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Causes for the Asymmetric Adoption of Active Learning Methodologies in Engineering Education: A Rogers' Theory Perspective*

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Active learning methodologies are educational strategies where students take a proactive role, and where they must meaningfully work and reflect on the competencies of the academic units. More than twelve different active methodologies have been developed in recent years. Selecting one or another usually depends on the available time and physical space, the nature of the academic unit to be learned, or the number of students. But many authors also highlight the comfort level of professors as a key factor to understand the adoption of some active strategies over others. This article aims to study how this "comfort level" affects the adoption of the different active learning methodologies, in engineering education centers, and using the Rogers Diffusion of Innovation theory. A collection of survey questions was conducted among engineering professors at Universidad Politécnica de Madrid and Universidad Alfonso X el Sabio. Responses were based on the Likert scale and statistical methods were used to analyze the collected data. Results confirmed that the relative advantage has the highest positive impact on the adoption rate and observability. However, complexity, the nature of the social system and the type of innovation-decision have a negative impact on the adoption rate. Engineering education centers are suggested to increase the social recognition of active learning adoption to improve the adoption rate.

Keywords: engineering education; Rogers theory; active learning; adoption of innovations; education research; statistical analysis

1. Introduction

Active learning strategies aim to achieve an effective learning environment, so students can take control of their own learning and have a clear feeling of progress [1]. This facilitates learning as students can connect abstract concepts to tangible experiences and allow them to test and experiment with their own conclusions, ideas, and doubts [2]. In general, nowadays most researchers agree that the memorization of packages of academic materials, followed by an evaluation where students must provide close answers extracted from the material, causes a very poor learning [3]. And active learning was proposed as one of the key good practices in higher education thirty years ago [4]. Although the adoption of these methodologies was much slower.

Active learning, on the other hand, is an open door to personalization. Learners must meaningfully work (talk, write, listen, read, . . .) the competencies associated with each academic unit, and they can choose those instruments or mechanisms that better fit their personality, mental structures, or background [5]. In most modern higher education institutions, including those associated with the Bologna Declaration, respect and integration of individual differences and learning styles of students is an essential principle [1].

Currently, more than 12 different educational strategies can be considered active learning, in the context of higher education in engineering [1]. From actions whose implementation is quite simple, flexible, and does not require any special resource (such as Brainstorming), to interventions where immersive environments with specialized infrastructures are needed (such as Simulation). Thus, the active learning methodologies to be integrated in any course are usually considered a function of the number of learners, the available physical space and/or infrastructure, the available time, and the learning objectives or competencies to be achieved [1]. In this context, the educational strategy to be used in any course is a purely technical decision. However, several authors have also identified a relevant but non-technical factor: the comfort level of professors with the different strategies [1, 6].

In fact, informal observations in engineering higher education centers and courses show an asymmetric adoption of active learning methodologies, which cannot be explained just by technical criteria. In the literature, it is even possible to find innovation experiences where the educational context is totally the opposite, but they are implementing the same active learning strategy. The open challenge is to investigate the enablers and barriers that influence the asymmetric adoption rates of the different active learning methodologies, which are

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previously represented by the generic name of "comfort level".

Therefore, this work aims to analyze and understand the factors and attributes that influence the adoption rate of active learning methodologies. For this study we are using the Rogers' Diffusion of Innovation (DOI) theory [7], which exhaustively describes the variables that modify the behavior of users (professors) and their willingness to adopt innovations (new educational strategies, in this case). This theory is used in many different scenarios and has been validated as a successful instrument to study the adoption rate of innovation when the user has the main role, including in higher education scenarios [8].

2. Literature Review

Active learning methodologies have received attention in the last ten years due to their ability to enable personalization and efficiency in learning [1]. However, research analyzes on the adoption of active learning methodologies are mostly descriptive, and they do not go deeper on the causes of the asymmetric adoption rates.

2.1 Active Learning Methodologies and Experiences

Active learning methodologies are any educational strategies where students take a proactive role, and where they must work and reflect meaningfully on the competencies of the academic units [1]. But to be feasible, these methodologies must integrate mechanisms to promote the participation of learners and professors. Interpersonal iterations are one of the instruments to achieve this involvement [9]. In fact, active learning experiences where technologies (such as computer simulations) [62] are the only innovation, tend to report a moderate impact. From the formal point of view, active learning methodologies redefine the information flows among actors in the education context, to construct an understanding ecosystem with students, peers, and professors [69].

Active learning methodologies are typically classified into four groups, depending on how they promote interpersonal collaboration. Namely:

- Individual actions: Creative activities carried out by learners without iteration with other students, such as the one-minute paper [10] (write the answer to a question in two or three minutes) or concept map [11].
- Paired actions: Most of paired actions can be easily adapted to informal small groups, so both groups are difficult to distinguish in a very strict manner. Scenarios or case studies methodologies [12] (where students discuss or analyze a scenario or case provided by professors) are the most extended strategies in engineering education.
- Informal small groups: Learners are organized in groups of three to six people, in a flexible approach. Team-based learning (TBL) [13] is the reference methodology in this group, where students propose solutions through critical thinking to open questions that typically cannot be answered using a closed response. Challenge-based learning (CBL) is a quite similar approach [14]. But panel discussions or collaborative writing are popular methodologies for informal small groups, too.
- Cooperative actions: In cooperative methodologies, all learners work together to address a large project. Problem-based learning or project-based learning (PBL) [15] are quite popular in engineering courses but brainstorming [16] or case-based instruction (CBI) [17] are popular approaches in other educational levels.

However, other customized strategies could also be considered active learning, if they meet the seven principles proposed by Barnes [18]: (1) the activity must be relevant to the learners' concerns; (2) learners must be encouraged to reflect on what they are learning; (3) methods and learning goals must be negotiated between professors and students; (4) students can use different means to achieve learning; (5) students must perform reflective analyzes on complex real-life scenarios; (6) learning actions must be adapted to the needs of every situation; and (7) real-life activities must be mapped into academic activities.

For example, in fluid mechanics, active experiences have been reported with specific instruments (such as Venturi meter) have been reported [64]. As well as other actions based on virtual platforms to acquire Industry 4.0 competencies [65]. However, these ad-hoc techniques cannot be easily replicated. And significant adoption studies (including different organization contexts, academic backgrounds, etc.) are difficult to carry out.

Globally, active learning became a popular issue in the United States around 1980 [6], while in Europe an extensive use of these methodologies was implemented with the Bologna declaration (1999). Therefore, most experiences and studies related to active learning are usually led by American organizations. In 1987, Pennsylvania University provided solid and final evidence of the improvement in student marks when active learning is implemented [19]. While, almost at the same time, the University of Michigan [20] reports the first description of an experience in which active learning methodologies are proven to be preferable to work competencies related to "information analysis", "creativity" or "evaluation". Later, organizations, such as the "Active Learning in Engineering Education (ALE) informal network" (created in 2001) started to promote active learning strategies and introduce novel active methodologies [66].

Initial experiences were based on importing to engineering education, techniques and methodologies well-proved from other fields. For example, role-play actions [67] or debates [68]. However, currently engineering education has defined its own strategies, and cooperative actions (mainly PBL) and small informal groups (CBL, in most cases) are the preferred methodologies to develop new experiences [23]. European Centers such as the Leiden University [21] or Asian institutions like the National Taiwan Normal University [22] stand out for their research nowadays.

Anyway, all the evidence reported only confirms the same knowledge [24]: active learning methodologies improve the students learning, motivation and satisfaction.

2.2 Barriers and Causes for the Asymmetric Adoption Rates

However, review works that performed a comparative analysis of reported experiences have generally found uneven support for the different methodologies and their core components [25]. Columbia University identified very soon the need for professors to be willing to drastically change their methods [26], while Northwestern University professors proposed that the relationship between professors and learners should be fully transformed [27] to be "a dialogue". Professors usually perceived some environmental barriers variables such as the size of the class [6], although the results provided by Wabash college [28] showed that active learning is not affected by the number of students attending. Other authors have reported tensions and organizational conflicts when active learning methods are implemented [63]. Similarly, in other works, professors have reported other similar obstacles [29, 30], such as the increase in the preparation time, the lack of resources and/or materials, and the difficulty to cover all the content in the limited class time when using these methodologies. But all these obstacles, and other similar ones reported by professors, are always related to management and administration.

Only a few sources go deeper and identify some causes for this asymmetric adoption rate, when even administrators are committed. Typically:

- The discomfort and anxiety caused by new methods. Several authors have identified the close relationship between active learning and information technologies as a barrier [31] for those professors who are not used to employing digital tools.
- The limited incentives to change.
- The influence of traditional culture. Where different previous papers [32] report that professors still think lectures are the best instrument to learn, contrary to students who prefer active strategies.
- The perception of the role of professors and their relation to learners. Experiences in different higher education institutions showed how professors feel that they lose control when they employ active learning strategies [33].

Different institutions tried to address these barriers and challenges, but the proposed solutions are always focused on increasing the support of professors. For example, with instructor preparation courses at Kansas State University [34], or with new assistants at Texas A&M University [35]. Other physiological or cultural barriers are not addressed.

Furthermore, these studies are not systematic and may identify some causes or others depending on the predefined questions making up the survey and the topics they address. In general, there is no methodological or theoretical framework that ensures that all possible causes or variables affecting adoption rates are considered. Our paper aims to fill this gap.

2.3 Rogers Theory and Engineering Education

Although different theories to describe innovation diffusion have been reported in recent years, such as "The Two step Flow Theory" [36] (promoted by the University of Twente) or the "Crossing the innovation chasm" model [37], Rogers' Diffusion of Innovation (DOI) [7] theory is the most used and validated in engineering higher education scenarios [38, 39].

In the Rogers' theory [7], five basic variables affect the adoption rate of innovations: ① the communication channel (such as mass media or interpersonal), ② the nature of the social ecosystem (for example, level of interconnections, organigram structure. . .), ③ the type of innovation-decision (optional, collective or authority), ④ the perceived attributes of innovation (relative advantage, compatibility, complexity, trialability and observability) and ⑤ the intensity of the promotion efforts.

Rogers' DOI theory is especially strong when applied to adoption processes where information technologies are present [40]. Rogers' theory has been successfully applied to analyze how Open Educational Resources are adopted by faculties [41], the adoption process of computers as instructional tool in engineering higher education [42], or how eLearning teaching methodologies are diffused along higher education systems [43]. General awareness about engineering education innovation in large geographical demarcations (for example, the entire Unite States) has been studied as well through Rogers' theory [70]. In this context, Rogers' theory can be used to study the perceptions of adopters of tools and methodologies in higher education [44, 45]. Furthermore, professor behavior and relation to active learning methodologies are absorbed by the social and institutional context [46] in Rogers' theory.

3. Methodological and Theoretical Framework

In this research, the five parameters that make up Rogers' DOI theory (including the five perceived attributes of innovation) are used to analyze the adoption rate of active learning methodologies. On the other hand, for this research, the following active learning methodologies were considered: one-minute paper, concept map, case studies, challenge-based learning, brainstorming, collaborative writing, and project-based learning.

In this context, the following hypotheses were formulated:

- H#1. Perceived observability has a positive impact on the adoption rate.
- H#2. Perceived relative advantage has a positive impact on the adoption rate.
- H#3. The nature of old universities (social system) has a negative impact on the adoption rate.
- H#4. The type of innovation-decision (optional) has a negative impact on the adoption rate.
- H#5. Perceived complexity has a negative impact on the adoption rate.

To carry out the research, a collection of in-person survey questions was performed. Professors from the Universidad Politécnica de Madrid and the Universidad Alfonso X el Sabio participated. Twenty-six (26) professors participated. Sixteen were affiliated with the Universidad Politécnica de Madrid and the remaining ten professors were affiliated with the Universidad Alfonso X el Sabio. All of them were professors in computer engineering courses, such as network engineering, data analytics, cybersecurity, or artificial intelligence. Sample size was selected to ensure an experimental error below 10%, for the given significance levels. No personal data was collected at any stage and participants had access to their responses. Responses were fully anonymous.

The survey was composed of three different parts. The first section contained demographic questions. For informative purposes, we asked participants to provide their age range, gender, and their experience in education. Participants were not forced in any manner to provide details they do not feel comfortable revealing. The second section focused on transversal topics related to the university organigram, its cultural or social background, the management strategies, etc. Finally, the third section was divided into seven subsections, one per each active learning methodology to be analyzed. All these subsections followed exactly the same structure. The initial questions were related to how much each active learning methodology is adopted by the participants. The remaining questions addressed why the participant adopted or not the referred methodology. Answers to questions in the second and third sections were used to validate the initial hypotheses.

All questions were close assertions in positive form. Participants answered using the Likert scale, ranging from "Totally disagree" (graded with one point) to "Totally agree" (graded with five points). Participants were allowed to answer with "Do not know" too, skip some questions or response partially to the questions. Because of that, an inhomogeneous number of responses are considered for each item.

Due to the nature of this research, no ethical approval was required. Later processing was performed using MATLAB 2022B software suite. In order to facilitate comparisons and mitigate the impact of the numerical precision, all results are rounded so the last decimal is either zero or five.

The responses to demographic questions were processed first to generate an understanding of the nature and social composition of the participant group. Table 1 shows the results. As can be seen, because of the dominance of men in most engineer-

Table 1. Participants (26): Demographic characteristics

Gender	**Percentage**
Male	73
Female	27
Other	0
Age	**Percentage**
Less than 30	11.5
Between 30 and 40	31
Between 40 and 50	23
Between 50 and 60	27
More than 60	7.5
Year of experience	**Percentage**
Less than 2	7.5
Between 2 and 5	23
Between 5 and 10	11.5
Between 10 and 20	31
More than 20	27

Table 2. Differences in active learning adoption

Age					
	Less than 30	**Between 30 and 40**	**Between 40 and 50**	**Between 50 and 60**	**More than 60**
Less than 30	N/A	NS	NS	NS	NS
Between 30 and 40	NS	N/A	NS	NS	NS
Between 40 and 50	NS	NS	N/A	NS	NS
Between 50 and 60	NS	NS	NS	N/A	NS
More than 60	NS	NS	NS	NS	N/A
Years of experience					
	Less than 2	**Between 2 and 5**	**Between 5 and 10**	**Between 10 and 20**	**More than 20**
Less than 2	N/A	NS	*	*	**
Between 2 and 5	NS	N/A	*	*	***
Between 5 and 10	*	*	N/A	*	*
Between 10 and 20	*	*	*	N/A	*
More than 20	**	***	*	*	N/A

NS not significant; * significant at $p < 0.05$; ** significant at $p < 0.005$; *** significant at $p < 0.001$.

ing fields, the group has a significant percentage of male participants. As this group is approximately equivalent to the global engineering higher education community, no validity threat is detected here.

For each demographic characteristic, categories are mutually exclusive. So, all sub-samples are independent. Besides, all questions in the survey could be independently answered as well. In order to facilitate the discussions and be exhaustive, comparisons are done between all possible pairs of sub-samples. Finally, since the responses (dependent variable) are quantitative and ordered, all further statistical studies can be developed through the Mann-Whitney U test.

4. Results

The first analysis we performed was aimed to discover to what extent the participants are familiar with active learning methodologies (globally) and if there was any correlation or bias to be considered. Mainly, we wanted to analyze whether demographic characteristics (age, experience, or specialty) affect the adoption rate (for example, the perceived attributes of innovation may change with the age). This study was based on the Mann-Whitney U test, so we can analyze whether the differences in responses are systematic and significant. Table 2 shows the results. In addition, to identify groups with an advanced adoption rate, we calculated the aggregated score of every group (in questions related to the use or adoption of active learning methodologies). Table 3 represents the results. Scaling factors are employed to remove the impact of inhomogeneous datasets.

Before any further analysis, it is a key finding how asymmetric the adoption rates of the different active learning methodologies are. Table 4 shows the responses and opinions of the participants. As can be seen, strong asymmetries are reported. In Table 5 we use the Mann-Whitney U test to analyze if these differences are significant or not.

With this study, we first want to investigate the influence of the ''nature of the social system'' on the rate of adoption of active learning (see Table 6), as well as the impact of the ''type of innovation-decision'' (see Table 7).

Table 3. Differences in active learning adoption: aggregated score

Age	**Aggregated score**
Less than 30	121
Between 30 and 40	113
Between 40 and 50	117
Between 50 and 60	109
More than 60	104
Year of experience	**Aggregated score**
Less than 2	136
Between 2 and 5	118
Between 5 and 10	114
Between 10 and 20	103
More than 20	93

Table 4. Responses related to the adoption rates

Question	**Mean**
I employ the one-minute paper methodology very often in my classes.	3.45
I employ the concept map methodology very often in my classes.	3.25
I employ the case studies methodology very often in my classes.	4.55
I employ the challenge-based learning methodology very often in my classes.	2.40
I employ the brainstorming methodology very often in my classes.	4.20
I employ the collaborative writing methodology very often in my classes.	3.90
I employ the project-based learning methodology very often in my classes.	2.75

Table 5. Asymmetric active learning methodologies adoption rates

	One-minute paper	Concept map	Case studies	CBL	Brainstorming	Collaborative writing	PBL
One-minute paper	N/A	NS	*	***	NS	NS	***
Concept map	NS	N/A	**	**	*	*	**
Case studies	*	**	N/A	***	NS	*	***
CBL	***	**	***	N/A	***	**	***
Brainstorming	NS	*	NS	***	N/A	NS	***
Collaborative writing	NS	*	*	**	NS	N/A	**
PBL	***	**	***	***	***	**	N/A

NS not significant; * significant at $p < 0.05$; ** significant at $p < 0.005$; *** significant at $p < 0.001$.

Table 6. Responses related to "social system"

Question	Mean
The structure or organigram of my university facilitates the adoption of new methods.	1.80
I am part of a network through which new methodologies are disseminated.	2.40
My university community facilitates the diffusion of successful experiences and new strategies.	2.15
I am interconnected with other professors to exchange learning experiences.	1.95

Table 7. Responses related to "type of innovation-decision"

'Question	Mean
In my university, decisions on the adoption of new methods are optional	4.20
I have incentives that pushed me to adopt new methodologies	2.20
Active learning methodologies are mandatory in my university	1.85
I feel a pressure to make a conscious decision about adopting or not active learning methodologies.	2.00

Table 8. Responses related to "promotion efforts"

Question	Mean
My institution promotes the one-minute paper in a very intense manner compared to other methodologies.	3.00
My institution promotes the concept map in a very intense manner compared to other methodologies.	3.10
My institution promotes the case studies in a very intense manner compared to other methodologies.	2.95
My institution promotes the challenge-based learning in a very intense manner compared to other methodologies.	3.00
My institution promotes brainstorming in a very intense manner compared to other methodologies.	2.85
My institution promotes the collaborative writing in a very intense manner compared to other methodologies.	3.05
My institution promotes the project-based learning in a very intense manner compared to other methodologies.	3.45

On the other hand, Table 8 shows the intensity of the promotion efforts does not have a significant impact on the asymmetric adoption rate of active learning methodologies.

Finally, we calculate the weighted mean and standard deviation of all the questions related to perceived attributes of innovation. Table 9 shows a selection of most representative questions and responses. In Table 9, the questions are classified into five categories (one for each attribute). To ensure that the proposed questions help us capture the perceptions of the participants about the attributes of innovation, the survey was designed following a strategy and questions similar to those of previous work in the state of the art [41, 57, 58].

As a last step, we must investigate the feasibility of four hypotheses. To do that, we use the Mann-Whitney U test to evaluate a significant correlation between the different variables in the Rogers' theory and the active learning adoption rate. Hypotheses are accepted if the correlation is true for at least 95% of the samples. That means that the p-value must be below 5%. Table 10 shows the results.

5. Findings and Discussions

Active learning methodologies are educational strategies where students take a proactive role, and where they must meaningfully work and reflect on the competencies of the academic units. More than twelve different active methodologies have been developed in recent years. Selecting one or another usually depends on the available time and physical space, the nature of the academic unit to be learned, or the number of students. But many authors also consider other external factors as key elements to understand the adoption of some active strategies over others. This article aims to study the "external factors" and how they affect the adoption of the different active learning methodologies. This study is focused on engineering higher education centers and professors and uses the Rogers' Diffusion of Innovation theory as main reference to build the research methodology. A collection of survey questions was conducted among engineering professors. Responses were based on the Likert scale and statistical methods were employed to analyze the collected data.

Table 9. Responses related to "perceived attributes of innovation"

Attribute	Question	Mean	Methodology
Relative advantage	This methodology helps me to be more effective in class	4.25	One-minute paper
		4.15	Concept map
		4.70	Case studies
		3.85	CBL
		4.15	Brainstorming
		3.95	Collaborative writing
		3.95	PBL
	Using this methodology, I can save effort and enhance my reputation	3.25	One-minute paper
		3.15	Concept map
		4.15	Case studies
		2.75	CBL
		3.65	Brainstorming
		3.55	Collaborative writing
		2.90	PBL
	This methodology helps to improve student learning.	3.65	One-minute paper
		4.00	Concept map
		4.35	Case studies
		2.95	CBL
		4.25	Brainstorming
		4.05	Collaborative writing
		3.05	PBL
Compatibility	This methodology requires a lot of time to be implemented	4.00	One-minute paper
		4.35	Concept map
		4.05	Case studies
		4.55	CBL
		3.65	Brainstorming
		3.90	Collaborative writing
		4.25	PBL
	I'm afraid of the uncontrolled consequences of this methodology	3.90	One-minute paper
		3.70	Concept map
		4.05	Case studies
		4.65	CBL
		3.70	Brainstorming
		3.95	Collaborative writing
		4.45	PBL
	I feel exposed to external opinions and critics when using this methodology	3.80	One-minute paper
		4.05	Concept map
		3.85	Case studies
		4.75	CBL
		3.95	Brainstorming
		3.80	Collaborative writing
		4.90	PBL
Complexity	I find this methodology easy to understand and use	2.75	One-minute paper
		2.95	Concept map
		4.00	Case studies
		4.75	CBL
		2.45	Brainstorming
		3.70	Collaborative writing
		4.65	PBL
Trialability	I would like to experiment with this methodology privately and in a safe environment	4.35	One-minute paper
		4.55	Concept map
		4.55	Case studies
		4.25	CBL
		4.50	Brainstorming
		4.75	Collaborative writing
		4.35	PBL

Table 9. (*Continued*)

Attribute	Question	Mean	Methodology
Observability	I can benefit from previous experiences when using this methodology	3.90	One-minute paper
		4.00	Concept map
		4.55	Case studies
		3.10	CBL
		4.35	Brainstorming
		4.10	Collaborative writing
		3.25	PBL
	I can lose my independence as a professor if I use this strategy	2.75	One-minute paper
		2.90	Concept map
		2.65	Case studies
		2.75	CBL
		2.75	Brainstorming
		2.85	Collaborative writing
		2.55	PBL

Table 10. Hypotheses validation

Hypotheses	Significance
H#1. Perceived observability has a positive impact on the adoption rate	**
H#2. Perceived relative advantage has a positive impact on the adoption rate	***
H#3. The nature of old universities (social system) has a negative impact on the adoption rate	*
H#4. The type of innovation-decision (optional) has a negative impact on the adoption rate	*
H#5. Perceived complexity has a negative impact on the adoption rate	**

NS not significant; * significant at $p < 0.05$; ** significant at $p < 0.005$; *** significant at $p < 0.001$

Regarding the influence of demographic characteristics on the adoption rate (see Table 3), the key finding is that the adoption rate does not depend on age or gender. Previous work confirmed that demographic variables do not influence technology adoption [47, 48]. But in our case, we did report a significant difference, depending on the experience of the participants. But all these factors could be considered part of the "nature of the social system" which is a variable in the Rogers' DOI theory.

In general, reported asymmetries in the adoption rate of the different active methodologies in this study (see Table 4) are compatible with previous work and studies [59], where active learning methodologies based on simple presentations or expositions are used more than strategies requiring a strong commitment or hard implementation efforts. In fact, statistical tests (see Table 5) confirmed the asymmetries, which are consistent with previous results and testimonials [60].

When focusing on each of the variables that impact the adoption rate according to Rogers theory, some relevant findings are reported.

Regarding the "nature of the social system" (see Table 6), most of the respondents agree that the nature of universities does not facilitate the use of active learning strategies. In general, participants report a lack of a structure that could be used to disseminate and learn about new methodologies. Therefore, most of the experiences remain isolated and disconnected. Experienced professors do not work in a network or collaborative environment and tend to be individualistic. Therefore, professionals with short experience are usually more networked and in constant communication with other professors and colleagues. And as they gain more experience and confidence, these interconnections break down. Observations that are consistent with previous research on scientific careers [49]. Because the distribution of professors with different experiences is not homogeneous (see Table 1), this contributes to the asymmetric adoption rate of active learning methodologies.

On of the essential elements that affects the type of innovation-decision in universities is the "organigram". In Table 7 we can see that most educational decisions are optional and individual in most higher education institutions. And this negatively affects the diffusion of active learning methodologies. As most professors do not find any incentive to adopt new methods. This is consistent with the state of the art in higher education governance [50]. In fact, most professors do not feel the need to make a conscious decision. So, in most cases, learning strategies are simply implemented by "inertia". This is the most comfortable decision for most people, as reported in the research literature [51]. This also contributes to the asymmetric adoption rate, as oldest methodologies are adopted as a "tradition", while the latest approaches are not pushed.

On the other hand, participants (see Table 8) do not report any differences in promotion strategies associated with different methodologies. This is fully consistent with previous studies on the same topic [52]. In general, universities and higher education institutions promote the adoption of active learning due to a justification given for better learning [53, 54], some recommendations at the policy level [55], or a general trend [56]. However, the absence of learning theories justifying the adoption of any specific active learning is prevalent, so promotion is transversal and not focused on any particular methodology.

When analyzing the impact of the perceived attributes of innovation (see Table 9), some clear differences arise. Regarding the relative advantage, in general participants agree that all active learning methodologies help engineering professors be more effective in class. But there are clear differences in how benefits and advantages for students are perceived. In general, most innovative methodologies (such as CBL) cause more doubts among faculties (but no negative opinion is gathered). In addition, the personal relative advantage of using active learning methodologies is not homogeneous. Again, most elaborated strategies are perceived as a risk more than as an opportunity, as reported in the state of the art too [59].

However, compatibility analysis is not conclusive. As can be seen, in general, the responses are positive. But in any case, no asymmetric values are detected among the different active learning methodologies. Similarly, questions related to trialability do not show a relevant difference among active learning methodologies. In general, all engineering professors prefer a safe environment for experiments before any further implementation. Although this could be a good recommendation to promote the adoption of active learning, in general, we could conclude that compatibility or trialability do not explain the asymmetric adoption rates.

But complexity shows a clear difference among the different active learning strategies. Responses are, globally, neutral or negative. From this behavior, we could conclude perceived complexity has a negative impact in the adoption rate, causing an asymmetric adoption where complex methodologies are adopted more slowly. Previous authors have also observed this effect in other educational scenarios, for example when implementing Open Educational Resources [41].

Finally, responses show first evidence of a positive impact of observability on adoption rates. We can intuit a positive cycle, where strategies that are already extended and can be shared among professors are adopted more quickly. Other variables, such as teaching independence, do not show a relevant impact. As reported in the state of the art, actions such as classroom observation (some professors observe how other colleagues use active learning strategies) contribute very positively to the adoption of active learning methodologies [61].

Finally, through the Mann-Whitney U test (see Table 10), we can conclude all the initial hypotheses are validated and accepted. The highest significance is obtained for perceived relative advantage (H#2), which shows the highest positive impact on the adoption rate. Followed by observability (H#1). However, complexity (H#5), the nature of the social system (H#3), and the type of innovation-decision (H#4) have a negative impact on the adoption rate.

Taking into account the results, engineering higher education centers are suggested to take two basic actions as a way to reduce the asymmetries in the adoption rates of active learning. On the one hand, promotion efforts should be focused on those methodologies supported by the pedagogic theory, and which face barriers in the natural and spontaneous adoption (because they are perceived as more complex, for example). On the other hand, centers are suggested to increase the social recognition of active learning adoption to improve the adoption rate. The highest impact on adoption rates is caused by the perceived relative advantage. Increasing the benefits and advantages of implementing those active learning methodologies may cause a great impact.

6. Conclusions

This article aims to study how this ‘‘comfort level’’ affects the adoption of the different active learning methodologies, in engineering education centers, and using the Rogers Diffusion of Innovation theory.

All hypotheses (five) are validated. Results confirmed that relative advantage has the highest positive impact in the adoption rate and observability. On the other hand, complexity, the nature of the social system, and the type of innovation-decision have a negative impact in the adoption rate.

Engineering education centers are suggested to increase the social recognition of active learning adoption to improve the adoption rate. As well, strengthen the promotion efforts of those methodologies which face barriers in the natural and spontaneous adoption (because they are perceived as more complex, for example).

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