Mapping the implementation of Active Learning approaches in a School of Engineering - the positive effect of teacher training

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Abstract

This study aims to propose a method for mapping the implementation of active learning approaches by quantifying engineering teachers' self-perception. It also seeks to examine the correlations between the implementation of active learning approaches and training, as well as publications focused on active learning. To conduct the study, active learning concepts were defined, and a set of approaches were selected for consideration in the survey. A questionnaire was developed to collect data, which was completed by teachers of 246 courses from 14 engineering programs within a school of engineering. The findings revealed that only 11% of the courses studied did not implement any active learning approach. Project-Based Learning emerged as the most implemented approach, which aligns with the context of the engineering school. Additionally, positive correlations were found between training and the implementation of active learning approaches. This work makes contributions both to the theory, as it presents a way for measuring the perceived implementation of active learning approaches and the correlation with training and publications, and for institutional policy, as it shows the importance of training for that same implementation.

Keywords: Engineering Education; Active Learning; Project-Based Learning; Teacher Training Effect; Engineering Teaching Staff

1 Introduction

The improvement of Engineering Education implies a deep understanding of its nature (Besterfield-Sacre et al., 2014; Finelli & Froyd, 2019). Considering Engineering Education as a field that aims to study and improve the methods of teaching, learning, and practice in engineering, involving research on Engineering Practice and Engineering Education (R. M. Lima & Mesquita, 2018), it is worthwhile to investigate the way teachers develop their teaching competences. Ensuring the effectiveness of engineering education lies in the hands of competent engineering teaching staff who employ the most effective strategies and methods in their teaching processes. One may consider active learning approaches as an effective way to support the learning process (Freeman et al., 2014), but, despite this, evidence suggests a slow adoption of active learning approaches among teachers (Nguyen et al., 2021). Thus, investigating the implementation of active learning approaches and the relation of the level of implementation with teacher development activities is key for enhancing engineering education.

Traditionally, instruction focused on content delivery, but now the emphasis is on fostering competence development, with teachers serving as facilitators and students actively engaging in the learning process (Abelha et al., 2020; Fink et al., 2005; Flores et al., 2012; Gibbs & Coffey, 2004; Stes et al., 2010). In the field of Engineering Education, this challenge requires teachers and students to collaboratively create an environment that nurtures the development of competences crucial to engineers. These competences involve applying both fundamental and specialized knowledge to address real-world challenges (Cruz et al., 2021; Mesquita et al., 2015; Passow, 2012).

In turn, teaching practice involves a set of complex activities, whose dynamics can only be understood in the relationships that are established between students, teachers, the knowledge and learning to be built, and the skills to be developed (Neves et al., 2021). Improving Engineering Education through changes in curricula, expansion of computerized rooms, and physical conditions of laboratories does not guarantee effective teaching, geared toward student learning. It is important, in this scenario, to support studies and actions aimed at the epistemological and pedagogical training of engineering teachers (Mesquita et al., 2020).

The transformation for active learning approaches demands the development of teaching staff, so higher education institutions are now confronted with the challenge of training their teachers to shift their teaching approach. White et al. (2016) argue that there are many examples of individual or small group actions developing innovative approaches to active learning in specific courses and programs, while there are very few reports of the adoption of active learning strategies and methods across a more research-oriented institution. In this context, answering some of the following questions is relevant both for engineering education researchers, engineering teachers, and managers of schools of engineering: RQ1 - What are the main active learning strategies and methods used in engineering undergraduate programs? RQ2 - Does teacher training correlate with the implementation of active learning approaches? RQ3 - Does a correlation exist between the publication of engineering education research and the implementation of active learning approaches?

This work aims to map the implementation of active learning approaches in a school of engineering, and if there are some predictors of that implementation related to teacher training and the development of publications of engineering education. The correlation between the implementation and the training would show indicators of the effectiveness of training. The correlation with the development of publications on active learning approaches would show indicators that teachers would be potentially deepening the reflection on their own practice.

The findings of this research will contribute to a method for determining the level of implementation of active learning approaches in higher education institutions. Furthermore, it aims to shed light on whether teacher training and research activities related to active learning serve as predictors for the level of implementation of these approaches.

The following sections present a discussion of the theoretical framework that underpins this work, the methodology used, some results and, finally, some considerations about this research work.

2 Theoretical Framework

This section describes the theoretical framework for active learning and a brief discussion on active learning approaches.

2.1 Active Learning Conceptual Overview

The term “active learning” encompasses meaningful, engaged, and reflexive learning experiences with several ways of implementation depending on the areas of knowledge and contexts (Lombardi et al., 2021). Recognizing the importance of teaching and learning competences (Neves et al., 2021), there is a clear need for thorough professional preparation among engineering teachers. This preparation becomes even more crucial to overcoming personal and cultural beliefs and behaviours, dealing with the complex process of planning teaching-learning strategies and activities (Booth et al., 2008) and developing the required competences (Felder et al., 2011; R. M. Lima, Mesquita, et al., 2017; Wankat, 1999). In this context, teaching and learning involve understanding reality through questioning, observation, and argumentation, fostering creativity and the ability to generate and recreate ideas. Such a teaching and learning process gains importance as Research suggests that active learning approaches, can enhance learning (Bonwel & Eison, 1991; Prince, 2004) and reduce failure and dropout rates in engineering courses and the STEM area (Freeman et al., 2014; Theobald et al., 2020).

Furthermore, active learning is grounded in constructivist epistemological theories, which provide a framework for understanding knowledge creation and development, as well as our perception of the world (Anthony, 1996; Kalpana, 2014; Kocevar-Weidinger, 2004). According to the constructivist model, knowledge is a product of action, transformation, and the establishment of connections (Anthony, 1996; Becker, 2016).

According to de Graaff and Christensen (2004), active learning and Engineering Education are a natural pair as the engineer should be educated to design and build solutions to real-world problems. This idea is reinforced by Lima, Andersson and Saalman (2017, p. 3) in the following excerpt:

“Active Learning is learning which engages and challenges students using real-life and imaginary situations where students engage in such higher-order thinking tasks as analysis, synthesis and evaluation. In Active Learning environments, students are engaged in meaning-making inquiry, action, imagination, invention, interaction, hypothesizing and personal reflection”.

2.2 Active Learning Approaches

Prince (2011) presented a full spectrum of active learning strategies and methods from one extreme of an Active Learning Continuum (an illustration of this continuum is presented in Appendix 1, Figure 5), with activities implemented in interactive lecture-type classes, to the other extreme of the continuum characterized by a higher level of students’ autonomy, fully planned in the light of approaches such as problem and project-based learning. Prince's (2011) message for fellow engineering teaching staff is that active learning comes in a variety of flavours. Consequently, there is no ideal strategy or method, but the one(s) that creates conditions for the development of the intended learning outcomes for a class, for a course or an entire program. While it is out-of-scope of this work to describe all existing active learning approaches in the literature, it is important to list the most widespread strategies and methods in the institution where this research was developed and the references supporting them.

To help increase the attention span in the STEM classroom, Felder and co-workers have been some of the biggest enthusiasts of the implementation of active learning strategies and methods in large classes and in how to incorporate them without sacrificing content coverage (Felder, 1997; Prince et al., 2020). Some of these approaches may be implemented in what could be seen as interactive lecture-type classes, encompassing strategies and methods such as quizzes (Aravinthan & Aravinthan, 2010; Bell, 1997; Cohen & Sasson, 2016; Cox & Clark, 1998), Minute Paper (Domokos & Huey, 2021; Levin-Banchik, 2022; Weaver & Cotrell, 1985), and Think-Pair-Share (Gok, 2018; Kaddoura, 2013; Lyman, 1981). Additionally, this study considers the following strategies and methods, which are described in detail in Table 5 of Appendix 1: Team-Based Learning (Leupen, 2020; Michaelsen & Sweet, 2008), Flipped Classroom (al Mamun et al., 2022; Lage et al., 2000), Peer Instruction (Mazur, 2013; Tullis &

Goldstone, 2020), Gamification/Game-Based Learning (Kapp, 2012; Patil & Kumbhar, 2021), Case Study (Boehrer & Linsky, 1990; Zuwala & Sztekler, 2018), Problem-Based Learning (de Graaff & Kolmos, 2003; Graaff & Kolmos, 2007; Kolmos et al., 2009), and Project-Based Learning (Edström & Kolmos, 2014; R. M. Lima et al., 2007; Powell & Weenk, 2003).

Within this frame of reference, it is noteworthy to know if the teaching staff is aware of active learning strategies and methods and if they are using them. It is also of great interest to know what kind of preparation the teaching staff had before using those strategies and methods, and if they are researching their own teaching practice.

3 Methods

Answering the research questions could have driven the research in different directions, and in this specific study, the team decided on non-causal type of study, as the study does not definitively try to identify causal relations between training and the level of implementation of active learning approaches. Instead focus on making diverse contributions both to the theory, as it presents a way for measuring the implementation of active learning approaches based on teachers' self-perception, and for institutional policy, as it shows indicators of the importance of training for that same implementation. This type of study has known limitations related to potential wrong interpretation of the items, and the team decided to use several validation steps and include self-explanatory descriptions to reduce this risk. Moreover, some studies show evidence between what teachers say are implementing and what may be verified by observation, and this study does not address that type of potential issue. The study will then be focused on creating a mapping instrument that could be easily replicated to obtain the self-perception of teachers about their own practice, and further, to study indicators of training effect on the implementation of active learning approaches.

Thus, to answer the research questions, a questionnaire was developed. The steps for the development of the questionnaire included: (1) active learning content review; (2) development of items; (3) review of the questionnaire based on teachers' and program coordinators' feedback; (4) application of the questionnaire; (5) analysis of results; (6) report of the results.

3.1 Development of items

The research team developed the items in 6 weeks, including concepts related to active learning and different approaches to its implementation. As above forementioned, some of the most popular (R. M. Lima, Andersson, et al., 2017) active learning strategies and methods were selected by the research team, and additionally, some approaches with relative interest in this institution were also added. Finally, while answering the questionnaire, the participants must have the option to add other approaches of their choice. The selected approaches are listed below and described in a glossary presented in Appendix 1. From now on, they will be referred to by a short name in tables and figures for the sake of simplicity:

- Short AL - active learning strategies and methods in large classes
- Team BL - Team-Based Learning
- Problem BL - Problem-Based Learning
- Project BL - Project-Based Learning

- Peer Instruction - Peer Instruction
- Case Study - Case Study
- Game BL – Gamification / Game-Based Learning
- Flipped Classroom - Flipped Classroom

The first version of the questionnaire was sent to nine teachers, with different experience backgrounds, including two program coordinators, to get their feedback for further improvement of the items.

The questionnaire (shared in Appendix 1) has an introductory part explaining the objective and presenting ethical aspects, mainly related to privacy and protection of data. If a participant does not want to answer, he/she might say so and would be instructed to close the questionnaire.

After this part, there are a few questions for identification of the course and program that are being addressed by the participant. It is important to clarify that the option was to address the courses, and only one teacher by course (its coordinator), and not all teachers involved in the course. Additionally, the following questions were of the utmost importance for the current work:

- In the last three years, how many training actions related to active learning approaches have you participated in?
- In the last three years, how many works have you published in journals and/or conferences on Engineering Education (International Conference of the Portuguese Society for Engineering Education - CISPEE, European Society for Engineering Education – SEFI Annual Conference, among others)?

3.2 Application of the Questionnaire

This study was developed in the 2020/2021 academic year at a Portuguese Engineering School with approximately 9000 students, including bachelor, master, and PhD students, integrated into a research-oriented University with approximately 19000 students. At this university, training is optional, but an extensive range of training opportunities is available to all teachers through the teaching and learning (T&L) unit. One of the most significant training provided in the three years before the study was focused on active learning, aiming to transform courses to use more interactive methods. Initially, this training took place in a retreat format, but during the pandemic, it shifted to online and later a hybrid model. Additionally, there is currently no institutional support for research in engineering education, and it is not highly valued in terms of peer recognition or teacher evaluation processes. Nevertheless, in the year preceding the study, the school introduced a teaching recognition certificate and a teaching award, which were granted by the dean team.

The questionnaire was sent to the program coordinators by an email sent by the school council president. The program coordinators were asked to send it to all course coordinators in their program. A course coordinator is responsible for overseeing and managing a specific academic course. They teach the whole or part of the course and handle curriculum development, faculty coordination in cases of more than one teacher, student support, assessment and evaluation, monitoring and reporting. Besides teaching, their role is to ensure the smooth operation of the course and facilitate effective teaching and learning experiences for students.

The course coordinators would have a planned period of 3 weeks to answer the questionnaire. A reminder was sent at the end of that period, postponing the collection of data for one additional week. Finally, the questionnaire was closed 5 weeks after the initial email.

It is important to note that there are a few introductory courses that may be simultaneously delivered to more than one program, and in these cases, the coordinator will be answering two or three courses (different programs) at the same time.

Another remark should be made about the program structure. All engineering programs from this School of Engineering comprise 5 consecutive years (integrated master structure), each year divided into two semesters. In most cases, each semester has 6 courses of 5 ECTS - European Credit Transfer System.

4 Results and Discussion

This section presents the main findings from the developed study.

4.1 Sample characterization

During the academic year of 2020/2021, there were more than 894 courses delivered in the 14 integrated master programs (
Table 1). The minimum sample size (n) for this research was estimated according to equation (1) (SurveyMonkey, 2022):

$$\mathrm{n} = \frac{\dfrac{Z^2 \cdot p(1-p)}{e^2}}{1 + \dfrac{Z^2 \cdot p(1-p)}{e^2 \cdot N}} \qquad (1)$$

Where, Z=Zα/2 is the critical value of the Normal distribution at α/2 (e.g., for a confidence level of 90%, the critical value is 1.65), N is the population size (N=894 courses), p is the sample proportion (p=0.5), and *e* is the margin of error (e = 5%). Thus, the minimum sample size is 208 courses for a confidence level of 90%.

A total of 246 responses were collected from course coordinators of these engineering programs, which corresponds to approximately 27.5% of the total number of possible answers, fulfilling the minimum value of responses to consider the sample statistically significant for a confidence level of 90%.

Table 1. Number of answers by program

Program	Nº of Answers
Integrated Master’s in Biological Engineering	21
Integrated Master’s in Biomedical Engineering	19
Integrated Master’s in Civil Engineering	29
Integrated Master’s in Materials Engineering	11
Integrated Master’s in Polymer Engineering	14
Integrated Master’s in Telecommunications and Informatics Engineering	16
Integrated Master’s in Information Systems Engineering and Management	30
Integrated Master’s in Information Systems Engineering and Mng. (post-work)	15
Integrated Master’s in Industrial Engineering and Management	20
Integrated Master’s in Industrial Electronics and Computer Engineering	29
Integrated Master’s in Physics Engineering	10
Integrated Master’s in Computer Engineering	18

Integrated Master’s in Mechanical Engineering	11
Integrated Master’s in Textile Engineering	3

As represented in Figure 1, the number of answers from each semester is almost the same; the number of answers obtained per each program year is also similar, except for the years 4 and 5. There is a larger percentage of answers from year 4 and a lower percentage from year 5, which was expected, as semester 10 is entirely dedicated to the master thesis, the sole course existing in that semester.

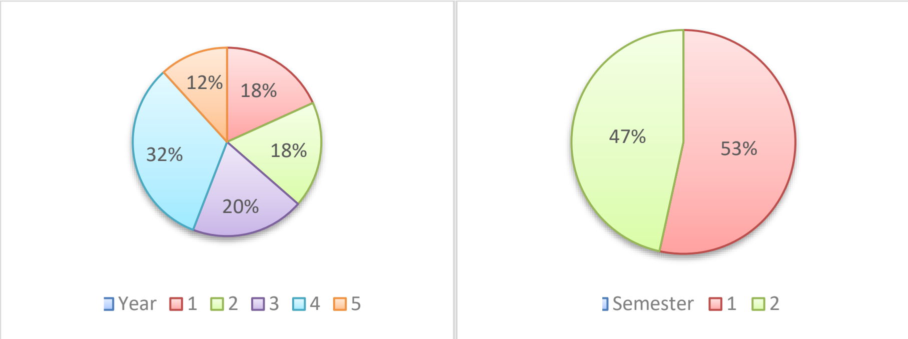

Figure 1. Year and semester frequency (in percentage).

4.2 Training

Considering the question “In the last three years, how many training actions related to active learning approaches have you participated in?”, 153 of the course coordinators (approximately 62%) answered that they did not participate in any training action (Figure 2). Of the ones that participated, most of them participated in 1 to 4 training actions. Most of the teachers referred to a 20-hour Active Learning training delivered by the [name removed for peer review] centre offer. Moreover, from the same centre, there are references to short training workshops on Flipped Learning, Perusall, Project-Based Learning, Team-Based Learning, Assessment, Challenge-Based Learning and Gamification. This is a university centre aiming at the improvement of teachers’ teaching and learning aspects.

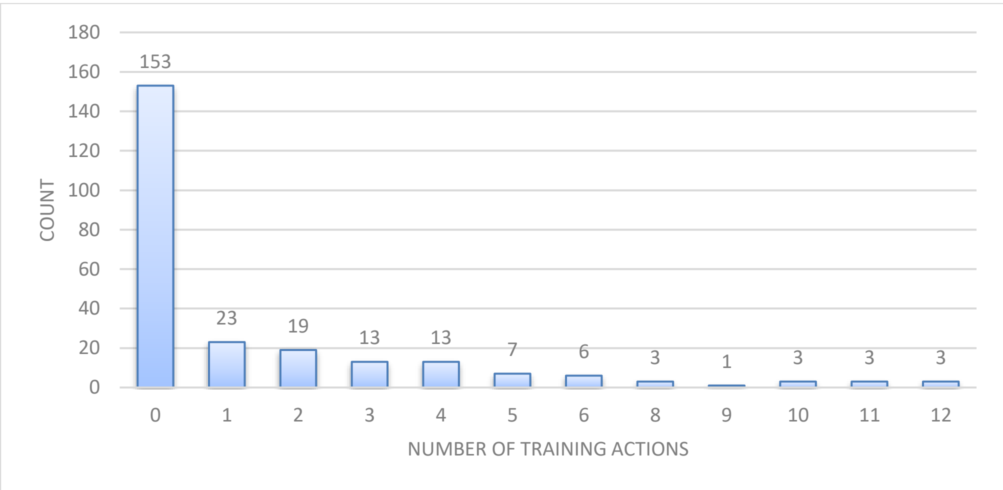

Figure 2. Number of participations in training actions

4.3 Publications

Considering the question “In the last three years, how many works have you published in journals and/or conferences on Engineering Education (CISPEE, SEFI, among others)?”, 221 of the course coordinators (approximately 90%) answered that they did not publish any article related to this subject. Thus, regarding this topic, only 26 of the course coordinators have published some work related to active learning in a conference or journal in the previous 3 years.

4.4 Active Learning Approaches - analysis

The responses to the questionnaire show considerable differences in the implementation of the different active learning approaches, as can be seen in Figure 3. The analysis of the figure shows that Project-Based Learning and Problem-Based Learning are the approaches with a higher level of implementation in the school of engineering. Project-based learning is the most frequently (28%) referred to as being "always" implemented), and the highest cumulative percentage when considering simultaneously "very often" and "always", above 40%. Problem-Based Learning has the lowest percentage of "never" implemented, below 30%. In the opposite direction, Peer Instruction (2%), Game BL (2%) and Flipped Classroom (2%) are the ones with lower references as always being implemented in courses reported by the coordinators. From the observation of the graph, it can be noticed that only three approaches have a higher frequency of "never" answers when compared to the sum of the other three levels of the scale: Peer Instruction, Game-Based Learning and Flipped Classroom. Thus, it is possible to conclude that these are the approaches with the lowest level of implementation in the engineering school understudy.

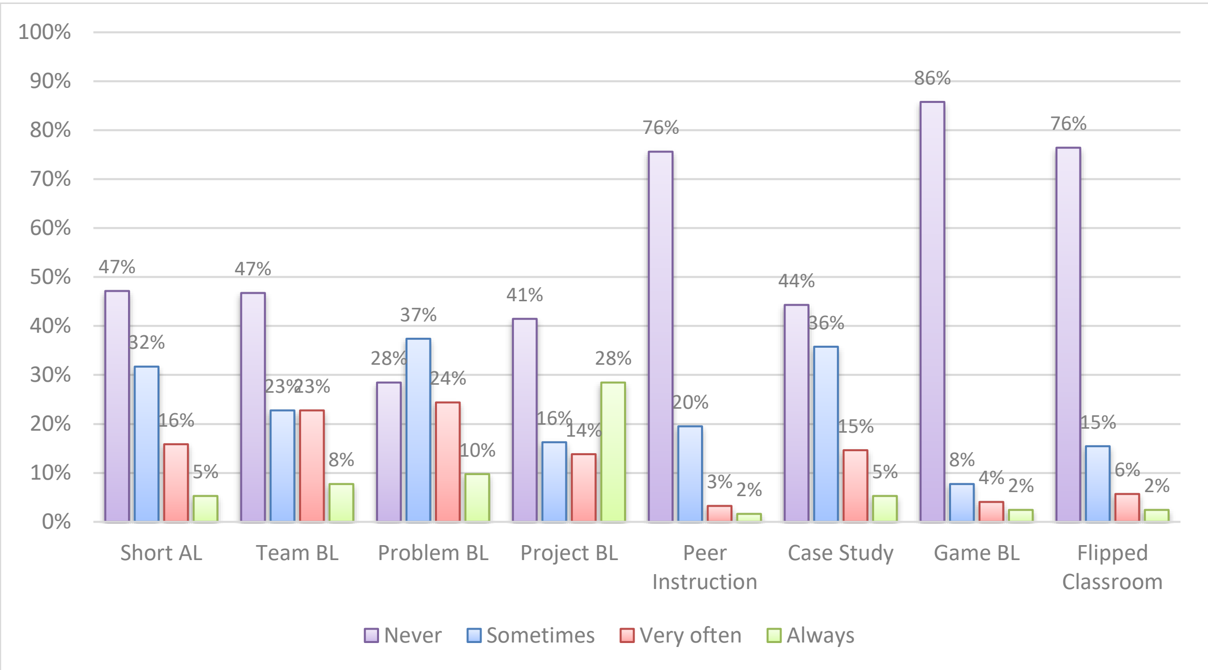

Figure 3. Mapping the implementation of different active learning approaches

Course coordinators indicate different frequency levels of implementation of active learning approaches for each course. Thus, an aggregated analysis may be constructed, considering for each course (i.e., each answer) a level of implementation as high as the highest frequency level. The rationale behind this analysis is that if one active learning approach is always implemented, then active learning is always implemented in that course, i.e., at least one active learning approach is "always" implemented. Furthermore, the same analysis may be done for "very often", "sometimes" and "never". Figure 4 presents the pie graph that represents this aggregated analysis. From this analysis, it is possible to conclude that only 11% of the courses do not implement any type of active learning approach, and also, that 35% always implement and 37% implement very often at least one active learning approach.

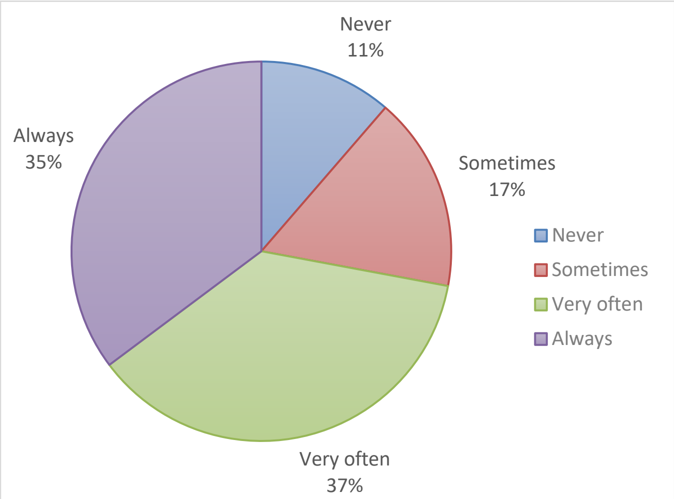

Figure 4. Aggregated perspective on the level of implementation of at least one active learning approach

4.5 Active Learning Approaches - correlations

A statistical analysis was obtained through Pearson's chi-square tests, which allows for testing whether two variables are independent (Pestana & Gageiro, 2014). The null hypothesis is that training and active learning methodologies are independent of a Significance level of 0.05 ($\alpha \leq 0.05$). The results from the statistical test that used Pearson's chi-square method can be seen in Table 2. According to the results presented, it is possible to infer that there is evidence of a significant statistical association between training and Short AL (25.45, p<.001), Team BL (35.30, p<.001), Game BL (14.88, .002), and Flipped Classroom (27.65, p<.001). Moreover, to measure the magnitude of the effect (Sun et al., 2010), the Cramer's V effect size was computed. Using the interpretation of Cramer's V for three degrees of freedom presented by Kim (2017), the effect size may be considered large for Short AL (.322), Team BL (.379), and Flipped Classroom (.335), and medium for Game BL (.246).

Table 2. *Chi-square tests (Training * AL methodologies)*

Active Learning Methodologies	**Pearson chi-square**	Df	Asymp. Sig. (2-sided)	**Fisher's exact test**	Exact Sig. (2-sided)	**Cramer's V**
Short AL	**25.45**	3	**.000**	25.34	.000	**.322**
Team BL	**35.30**	3	**.000**	34.71	.000	**.379**
Problem BL	4.00	3	.377	3.11	.375	.112
Project BL	3.52	3	.318	3.53	.318	.120
Peer Instruction	4.51	3	.211	4.09	.237	.135
Case Study	2.43	3	.488	2.42	.493	.099
Game BL	**14.88**	3	**.002**	14.21	.001	**.246**
Flipped Classroom	**27.65**	3	**.000**	26.81	.000	**.335**

Moreover, to know if there is a correlation between the usage of some active learning methodologies and the publication of scientific works in journals and conferences, the independent Chi-Square test was also used, and the null hypothesis is that publications and the active learning methodologies are independent for a Significance level of 0.05 (Sig. ≤ α = 0.05). The results from the statistical test that used Pearson's chi-square method can be seen in Table 3. According to the results presented, it is possible to infer that there is evidence of a significant statistical association between Problem BL (7.65, p=.050), Project BL (9.79, p=.020), and Game BL (46.52, p=.000) and scientific publications. Using the interpretation of Cramer's V presented by Kim (2017), the effect size may be considered medium for Problem BL (.176), and Project BL (.199), and large for Game BL (.435)

Table 3. *Chi-square tests (Publications * AL methodologies)*

Active Learning Methodologies	**Pearson chi-square**	Df	Asymp. Sig. (2-sided)	**Fisher's exact test**	Exact Sig. (2-sided)	**Cramer's V**
Short AL	5.38	3	.146	5.38	.128	.148
Team BL	6.28	3	.099	5.62	.110	.160
Problem BL	**7.65**	3	**.050**	8.67	.027	**.176**
Project BL	**9.78**	3	**.020**	10.41	.012	**.199**
Peer Instruction	1.98	3	.576	0.76	.758	.090
Case Study	2.53	3	.470	2.13	.538	.101
Game BL	**46.52**	3	**.000**	28.81	.000	**.435**
Flipped Classroom	4.59	3	.205	5.28	.114	.137

This study searches for correlations between the number of training actions attended by the teachers and between the number of publications in this field done by the teachers, with the implementation of different active learning approaches. As can be seen in Table 4, correlations are identified based on Spearman's one-tail coefficient test, which confirm most of the analysis previously developed through chi-square tests.

Table 4. Results of the Spearman correlation between active learning approaches, training, and publications

Variable	Training attended	Pub. (number)	Short AL	Team BL	Problem BL	Project BL	Peer Instruct.	Case Study	Game BL	Flipped Class.
Number of attended training		.21** (p=.001)	.32** (p<.001)	.17** (p=.004)	-.02 (p=.410)	.05 (p=.240)	.05 (p=.202)	-0.01 (p=.424)	.26** (p<.001)	.38** (p<.001)
Number of publications			.08 (p=.110)	.10 (p=.051)	-.13 (p=.023)	.18** (p=.002)	-0.08 (p=.111)	0.01 (p=.418)	.32** (p<.001)	-0.02 (p=.358)
Short Active Learning activities				.21** (p=.001)	.06 (p=.169)	.23** (p<.001)	.22** (p<.001)	.17** (p=.004)	.28** (p<.001)	.38** (p<.001)
Team BL					.39** (p<.001)	.46** (p<.001)	.30** (p<.001)	.43** (p<.001)	.18** (p=.002)	.17** (p=.004)
Problem BL						.29** (p<.001)	.20** (p=.001)	.44** (p<.001)	.16** (p=.006)	.17** (p=.004)
Project BL							.15** (p=.008)	.31** (p<.001)	.30** (p<.001)	.08 (p=.114)
Peer Instruction								.21** (p=.001)	.26** (p<.001)	.41** (p<.001)
Case Study									.21** (p=.001)	0.089 (p=.082)
Game BL										.34** (p<.001)
Flipped Classroom										

** Correlation is significant at the 0.01 level (1-tailed).

There is a significant positive association between the participants of active learning training with the use of short AL ($r(244)=.32$, $p<.001$), Team BL ($r(244)=.17$, $p=.004$), Game BL ($r(244)=.26$, $p<.001$) and Flipped Classroom ($r(244)=.38$, $p<.001$). The correlation with Team BL indicates a small effect size and the other three indicate moderate effect sizes.

Moreover, a significant positive correlation was observed between the number of publications and Game BL ($r(244)=.32$, $p<.001$), indicating a moderate effect size, and there was a significant positive association between the number of publications with Project BL ($r(244)=.18$, $p=.002$), indicating a small effect size.

5 Discussion

This work proposes an approach for mapping the perception of engineering teachers about their own level of implementation of active learning. Thus, concerning the first research question "What are the main active learning strategies and methods used in engineering undergraduate programs" the results of this study suggest that throughout the mapping it is possible to have an overview of the active learning strategies selected by the teachers to foster their teaching in engineering. To our knowledge, similar approaches were never published, and this is a contribution from this work to engineering education researchers and managers of engineering schools. However, the results show that they may be compared with publications about learning approaches. Lima, Andersson and Saalman (2017) identified Problem and Project-Based learning in engineering education as the approaches with a higher number of publications in journals. Moreover, this idea of an existing “natural” connection between PBL and engineering is also presented by Christie and Graaff (2017):

> “Engineering educators who promote PBL argue, as the McMaster staff did, that good pedagogical models should emulate the way practitioners work in their own field. Doctors diagnose medical problems and try to find remedies. Engineers design, build and test products” (p.13).

These were also the approaches with a higher level of implementation in this study, which may indicate that these pedagogical approaches have a higher level of correspondence with the nature of the subjects of engineering programs. Moreover, despite being out of the scope of this study it would be interesting to understand what type of Project Based Learning approaches have been implemented: project exercise, project component, and project orientation (Helle et al., 2006). The identification of the current level of implementation of active learning can be seen as a step for being able to analyse where an institution is and, in that way, make decisions for their strategy regarding the implementation of active learning.

Research questions 2 and 3 are related to the motivation to understand if training and researching may be seen as predictors of the implementation of active learning.

Despite the intensity of correlations not being very strong (<0.5), there are statistically significant correlations between most of the active learning approaches, which means that there are significant associations between the implementation of the approaches in interlinked ways, i.e., it will be likely to see the implementations of additional approaches when a teacher is focusing on one of them. This correlation may be explained by the development of competences of teachers, that gain knowledge and skills which enlarge their confidence in developing other approaches (Andrews et al., 2020; DeMonbrun et al., 2019; Finelli et al., 2014).

The number of training modules attended has positive correlations with publications in the field and with four active learning approaches: Active Learning strategies and activities (Short AL); Team-Based Learning; Gamification / Game-Based Learning; and Flipped Classroom. One can conclude that, at least in the context of this school of engineering, attending training in the previous 3 years is a likelihood predictor of the implementation of active learning approaches. There is no evidence of an association with the following approaches: Problem BL, Project BL, Peer Instruction, and Case Study. It is worth noting that the context may provide some insight into this lack of association. For example, Peer Instruction and Case Studies have not received any training from the Teaching and Learning unit in the past three years, which could explain the absence of association. As for Problem and Project Based Learning, this engineering school has a history of implementing these approaches, so teachers have either received training in the past or are currently developing competences by other means, including through collaboration with their peers during implementation.

Even though some studies do not find a positive effect of training on the teacher practice (Peters & Jolly, 2018; TNTP, 2015), it would be expected positive effects from training as referred to in some works that show efficacy results after teacher training (Fernandez et al., 2015; R. M. Lima, Mesquita, et al., 2017; Moreno Andrés et al., 2010; Shechtman et al., 2005). Most of the developed studies are related to teachers working in K12 environments, and as far as we know there are no studies that quantitively demonstrate the effect of training on the implementation of active learning approaches in Engineering Education. The specific influence over learning approaches may depend on the training offered and its effectiveness and on the individual, students, and curricular contexts (Finelli et al., 2014), which may be the object of further studies.

The number of publications on active learning has positive correlations with two active learning approaches: Project-Based Learning and Team-Based Learning. Concerning Gamification/Game-Based Learning, the correlation seems to be a result of the developments of specific teachers who are implementing and publishing the results. The engineering school in question has a rich background in the development, implementation, and publication of Project-Based Learning approaches. Consequently, the discovered correlation suggests that these publications are directly connected to the practical application of this approach. Additionally, this finding strengthens the importance of the Scholarship of Teaching and Learning (SoTL) in the professional growth of faculty members (Adams, 2009). To better understand the absence of a significant association between publications and other approaches, further data would be required. However, this observation potentially indicates a relatively lower emphasis on Engineering Education research for academic advancement or career progression.

Considering that this study does not aim at identifying correlations with specific training actions, but to find out if the training attended by the teachers, in whatever environment, has influenced the implementation of active learning, one can conclude that in the context of this study in this school of engineering, attending training actions in the previous 3 years can be seen as likelihood indicator for the implementation of active learning approaches. This result reinforces the idea that those teachers looking for training actions will tend to implement them in their courses. Nonetheless, it is worth noting that participation in training does not necessarily result in an immediate implementation of active learning approaches. In essence, a clear cause-and-effect relationship cannot be established. However, it does serve as a promising indication that exploring training paths could be valuable toward the promotion of active learning approaches. Importantly, it is essential to recognize that transitioning from conventional teaching methods to active learning may require a significant temporal investment, prompting the pursuit of a combination of strategies to facilitate this transformation.

6 Conclusion

Recent research has consistently demonstrated the enhanced effectiveness of active learning methods in promoting student learning (Freeman et al., 2014). In light of this established body of research, our study focuses on gathering self-assessments from educators regarding the extent to which they have incorporated active learning approaches. This approach serves as a valuable means of assessing the progress and integration of active learning strategies within a research-oriented engineering school. The results showed a perspective on the level of implementation, revealing that only in 11% of the courses there is no reference to the implementation of any type of active learning approach. Additionally, this work revealed a likelihood effect between attending training and publishing papers in conferences and journals, and the implementation of active learning approaches. In this context, at the institutional level, the results obtained in this work can be used to encourage more training and show the importance of engineering education research, as there is a correlation between publishing on engineering education and the use of some active learning approaches.

This study also reveals that mapping the implementation of active learning approaches can be essential for institutions, to strategically think about what to do in terms of faculty development initiatives. In other words: by knowing the strategies that teachers have been promoting with their students, it is possible to identify what is needed in terms of faculty development to become more effective in the adoption of teaching practices, considering the specific and local contexts (Finelli et al., 2014). Thus, one important contribution of this work is the methodological approach used to enable the mapping of the active learning approaches carried out by the teachers in one institution.

Finally, it is possible to conclude that this research work contributed to showing the importance of pedagogical training as a way of professional development, with a positive effect on the implementation of active learning strategies and methods. Such a result brings encouraging reinforcement to the institutional decisions for the implementation of training programs in higher education.

This study has the common potential limitations of self-perception surveys, namely the potential risk of participants answering what they think may be expected, and the exact understanding the participants may have about the items. The research team implemented countermeasures to reduce these risks, namely considering volunteer participation; guaranteeing privacy and that the data would not be used for individual course reports; adding a link for a glossary to explain the meaning of different terminology used in the questionnaire.

Further work may be developed to analyse the effect of specific training programs and models; analyse the effect of other professional development models; to analyse complementary ways of mapping the level of implementation of active learning strategies and activities and their results on the students' learning, and according to the students' perspectives.

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Appendix 1 – Active Learning Glossary

A glossary was shared with the questionnaire for clarification of the specific meaning of the active learning approaches. As the glossary is written in Portuguese, this section presents a translation of its relevant parts (https://idea.uminho.pt/pt/ideadigital/entradas/Paginas/entrada33.aspx).

Active learning encompasses a set of approaches related to the ability to create meaningful learning experiences, inside and/or outside the classroom. There are many ways to conceptualize active learning, and the aim here is to present a synthesis of ideas about active learning and approaches to its implementation, in a referenced way and provide a glossary of terms that can help teachers to position themselves about these approaches. This glossary is not intended to be complete or conclusive, as it is seen as being open and evolving, and above all, aiming to be useful.

The term "active learning" encompasses several approaches, all of which focus on student autonomy, engagement, action, and reflection on their learning. The glossary presented below lists some of these approaches: Team-Based Learning - TBL; Problem-Based Learning (PBL); Project-Based Learning (PBL); Service-Based Learning (SBL); Peer Instruction; Buzz Group Discussion; Case Study; Gamification; Just-In-Time Teaching; Research-Based Learning; Flipped Classroom; One (or Two) Minute Paper.

Active learning approaches can be analysed on a continuum depending on the students' level of autonomy and, consequently, on the level of complexity of their implementation. The continuum presented in Figure 5 is inspired by a lecture by Professor Michael Prince in 2011, at the American Society of Engineering Education conference.

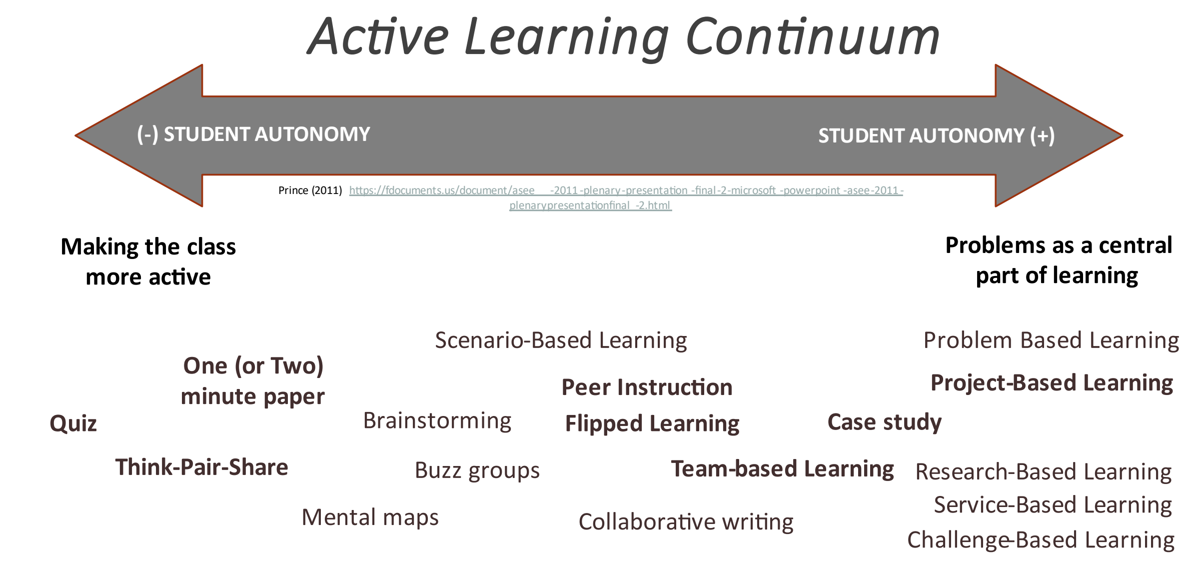

Figure 5. Active Learning *Continuum – inspired by* Prince (2011)

Table 5 presents a list of several active learning approaches and a descriptive short definition.

Table 5. Active Learning Glossary

Concept	Description
Active Learning	Active Learning is a term encompassing a set of approaches that aim to involve students in the teaching and learning process, based on meaningful experiences that allow students to understand the relevance of what they learn and for what purpose. An active learning environment is thus characterized by student engagement, through enthusiasm, action, and reflection on their own learning process (Christie & de Graaff, 2017; Freeman et al., 2014; Prince, 2004). Additional resources: Rebecca Brent and Richard Felder's *Website*: https://educationdesignsinc.com
Short Active Learning strategies and methods	Different active learning strategies can be used, considering the objectives underlying the teaching and learning process. In other words, some strategies require a higher or lower level of student autonomy, as referred to by Prince (2011). The short strategies and methods are the ones that can be used in lectures and include among others the following: Think-Pair share, quiz and one-minute paper, buzz group discussion.
Team-Based Learning	Team-Based Learning (TBL) is an evidence-based collaborative teaching strategy, which is based on a three-step cycle: individual preparation (solving a test, guarantee of preparation, IRA - Individual Readiness Assignment), team resolution (Group Readiness Assignment) and application exercises. The TBL strategy is adaptable to small and large groups, allowing you to work with large classes in small team formats (Haidet et al., 2014). Additional resources: Team-Based Learning Collaborative website. www.teambasedlearning.org
Problem-Based Learning	*Problem-Based Learning* (PBL) has a "problem" as a central element of the teaching and learning process. Students work in a collaborative environment that allows them to identify what they already know and what they need to know, developing research and analysis of information that allows them to solve the problem at hand. The "problem" is thus defined and selected according to the learning objectives. This principle is fundamental, as it allows the content of a given subject to be related to the context inherent to the problem, thus contributing to the student's understanding and motivation (de Graaff & Kolmos, 2003; Savin-Baden & Major, 2004).
Project-Based Learning	*Project-Based Learning* (PBL) is an approach that integrates the development of a solution to an open problem, in which students must be able to formulate the problem before developing their solution. Dealing with an open problem, student teams can develop multiple solutions, allowing for creativity and innovation. Teachers act as facilitators, mentors or supervisors, depending on the phase of the project and the learning environment developed for that purpose. In most situations, the project approach is developed over a longer period (e.g., one semester) than the problem approach (e.g., 4 weeks) (Edström & Kolmos, 2014; Lima, R. M., Dinis-Carvalho, J., Sousa, R. M., Alves, A. C., Moreira, F., Fernandes, S., & Mesquita et al., 2017).
Service-Based Learning	It is a strategy that is based on the premise that students can mobilize their competences, enthusiasm and energy to support an organization, institution or community in solving a real problem. This context emerges as an opportunity to learn the contents and develop the competences, leading to a meaningful learning experience (M. Lima & Oakes, 2013).

Buzz Group Discussion	It is a strategy in which small groups (3 people) discuss a particular subject, to produce several ideas about it in a short period. "Buzz" refers to the sound generated by the intensity of group discussion (Renner, 1993).
Case Study	It is a strategy that focuses on the detailed analysis of a real, complex and in-depth situation, which involves a decision-making process. This analysis should allow students to be able to mobilize a set of skills associated with the learning outcomes in which this strategy is inserted (Kaplan, 2014).
Gamification	Use of game design elements in non-playful contexts, to create an environment of involvement similar to that of games, with possibilities of trial and error, to motivate action, promote learning and solve problems. As an example, game design elements include, among others, challenges, scoring schemes, badges, time pressure, collaboration, and achievement (Kapp, 2012; Zichermann & Linder, 2013).
Just-In-Time Teaching	This strategy promotes an intentional link between activities performed outside the classroom period and activities performed in the classroom. It is, therefore, a strategy in which the student's prior knowledge is taken into account in the preparation of the class itself. At first, the teacher launches exercises or warm-up questions, to be answered by the students before the class and whose results allow the teacher to plan the class approach considering the potential difficulties or interests of the students. It is a strategy that can be enhanced with the introduction of technologies (Novak et al., 1999).
One Minute Paper	It is a strategy used for the purpose of formative assessment, in which, at the end of the class, the teacher asks students to individually write about the topic addressed in class, through one or two questions posed by him. The main objective of these questions is to enhance student learning through assessment (assessment for learning). It is also a useful mechanism for getting feedback on lessons and can be used at the end of a block of lessons dedicated to a particular topic (Angelo & Cross, 1993; Light & Cox, 2001).
Peer Instruction	It is a strategy that promotes the involvement of students outside the classroom with texts, viewing multimedia content, answering questions or using other materials. Later, in the classroom, the teacher involves the students in conceptual questions (Concept Tests) related to the material analysed previously before the class. Next, students are expected to learn among peers, i.e., through peer or small group discussions. The teacher has the role of facilitator of the process, being fundamental during feedback and clarification of doubts that the students may present (Mazur, 2013).
Flipped Classroom	It is a pedagogical approach in which the times and spaces inherent to the teaching and learning process are reversed: the exploration of contents is first carried out by students before class (e.g., through readings, video analysis, etc.), in a space that tends to be more individual than in a group. In class, students have the opportunity to interact with the teacher and with each other, fundamentally in a group space, to apply, develop and clarifying the previously explored content. This inversion thus transforms the teaching-learning process into an interactive, dynamic, and personal logic (Bergmann, 2014).
Research-Based Learning	This approach implies that learning is developed from research activities, to promote the creation and development of new knowledge. Learning development is focused on research processes, such as problem identification, the definition of research questions, methodological design, and collection and analysis of information. The type of research will depend on the subject area and learning objectives (Healey et al., 2014; Healey & Jenkins, 2009).
Work-Based Learning	Is the term being used to describe a class of university programs that bring together universities and work organizations to create new learning opportunities in the workplace. Typically, this may include the following types of activities: visits to professional places, networking interaction opportunities, and project-based learning approaches in interaction with external organizations (Boud & Solomon, 2001).

Appendix 2 – Active Learning Mapping Questionnaire

This appendix describes some specific items (translated from Portuguese) of the questionnaire used in this research.

General information

a. Course? [Short text]

b. Program? [List]

c. Year of the course? {1,2,3,4,5}

d. Semester? {1,2}

e. In the last three years, how many training actions related to active learning approaches have you participated in? {0,1,2,3…}

f. If you participated in one or more actions, say which one(s). [Text]

g. In the last three years, how many works have you published in journals and/or conferences in Engineering Education (CISPEE, SEFI, among others)? {0,1,2,3…}

h. If you published one or more works, indicate the journals/conferences in which you published these works. [Text]

Active Learning Approaches

The following link allows for clarification of some of the terms used in this questionnaire (in Portuguese): https://idea.uminho.pt/pt/ideadigital/entradas/Paginas/entrada33.aspx

In this curricular unit, indicate the frequency with which you use the following active learning practices. (Never / Sometimes / Often / Always)

1. Short Active Learning strategies and methods (Quizzes, Think-Pair-Share, One-minute paper...)
2. *Team-Based Learning*
3. *Problem-Based Learning*
4. *Project-Based Learning*
5. *Peer Instruction*
6. *Case Study*
7. *Gamification / Game-Based Learning*
8. *Flipped Classroom*
9. Other: ____

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