OmniaScience

Journal of Technology and Science Education
JOTSE, 2022 – 12(3): 551-566 – Online ISSN: 2013-6374 – Print ISSN: 2014-5349
https://doi.org/10.3926/jotse.1696

CHALLENGES, DIFFICULTIES AND BARRIERS FOR ENGINEERING HIGHER EDUCATION

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Received April 2022
Accepted May 2022

Abstract

Higher education in general, and engineering higher education in particular, is constantly under pressure to introduce reforms that improve the employability of graduates. Among the most common claims is the development of a more active and competency-based teaching oriented to the development of professional and personal skills. The university institution responds to these claims, sometimes in a timid way, but others by embarking on great transformation projects. A good example of this is the project to build the European Higher Education Area.

However, the challenge of developing a more active and competency-based teaching faces numerous difficulties and barriers because many of the necessary changes are in sharp contrast with a status quo that has been consolidated over centuries. Difficulties and barriers include a lack of deep understanding (and even lack of acceptance) of some of the implications of the challenges we are facing, the learning of new techniques and tools that are not easy to use or unsuitable organizational structures.

In this paper, we explore the nature of some of the challenges and review the difficulties and barriers most often mentioned by those who dare to try. Anyone who wants to address the challenges or has a responsibility to facilitate changes should be aware of all these difficulties and barriers.

Keywords – Competency-based learning, Active methods, Cooperative learning, Project-based learning, Difficulties, Barriers.

To cite this article:

Valero, M. (2022). Challenges, difficulties and barriers for engineering higher education. *Journal of Technology and Science Education,* 12(3), 551-566. https://doi.org/10.3926/jotse.1696

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1. Introduction

As with many other disciplines, engineering higher education is constantly under pressure to improve the training of graduates who have to build the future.

These pressures sometimes come in the form of recommendations made by international organizations and, sometimes, even in the form of mandatory regulations and guidelines. This is the case, for instance, in Europe, with the construction of the European Higher Education Area (Wächter, 2004) some time ago, that had a strong influence in other areas such as ALC (Latin America and the Caribbean) where Heads of Government declared their intention to work to build, in analogy with the European process, the Common Space for Higher Education UEALC (Bugarin, 2009).

The recommendations, regulations and guidelines usually emphasize aspects such as training oriented towards the development of competencies (not only the acquisition of knowledge), including transversal competences, the use of more active teaching methods, the development of continuous assessment or, in the case of the EHEA, the adoption of the European Credit Transfer System (ECTS), to account for the student effort and not only for the teaching hours. These aspects represent important challenges for the University because some of them have implications that differ significantly from a status quo consolidated over centuries.

The claim for these changes is not only motivated by the necessary adaptation of graduates to the needs of the society that is waiting for them. It is also based on what is known from scientific research about how people learn and what are the most effective methods to facilitate their learning. That knowledge and that abundant scientific research, which have precedents that are already very old (Glassman, 2001), are largely ignored by the university, where we continue using, since many centuries ago, methods whose effectiveness has yet to be demonstrated.

However, thanks to external pressures, and with the support of knowledge about effective teaching, in recent years we are witnessing an explosion of activity in terms of teaching innovation in university education in general and in engineering education in particular. Institutional initiatives are frequent, and individual ones much more, in which the aforementioned challenges are tackled with different degrees of ambition. A good example is the collection of works that are presented in this special issue of the magazine, which contain some of the results of the project (Cano, 2020).

These institutional and individual initiatives often encounter a wide range of difficulties and barriers. From the lack of deep understanding (and even lack of acceptance) of some of the implications of the challenges we are facing to the resistance of the university organizational structures themselves, which for many years have been adapted to the requirements of the scenario that we now intend to change.

This paper aims to be a review of some of the most important challenges facing university engineering education, the implications of these challenges, and the difficulties and barriers that are most frequently mentioned by people who have decided to tackle them, according with the author's experience after more than 20 years using and helping others to use active methods.

The rest of the paper is organized into 5 more sections. In sections 2 and 3 we review the nature of the challenge: a more active and competency-based teaching and learning. In section 4 we review the most important difficulties and barriers encountered by people when facing this challenge. Finally, in section 5 a last argument in favor of changes is proposed, especially intended for those who wonder if the effort is worth it.

2. Competency-Based Teaching and Learning

One of the most important challenges facing university engineering education is to develop an approach more oriented to the development of competencies and not only to the acquisition of knowledge.

This requirement is clearly reflected, for example, in the framework documents of the EHEA. In particular, the Dublin descriptors (Gudeva, Dimova, Daskalovska & Trajkova, 2012).generically state the competencies that students must have developed at the end of their bachelor's, master's or doctorate degrees. Two examples of descriptors corresponding to undergraduate degrees are:

1. can apply their knowledge and understanding in a manner that indicates a professional approach to their work or vocation, and have competences typically demonstrated through devising and sustaining arguments and solving problems within their field of study
2. can communicate information, ideas, problems and solutions to both specialist and non-specialist audiences

An example of a descriptor corresponding to the master level is:

3. can apply their knowledge and understanding, and problem solving abilities in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their field of study

These descriptors have been integrated into the legislation of each of the EHEA countries. In the case of Spain, for instance, the descriptors appear in (BOE, 2007).

Naturally, all universities have had to transfer the generic formulation of descriptors to specific competences depending on their field of study, such as engineering (or even different types of engineering). However, some of the descriptors can be considered generic (or transversal) competences, which correspond to aptitudes and abilities independent of the specific field of study. This is the case of example 2 above.

The challenge of competency-based teaching and learning has reached the teachers' table, who have seen their work become a little more complicated. For example, many have had real headaches to fill in the new subject guides, in which it is necessary to specify the competencies to be developed, differentiating between basic, general, specific, transversal, instrumental, etc. In quite a few cases you can find someone in the department who has specialized in filling in these sections of the subject guides so that the controls established by the academic direction are easily passed.

Probably it is not an exaggeration to say that the competences often remain in the subject guides without significantly affecting the development of the subjects. This is so because addressing in a rigorous way the challenge of competency-based teaching and learning puts us directly in front of many of the difficulties and barriers that will be described in more detail in section 4, including difficult changes in beliefs about our role as teachers, learning new strategies and tools (some of them not easy to learn), absence of the necessary levels of coordination or organizational structures optimized for previous models but not for new challenges.

In any case, the challenge is still there, waiting for an adequate and professional response from us. The key questions are:

- Can we clearly and precisely describe what our students will be able to do when they pass our course?
- Can we formulate more ambitious competencies than writing definitions or solving stereotypical exercises with pencil and paper in a limited time (a couple of hours)?
- Can we design the most appropriate activities for our students to exercise these skills throughout the course?
- Can we design the most appropriate instruments to verify that students have acquired these skills?

Ultimately, it is about being ambitious and also consistent (what in other more technical contexts is called constructive alignment (Biggs, 2014).

The issue of competency-based teaching and learning has also risen two very passionate but somewhat pointless debates.

On the one hand, many point out a tension between competencies and content, because competency-based teaching should to be at the cost of a reduction in content, a very painful issue in academic circles. This is true in part, since, for instance, if you have to dedicate some time in class for students to make their oral presentations to practice communication skills, you will have to reduce the syllabus to free up a portion of class time. Who can deny that?

On the other hand, it has also been argued that an orientation to the development of competencies (many of them professional, especially in the field of engineering) is putting the university at the service of what

the productive sector needs at all times. And from there you quickly come to the accusation of commercialization of the university.

These debates are exciting (and exhausting). However the decision has already been made. The authorities have already enacted mandatory laws that tell us that at the university we must also spend time for students to develop competences (including transversal ones). And we will have to do it if we want to be respectful of laws and regulations.

3. Active Learning

The claim for teaching that stimulates active learning occupies also a prominent position in the challenge palette.

The term active learning is a little bit confusing, since when we talk about active learning, it seems as if there is learning that is not active. That is not like that. Learning is always active to some extent (some neurons must move in order for learning to occur).

When we talk about active learning, we mean a situation in which students do more than just take notes. In fact, the most accepted definitions of active learning don't say much more than that. For example, this is the definition of Bonwell and Eison, who are two of the most recognized authors on the subject (Bonwell & Eison, 1991):

> "In active learning, students participate in the process and students participate when they are doing something besides passively listening."

However, this definition is missing two elements that constitute the most important challenges of active learning:

Active ALL

Active in and OUT of class

We all have a particularly active student in class. If you say "any questions?" he is the first to raise his hand. If you ask for volunteers to solve the exercise on the blackboard, there he is. And if he does not come out, he will surely intervene in the discussion. Sometimes you are lucky and there are several. In fact, it is enough that you have 4 or 5 active students to give yourself the illusion that your classes are especially active. But what about the others? Most have probably been waiting for you to announce that the solution on the blackboard is the correct one, at which point they will pick up the pen to write down in their notebook the announced solution (or they will pick up their mobile to take a photo). Until that moment comes, they have had time for relaxation and perhaps for thoughts outside the subject. The challenge is, therefore, to ensure that everyone is active in class and not just some (or many).

In addition, they must not only be active in class but also outside, according to the predetermined hours of dedication. We have always expected our students to spend time outside of class on our subjects. But often we haven't done much more than that: wait. An aspiration, a desire often unsatisfied, which, by the way, has not prevented the course from developing as planned.

The ECTS system poses this second challenge very clearly in front of us: ensuring that students are active during all the hours corresponding to the ECTS of the subject (25 hours per ECTS), many of which are outside of class. In fact, when we give a student a bachelor's degree we are certifying that he has devoted 6000 hours to studying the subject (if the degree is 4 years long). That is what his certificate of studies in the framework of the EHEA says.

Is it true that students dedicated all those hours? And if this is not the case (which many of us suspect), how do you make it so? That is the second challenge of active learning.

Cooperative learning techniques help us face the two challenges of active learning (all active, in and out of class). In addition, they allow us to tackle the challenge of helping our students developing some of the transversal competences. Let's look at some examples.

3.1. Informal Cooperative Learning

After a short presentation (no more than 20 minutes), propose a task to your students to do in small groups (2 or 3) with the classmates who are sitting closer. The task can be to prepare a question together about what has just been explained, or to answer together to a question asked by the teacher, or to exchange the notes they have taken and comment on the differences. This task does not have to take more than 3 or 4 minutes and will help them regain their attention and use that content soon. This is informal cooperative learning (Johnson, Johnson & Smith, 1984). It is cooperative learning because students cooperate in small groups to perform a task and it is informal because no more formalities are necessary. You just have to define the task and give them the necessary time to do it. This is a good example of a situation in which all students are active, without exception, but only 3 or 4 minutes.

3.2. The Jigsaw Puzzle

A more ambitious cooperative learning format is the classic Aronson jigsaw puzzle (Aronson, Blaney, Stephin, Sikes & Snapp, 1978). In this case, the material to be learned is organized into three blocks that can be studied independently. The students are organized into teams of 3 in such a way that each member of the team takes responsibility for learning one of the blocks. After a period of time for individual study, they will participate in a meeting of experts in which they will be able to share their doubts about the content of that block with students from other teams who have studied the same block. Finally, students will meet their teammates to share what they have learned independently.

In its most modest version, a jigsaw puzzle can occupy a class session of 2 hours (15 minutes for individual study, 20 minutes for expert meeting, 30 minutes for sharing and the rest for some evaluation task). Again, it is an example of a situation in which all students will be active, because they will not be able to escape without participating. In addition, some of the transversal skills begin to come into play in the activity, such as the ability to synthesize orally in a short time what has been learned (a skill that will be useful in their jobs when someone new joins the team and needs to be updated quickly on the status of the project).

The jigsaw puzzle can be presented in more ambitious formats. Imagine, for example, a puzzle in which individual study requires several hours of work, which each student dedicates outside of class. The next class session begins directly with the expert meeting. The sharing meeting with teammates can be planned for the next class session, so that each student has time to prepare at home a formal presentation of what they have learned. Finally, after the sharing, each team has to prepare a joint result in which they must relate the contents of the three independent blocks, for which they will have a deadline and will have to use part of the time outside of class again.

In this extended puzzle, we are addressing the challenge of getting students to use their time outside of class effectively (according to the amount of ECTS) and practicing skills such as communication or organization of teamwork, as well as in attitudinal aspects such as commitment to the team and the responsibility to carry out the assigned tasks on time.

3.3. Project Based Learning

In its most ambitious version, cooperative learning adopts the project-based learning format (Kokotsaki, Menzies & Wiggins, 2016) or other close modalities such as problem-based learning (Boud & Feletti 1997), the case method (Hammond, 1980) or service-based learning (Felten & Clayton, 2011).

In the particular case of project-based learning (PBL), which is especially suitable in the case of engineering education, the task of the team is to develop a product, which is ideally ambitious, realistic,

complex and multidisciplinary, acquiring along the way the necessary knowledge for the success. In this case, the activity can last several weeks (a minimum of 6) so that the teams have the opportunity to develop several versions of the product and receive, for each of them, the appropriate feedback from the teacher that will allow them improve the product in its next version.

There are many studies that indicate that students in a well-planned PBL scenario are more motivated, acquire a deeper learning and a higher level of competence, use regularly the time outside of class and exercise important skills such as teamwork, communication or autonomous learning (Thomas, 2000).

4. Difficulties and Barriers

Much more can be said about the nature of the challenges that engineering higher education must face, and about the most appropriate methods and techniques to address them. However, the focus on this paper is on the difficulties and barriers encountered by teachers these challenges.

The difficulties and barriers are many and diverse. Some of them have to do with a deep change in the perception of our role as teachers. Some others have to do with the learning of new techniques and methods that are not easy to use. And some more have to do with the resistance of the institution to accommodate changes that are in sharp contrast with the status quo, strongly established for centuries. Anyone who wants to address the challenges or has a responsibility to facilitate changes should be aware of all these difficulties and barriers.

4.1. Philosophical Transition

Many of the most important difficulties have to do with the conflict that occurs between the principles and strategies described in previous sections and our deepest beliefs about our role as teachers, well founded on years of experience. These are conflicts that can only be resolved by making the appropriate adjustments in our beliefs. Let's review some examples of those conflicts. In some cases, observations are provided to help in this philosophical transition.

4.1.1. The Order of Things

Some of the strategies presented, such as PBL, are based on assigning a task to students when they do not yet have all the necessary knowledge to carry it out, so that such knowledge will be acquired along the way. This is in sharp contrast to the classical approach according to which theory is first studied and then its practical application is worked on. Our study plans are organized like this. In the first-years courses there are the subjects that provide the theoretical basis so that in last-years courses the practical applications can be addressed. It is not easy to accept that things can be done the other way around, starting from application cases.

To help in this adjustment, it is convenient to remember that throughout their lives it is usual for people to face practical problems without even having all the necessary theoretical knowledge. It is only within the academic world that things work the other way around, because we strive to put theory before practice.

4.1.2. The Tyranny of the Syllabus

The obligation to cover the syllabus of the subject is often presented as a difficulty in adopting active methods. On the one hand, it seems that if we do not explain the contents on the backboard, we are not doing our job. In fact, in some places there are some absurd implicit rules such as: "If something has not been explained in class, it cannot appear in the exam." This makes many colleagues uncomfortable using methods in which students have to learn things on their own, since not all the contents will be explained in class.

On the other hand, when using some active methods, such as PBL, it is evident and explicit that not all students will learn the same. For example, if in a project we accept that each member of the team specializes in a part of the contents (which we should not only accept but also encourage so that the team

is really powerful), we are normalizing the fact that not all students will learn the same and that some are even going to learn very little about some parts of the syllabus. This can be hard to accept.

Actually, this is not a new question, because when we pass students with a grade of 5 (out of 10) we are accepting that they pass the subject even if they have not acquired half of the syllabus, which, by the way, will be a cause for disgust for the teachers of the following subjects, who have organized their activities under the (erroneous) assumption that the students they will receive have learn the complete syllabus of the preceding subjects.

4.1.3. This is Going to Hurt Bright Students

It is often argued that active methodologies (especially cooperative learning) may help students with difficulties, but harm the brightest ones. This is especially true if the essential principles of cooperative learning are properly applied. For example, it is essential that there is positive interdependence in the cooperative learning task, that is, that the success of each student depends in part on their teammates doing their part of the work as well (Felder & Brent, 2007). The existence of positive interdependence implies that a student who, in a traditional setting, would have obtained the highest grade in an individual exam, may be adversely affected by the performance of one of his teammates, which will be the cause of bitter complaints, especially if students couldn't even choose their teammates.

On the basis of this circumstance, it is argued then that brilliant students will not be able to obtain the best grades, which they will need to qualify for scholarships or awards.

Stated in those terms, it is evident that the complaint is well founded. But it is also evident that the argument refers to a certain type of brilliance, to be demonstrated in the particular scenario of an exam, where students must answer a set of stereotyped questions in a short period of time. We are not going to question the importance of that kind of brilliance (although we could). The important thing is to note that there are other kinds of skills and talents and that other students need an opportunity to bring them out. There are students who do not have the talent to respond well to exam questions, but do have the talent to get the team to stay together and with high morale, or the talent to clearly communicate their ideas in public. Aren't those talents important too? When will those students have their chance to show them off?

4.1.4. ECTS Dedication

Students taking a 6 ECTS subject (a common size in many study plans) must dedicate a total of 150 hours to working on the contents of that subject. It is usual that no more than 60 of them are class hours. The rest correspond to hours of dedication outside of class. If a student passes the subject with a grade of 10 we are accrediting that he has dedicated 150 hours and that in that time he has done an excellent job. If the student passed the subject with a grade of 5, we are accrediting that he dedicated 150 hours but his work was not so excellent. The important thing is that both students have dedicated 150 hours, at least if we accept the real meaning of the ECTS system.

Naturally, this approach is in sharp contrast to the more traditional scheme in which a student must spend whatever time is necessary to achieve the learning objectives. The most gifted students will need less time (probably much less than those 150 hours) than the less gifted students will need more. Why insist that everyone, both gifted and less gifted students, dedicate the same 150 hours?

Both approaches are equally valid. In approach A we fix some learning objectives and students try to achieve them with the least possible effort (although many will recognize that the "law of least effort" is not very appreciated in the world of academia). In approach B we fix a dedication time and assess what students are capable of achieving in that time. In the cycling world we find also these two approaches. In the Tour de France, we have some stages that are individual time-trial. The distance (the objective) is set and it is a matter of covering it in the shortest time. But the hour record specialty is also very appreciated,

where the time is fixed and it is about travelling the greatest distance in that time. Is one of these modalities better than the other?

The important issue is that if we accept the concept of ECTS then we have to accept approach B. It is what has been chosen as the context of the EHEA in which we have agreed to participate. On the other hand, given the choice, one would say that approach B seems more formative because it is what our students will find outside. Most will have to dedicate a fixed weekly time to their work (perhaps 37.5 hours) and do their best in that time to get the best salary.

4.1.5. Do We Have to Teach Them This?

This is one of the most common concerns of teachers who, many times without having been able to avoid it, have been committed to helping their students in the exercise of skills and competences outside their field of knowledge. I am good at computer architecture, but am I the best person to teach my students the skill of teamwork? Shouldn't there be experts in these skills in this school?

This is a reasonable claim but it does not lead to any practical and realistic solution, because no university is going to create the department of teamwork, or the department of autonomous learning. So, there is going to be no choice but to accept that although we are not the best people to teach transversal skills, those people are not here and we are.

To this claim regarding transversal competences, another is frequently added. There are many who claim that students should already possess these transversal competences upon entering university. They should already be able to learn autonomously, write correctly and interact with their fellow group members in a positive and effective way. Surely the teachers of the pre-university educational levels are doing their best to make it so. But they will not be able to do enough and we will have to give them the relief in the university. In fact, we are talking about skills that can take us a lifetime to acquire at their highest levels of competence. It is not difficult to find seminars for senior managers (surely with exceptional qualifications in the past) to help them improve their leadership or communication skills. In any case, this discussion is now closed. All university institutions are already committed, sometimes by law, to the development of transversal skills in their students.

The questions to be answered now are: can we reorganize our subject so that students have to do, for example, an oral presentation? Can we give them guidelines and criteria on what a good oral presentation looks like? Can we give them examples of good and bad oral presentations? And finally, after attending their presentation, can we give them feedback on what we liked and what they can improve in the future, according to the criteria previously set? This is not out of our reach as teachers. At the University we do much more difficult things than that.

4.2. Learning New Tools Outside of Our Comfort Zone

The challenges we are talking about require not only an adjustment in our teaching beliefs and philosophies, as has been shown in the previous section. They also require the learning of new techniques and new tools, many of them far from easy. That is a second source of difficulties.

Now we are no longer going to class to teach the lesson in an orderly manner and to answer the (few) questions that our students will ask at the end, or to take a student to the blackboard so that he is the one who solves the exercise in front of all his classmates. Now we are going to class, for example, to give the instructions for the next phase of the project, to briefly interview each of the groups and give them feedback on their latest deliveries, which is a task that can be difficult to do due to the constant interruptions of groups that request our help to solve their difficulties. And when we return to our office it is not to finish the Power Point slides that we will use in the next class but to review the new deliveries of the course in order to be able to give the corresponding feedback as soon as possible. Being effective and efficient in these new tasks requires learning that is not always easy and fast. Here are three examples of skills that are needed and often appears in the top positions of teachers' lists of concerns.

4.2.1. Conflict Management

Some of the difficulties students face when using cooperative learning methods do not have to do with understanding the course content but with very different aspects, such as team conflict. Having accepted the responsibility of helping them in that facet of their training as well, the immediate question is: How do we do it? What do we have to learn to be effective in helping them? What resources do we have available?

Fortunately, regarding transversal skills, there are many people who have worried about it before and, therefore, it will not be difficult to gather materials and criteria. For example, just write in google: "how to deal with Hitchhikers and Couch Potatoes" to already have a first information that can help us give our students guidelines to face this type of conflict when working in teams (Oakley, Felder, Brent & Elhajj, 2004).

4.2.2. Frequent and Timely Feedback

Offering frequent and timely feedback is an essential ingredient of quality teaching, regardless of the teaching method used. However, it is even more necessary when students exercise high doses of autonomy, as may be the case, for example, when using PBL. It is not uncommon in this context that students have to learn things that they then have to explain to their teammates. Doubts will assail them: have I understood the material correctly? Couldn't someone tell me if I'm doing okay or not?

If feedback has to be frequent and timely, then it will occupy a significant part of our time and it will be a priority task that does not allow for delays. This is going to be especially difficult to manage if we have a lot of students in class. In this context, we need to learn self-evaluation or peer evaluation techniques (Boud, Cohen & Sampson 1999) which will help us to involve students in this feedback task, in addition to helping them develop interesting skills. And we will also have to learn to be efficient in managing the feedback process, distinguishing between deliveries that require little processing time from those that require a more in-depth analysis. That learning process takes time. For example, in our department we have recently learned that if, in addition to requesting the new version of the software project that our students deliver every week, we ask them for an explanatory video of no more than 3 minutes showing the correct operation of the code, we can be much more efficient identifying the aspects to be included in our feedback for each group in the next session.

4.2.3. Tools to Produce Quality Content and Free Up Class Hours

The adoption of cooperative learning, which require the use of class time for teamwork, and which are frequently accompanied by high doses of self-learning, requires the development of support materials, if they do not exist.

Most universities offer services to help in the preparation of high-quality learning materials, such as video production. But frequently financial support is required to use these services and the processes are often not fast enough to produce the material from one week to the next, which is sometimes necessary.

Fortunately, the production of videos quickly and with sufficient quality is within the reach of all teachers. There are many free computer video and audio capture tools. If one is not especially demanding with the quality of the final result, the effort is not much greater than making a click to start the recording and another click to finish. But in any case, it is necessary to learn to use these tools.

In fact, as a result of the need to teach classes online during the COVID-19 pandemic, many teachers who were reluctant in the past to record their classes on video now have them recorded because their students asked them to (just a mouse click before starting the presentation). Surely these recordings are not high-quality materials, but there they are. Will these teachers explain the lesson again in class, being it recorded on a video? Wouldn't this be the ideal opportunity to go one step further and get closer to the flipped classroom (Alvarez, 2011), in which students study the material at home and work with their peers in class?

4.3. A Lot of Energy to Start

The most ambitious and potentially transformative methods, such as PBL, require a significant start-up effort. Even the smallest PBL activity which include the essential ingredients, requires a deep transformation of at least six weeks of the subject activity plan (Valero & Calviño, 2021). This is so because students in a PBL activity must have time to acquire the knowledge involved and develop each of the different versions planned for the project (at least two). Moreover, teachers should have time to review students work and give them the necessary feedback so subsequent versions of the project products can be improved.

So, teaches have to gather a lot of energy to take the first step, even if this first step is modest. This is undoubtedly a difficulty that cannot be ignored and that makes many teachers think about it a lot before trying it.

On the other hand, it must be said that before undertaking ambitious challenges, it is advisable to try more modest strategies, lowering our expectations accordingly. For example, before embarking on the PBL adventure, it is a good idea to experience activities such as the modest puzzle described in the section 3.1. To do this, it is only necessary to prepare a set of 3 materials that the students are going to study independently in class and perhaps some material to do some kind of evaluation at the end of the activity.

In teaching innovation, it is a good idea to tackle ambitious challenges on the basis of small previous successes. The worst scenario is the one that occurs when teachers without previous experience, motivated by the potential of methods such as PBL and by the idea of facing ambitious challenges that involve a large part of the teaching staff, launch large projects that require the efforts of many and that derail when the first difficulties arrive, the members lacking the experience that they should have acquired before with more modest activities.

4.4. Emotional Instability for Teachers

Incorporating active methods is often a traumatic process for teachers. In our experience, this process has, to a greater or lesser extent, the following phases:

Denial: "These innovations are fine, but they can't work in my subject, or with my students."

> In the years that we have been working on these issues, we have heard this statement from teachers of all kinds of disciplines.

Acceptance: "The academic leaders insist. Let's give it a chance. After all, the results we have now are not especially good."

> The truth is that the current situation is more conducive to teaching innovation than a few years ago. More and more teachers are willing to try.

Enthusiasm: "Wow! I've never seen them so active!"

> When you put the students to do things in class (for example, discuss the decisions to be made in the project) the first thing that is observed is that the activity increases. When we ask students to be quiet and listen to our explanations, they seem somewhat passive to us. So far, nothing particularly surprising.

Disappointment: "You should see the atrocities they do! This method is a disaster!"

> When students do things, they make mistakes. In fact, it is necessary to make mistakes to learn. When using active methods students make mistakes in class in front of their teachers. It is not necessary to wait for the final exam to realize that things are not going well. It is not a problem with the method. On the contrary, the method reveals the difficulties of learning, and gives us an opportunity to intervene in the process in time.

Indifference: "Well, the truth is that they are still there, working. And the results are no worse than before."

> The reduction in class absenteeism is one of the first things to be observed when using active methods. This, sooner or later, leads to better results than before (it can hardly be worse).

Let's get to work: "The truth is that now I have much clearer where the difficulties are in my subject, and I know which materials are not working (I have been seeing it since the first day of class). I'm going to see if I improve a little bit every semester."

> This is a critical moment. If we manage to enter into a process of continuous improvement, based on objective data obtained during the course, in a short time the results can be significantly improved.

Return to enthusiasm: "I never believed they were capable of doing something like that!"

> If we give them a chance, most of the students end up surprising us (positively).

Our experience is that one of the most important difficulties when using active methods (especially PBL) is to deal every day with student's mistakes and disorientation. Teachers must be very clear that all this is necessary for learning to take place. We know some teachers (not many) who have not been able to resist that situation and have returned to the more comfortable terrain of traditional methods, where everything seems to work fine.

4.5. A trauma for the Students Too

The students may also experience active learning methods in a traumatic way, especially if they perceive the experience as something isolated, within a course in which most of the subjects use more traditional methods. That will, for sure, be the situation of many teachers who dare to take the step. In this case, the process of trauma for students can have the following phases, adapted from (Felder, 1995):

Shock and denial: "I can't believe it. Do we have to do group work and the teacher is not going to explain the theory in class before we face the exercises? The teacher cannot be serious."

> At first, the students hope that some resistance will be enough for everything to return to its normal course.

Strong emotion: "I can't do it. I'd better drop out of the course and I'll try next semester" or "He can't do this to us. Let's complain to the school director!"

> It is convenient that the change initiatives have the support of the school director and that he is prepared for the visit of angry students.

Resistance and abandonment: "I am not going to play this game. I don't care if I fail the subject."

Surrender and acceptance: "OK, it seems stupid to me but I have no other choice. I guess I have to give it a try."

Struggle and exploration: "Those classmates seem to be progressing. Maybe I should try harder or try different things to make it work for me too."

> This is a critical moment, when the students who are most resistant perceive that other classmates have entered the game and begin to progress. Teachers can learn a lot about how to quickly project in class the image that the majority are already entering the game, to overcome the resistance of the most reluctant as soon as possible.

Return of confidence: "Hey, it seems that I am controlling the situation. I think things are starting to work."

Integration and success: "YES! I have succeeded. Now I don't understand why I had so many difficulties and hit at the beginning."

> Indeed, one of the most grateful moments is usually, at the end of the course, when a student approaches and asks you: "Do you think that what we have done could be sold?" This rarely happens when the most ambitious task for students is to answer a difficult exam.

It must be taken into account that in a four-month long subject, the activity can end right in the middle of the trauma process, at the time of greatest resistance or frustration. For this reason, it is very important to carry out a vertical coordination work in the study plan, in such a way that subsequent subjects continue to insist on the active methods, and can thus reap the fruits of what was sown in previous subjects.

4.6. Lack of Coordination Skills

Some of the challenges we have on the table will require high doses of coordination, which is often lacking.

Our ability to coordinate is beyond question. There is high coordination in our research or technology transfer projects in which various research groups and companies from different countries participate, tackling ambitious challenges together. Without a doubt, we are able to coordinate with others.

However, in the teaching area we have had to coordinate little. That is why our skills in this area are scarce. Coordination has often been limited to clearly marking the boundaries between subjects when deciding on the study plan, or to setting an examination schedule in which tests for different subjects are sufficiently separated in time.

Now we will have to coordinate for other things as well. And some will be more difficult. For example, if we want to do a good job developing the communication skills of our students, the teachers involved in the different subjects of the curriculum committed to this skill will have to agree on the quality criteria of a good oral presentation. They will have to agree on which criteria should be emphasizes during the first, second or third year. They should be coordinated to ensure that all students make at least three oral presentations throughout the curriculum. And if they want to be excellent, they will have to organize themselves to exchange data on the shortcomings of each of the student when doing oral presentations, so that they can be efficient helping them to overcome these shortcomings.

These are not coordination exercises beyond our possibilities. But it is not part of our habits today and it does not seem that many steps are being taken in the right direction

In fact, the absence of coordination at the levels described is often pointed out as one of the most important difficulties. In some cases, it becomes the perfect excuse not to move.

It is fair to demand that the institution provides the means for this coordination, but it is also true that the teaching staff must do preparatory work before the coordinator arrives. If an orchestra is required to play a symphony, it is fair that the musicians demand a conductor. But it is important that when the conductor arrives, he finds musicians who know how to play their instrument and who have even practiced doing duets and trios.

Lack of coordination is a problem but it cannot be an excuse for not taking the first steps in putting these methods and tools into practice, first individually in our subject and then in small coordination exercises with other subjects, which do not need a coordinator to come.

4.7. Institutional Barriers

An important part of the difficulties and barriers perceived by teachers should be attributed to the institution itself, which, despite urging us to face the challenges, does not seem to be agile in changing the scenario to facilitate our efforts. Let us look at some examples.

4.7.1. Seemingly Hostile Regulations

In conversations about the viability of applying active methods it is common to listen someone saying something like: "I can't do that at my university because the academic regulations would prevent it." For example, when arguing that students should not be able to pass the course if they do not dedicate the hours corresponding to the ECTS (or in other words, if they do not make on time all the deliveries throughout the course) it is usually pointed out that, although desirable, this is not possible because the academic regulations indicate that all students have the right to pass the subject in a final exam.

It is true that academic regulations, which have been renewed in recent years with the aim of stimulating and facilitating changes, are probably not achieving their objective because they have not been ambitious enough. For example, assessment regulations continue to focus on regulating with millimeter precision the summative assessment processes (how to determine grades) but they say little, and frequently nothing, about how formative assessment should be to guarantee that students receive frequent and timely feedback.

However, it must also be said that regulations often have elements (sometimes the fine print) which can facilitate the introduction of active methods. For example, at the Universitat Politècnica de Catalunya, where the author is working, the evaluation regulation indicate that a student's assessment may be conditional on carrying out the practical tasks that have been established in the teaching guide. This remark is enough for us to establish a basic requirement in our courses: to pass the subject, it is necessary to complete at least 80% of the course deliveries on time, thus creating the basis to guarantee dedication to the subject, according to ECTS.

4.7.2. Inadequate Physical Spaces

The campuses are still full of classrooms set up in such a way that it is clear what is going to happen in them: one person will go up to the stage to explain things on the blackboard and many others will sit looking at the blackboard to listen to him and take notes. This scenario does not invite the use of active methods.

It is true that even the most hostile classroom setting does not have to prevent the teacher from organizing some forms of group tasks. You only need your students to talk to their closer classmates. It is also true that little by little the typical shovel chairs screwed to the ground are being replaced by tables and chairs that can be moved and that facilitate the interaction of students with each other.

However, the institution has very internalized the role of the teacher as someone that communicates contents and it will cost a lot to change this. We have had a good example of this recently, as a consequence of the COVID-19 emergency. Universities have invested heavily in technology (cameras and microphones) to create hybrid classrooms in which the teacher can continue teaching the lesson, with half of the students in class and the other half at home, following the class online. It is still curious that technology, which in any other profession is changing the way professionals do their work, in the case of university teaching it is being used so that teachers do not have to change at all.

4.7.3. Inadequate Teacher Evaluation Mechanisms

Another major barrier to change is the existence of a teacher evaluation system that does not seem to sufficiently value the efforts made in teaching innovation. At least that is how it is perceived by a large part of the teaching staff. Implementing active teaching methods, devoting more time to maintaining a good feedback system, preparing teaching materials or making superior coordination efforts such as those described in previous sections do not seem to be tasks as meritorious as accumulating publications in journals with a high impact factor, in the eyes of the commissions that must make decisions on stabilization or promotion.

The fundamental reason for this situation, which is common in many universities around the world, is the coexistence of a teacher evaluation system based on low-demanding criteria with a much more demanding

research evaluation system. It is not easy to publish in a journal with a high impact factor because they are very selective. However, it is not particularly difficult to obtain an excellent rating in the teacher quality evaluation system of the majority of universities. For example, in Spain, where the DOCENTIA program for teacher evaluation (ANECA, 2021) has been developed for years, it is not surprising that more than 75% of the teachers evaluated every year obtain a very satisfactory or excellent qualification. It might seem that this is a result of the fact that most of the teachers actually do an excellent teaching job, but in reality it is a result of the fact that the criteria are not excessively demanding and it turns out that teachers who incorporate active methods, prepare abundant materials , assign ambitious projects, maintain a good feedback system or make their students practice transversal skill receive the same qualification than teachers who simply master the contents they teach, explain it well and maintain their teaching guide updated (and who can spend much more time preparing papers for research journals).

Since all teachers have legitimate aspirations to stabilize and promote ourselves, this is undoubtedly one of the main barriers to the extension of active methods and more ambitious reforms. Therefore, it is urgent to review the criteria used in teacher evaluation systems.

4.7.4. Inadequate Organization of Departments and Study Plans

University faculty is frequently organized into departments according to areas of knowledge (departments of mathematics, physics, computing, economics, etc.). In some universities we can even find the building for mathematicians or the building for physicists.

This organization undoubtedly has some advantages (for instance, shared services such as library or research labs), but it is not the most appropriate one if you want to create a scenario in which teaching is multidisciplinary. Usually in universities with this type of departmental organization, the study plans are made up of a good number of subjects with few credits and with contents directly related to the knowledge area of the departments to which each subject has been assigned (Mathematics I, Mathematics II, Physics III , Computer programming IV, etc.). How do we create in study plans like these scenarios in which multidisciplinary projects can be developed, integrating knowledge from different areas, as is usual in the engineering world, and with enough time for students to practice transversal skills?

Study plans in which teaching by multidisciplinary projects is the base model have large subjects (for example, two subjects of 15 ECTS each in every semester) and naturally different departments collaborate in the teaching of each subject (Kjersdam, 1994). However, despite the claim for multidisciplinary teaching based on competencies and after an enormous effort to redefine thousands of undergraduate and master's study plans in the process of adapting to the EHEA, the vast majority of study plans have come out again as always (a large amount of small uni-disciplinary subjects) , perhaps because the study plan design commissions were made up of representatives from different departments, who attended the meetings with the mission of getting a good number of subjects for their department, where they would receive honors when coming back.

It is certainly possible to combat this situation, eliminating the boundaries between subjects. For example, there should not be too many impediments for three subjects (physics, mathematics and computer science) to come together to form a block (for example, of 18 ECTS), indivisible for the purposes of student enrollment. The teachers involved, working as a team, can now propose an interdisciplinary project that covers the three areas of knowledge (for example, carry out a simulation of the aerodynamic behavior of the profile of an airplane wing), with enough space and time to practice transversal competences. To do something like this, it is enough for the academic direction to accept the possible political cost of this decision (surely initially the students would resist) and for the teachers involved to accept the challenge of coordinating their efforts with colleagues from other departments, something that may not be easy if there are dark histories from the past, related to bitter arguments when they had to distribute the subjects of new study plans among their departments.

5. Conclusions

In this paper we have reviewed the most important challenges facing university engineering education (a claim for a more active competency-based teaching and learning). We have also seen that the difficulties and barriers that we encounter when facing these challenges are many and of a very diverse nature. Despite this, many teachers are trying, sometimes individually and sometimes as part of a more ambitious institutional project. Perhaps reading this paper can encourage others to try as well.

But it is also possible that the enumeration of all these difficulties and barriers may represent a brake for some, who may wonder: is it really worth all that effort? Are we now doing so bad? It is time then for one last argument in favor of change due to these arguments:

What I personally value the most since I have been using active methods, and especially PBL, is that now my students seem like better people to me.

Before changing to active methods, in addition to explaining the lessons to my students, I gave them tests to see if they did well. And while grading their answers, I became a "mistake hunter." It is very sad to dedicate yourself to catch other people's mistakes. Each new mistake inevitably conditions, for the worse, the opinion that you are developing of your students, to end up convinced that they will not achieve great things.

When you use PBL things are very different, because it is no longer about catching the mistakes that students make, but about discovering what they are capable of doing. I love the first class in which I explain what they are going to have to do and show them what their classmates from previous years were capable of doing. Then they look at me amazed but also convinced that the challenge is viable. The motivation is triggered when I finish the class by saying to them: "I'm looking forward to seeing how you are going to surprise me this year." And in the end, after having seen them every course working, making mistakes, falling, getting up again and, in many cases, finally surprising me with their achievements, I am convinced, now, that these people will be better than us.

Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author received no financial support for the research, authorship, and/or publication of this article.

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Published by OmniaScience (www.omniascience.com)

Journal of Technology and Science Education, 2022 (www.jotse.org)