declarations

This study was approved by the Research Ethics Board 1 of the University of Alberta (protocol Pro00107339).

Informed Consent Statement

Informed consent was obtained from all participants for involvement in this study.

Competing Interests

The authors have no financial nor non-financial interests that are directly or indirectly related to the work submitted for publication.

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