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The Change of University Teaching in Science and Technology According to Students: A Qualitative Study

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ABSTRACT

Background: In different areas, a profound transformation of university teaching has been demanded, especially in science and technology subjects, towards an approach focused on the active learning of the student, which implies changes in the way of conceiving and practising the contents, the methods, and assessment forms. To promote these changes, teacher education programs accompanying and guiding teachers are required, as is student involvement as a source of privileged information. **Objectives:** To know the opinions and appraisals of science and technology students about the classroom improvement cycles (Ciclos de Mejora en el Aula—CIMA) applied by their teachers during a teacher education program. **Design:** A qualitative methodology whose design is framed in the descriptive-interpretive and categorical analysis of the content. **Setting and participants**: Eighty-six students of scientific-technical curriculum components who received innovative classes from teachers participating in the Teacher Education, Innovation, and Research program (Formación, Innovación e Investigación Docente - FIDOP) of the University of Seville. **Data Collection and Analysis:** The responses to the open questions of the C-Renoves (Creencias de los estudiantes sobre innovaciones en la Educación Superior) [Students' Beliefs about Innovations in Higher Education] questionnaire, validated by the judgment of experts in scientific-technical areas, were categorised and analysed according to four previous categories: contents, methodology, evaluation, and appraisal of the experience. **Results:** The results indicate that most teachers followed an active approach focused on learning, with a very positive assessment of the students, especially concerning working with problems and cases connected to reality, developing reflective thinking, considering students' ideas, and teachers' attitudes and commitment. They also criticise and suggest improvements regarding the persistence of traditional evaluation and the need to adjust the time and workloads of the activities better. **Conclusions:** Students' answers show a positive evolution of science and

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technology teachers participating in the FIDOP Program. They have provided valuable information for their teachers and helped improve the program.

Keywords: Higher education, Teaching innovation, Student opinion, Science and technology.

El cambio de la enseñanza universitaria en ciencia y tecnología según los estudiantes: Un estudio cualitativo

RESUMEN

Contexto: Desde diferentes ámbitos se viene reclamando una profunda transformación de la enseñanza universitaria, también en las materias de ciencia y tecnología, hacia un enfoque centrado en el aprendizaje activo del estudiante, lo que implica cambios en la manera de concebir y practicar los contenidos, los métodos y las formas de evaluación. Para promover dichos cambios se requieren programas de formación docente que acompañen y orienten al profesorado, así como la implicación de los estudiantes como una fuente de información privilegiada. **Objetivos:** Conocer las opiniones y valoraciones de estudiantes de ciencia y tecnología sobre los Ciclos de Mejora en el Aula (CIMA) aplicados por sus profesores, mientras participaban en un programa de formación docente. **Diseño:** Se utilizó una metodología de naturaleza cualitativa cuyo diseño se enmarca en el análisis descriptivo-interpretativo y categorial del contenido. **Ámbito y participantes**: 86 estudiantes de materias científico-técnicas que recibieron clases innovadoras de docentes participantes en el programa de Formación, Innovación e Investigación Docente (FIDOP) de la Universidad de Sevilla. **Recolección y Análisis de Datos:** Se categorizaron y analizaron las respuestas a las preguntas abiertas del cuestionario C-Renoves (Creencias de los estudiantes sobre innovaciones en Educación Superior), validado por juicio de expertos en áreas científico-técnicas, según cuatro categorías previas: contenidos, metodología, evaluación y valoración general de la experiencia. **Resultados:** los resultados indican que la mayoría de los profesores siguieron un enfoque activo centrado en el aprendizaje, con una valoración muy positiva de los estudiantes, especialmente en relación con el *trabajo con problemas y casos conectados con la realidad*, *el desarrollo del pensamiento reflexivo*, *la toma en consideración de las ideas de los estudiantes* y *la actitud y el compromiso de los docentes*. También expresan algunas críticas y propuestas de mejora en relación con cierta *persistencia de la evaluación tradicional* y con la necesidad de *ajustar mejor el tiempo y las cargas de trabajo* de las actividades. **Conclusiones:** Las respuestas de los estudiantes muestran una evolución positiva de los docentes de ciencia y tecnología participantes en el Programa FIDOP y han aportado una información valiosa para sus docentes y para la mejora del Programa.

Palabras Claves: Educación superior, Innovación Docente, Opinión estudiantes, Ciencia y tecnología.

INTRODUCTION

For some time now, researchers and international organisations have been arguing for changes in the predominant transmissive model in higher education. For example, in the "World Declaration on Higher Education for the Twenty-first Century", Article 9 discusses the need for a new approach to teaching focused on students' active learning, which implies a review of content treatment, methodology, and evaluation forms (Delors, 1996).

Consistently, and because most university faculty do not have teaching training (Gibbs, 2014), the University of Seville created the *Teacher Education, Innovation, and Research Program* (FIDOP) in 2012 to promote teaching based on student activity. In the program, teachers learn to work with problematised content, apply research methodologies, and promote formative evaluation through classroom improvement cycles (CIMA) (Delord et al., 2020 and 2022), in which they design and apply, collaboratively, this new teaching model. In this context, our research has focused on knowing students' opinions and evaluations in science and technology classes where their teachers have applied a CIMA.

THEORETICAL FRAMEWORK

Focus teaching on learning and the student

For Uiboleht (2019), it is necessary to identify the basic patterns that differentiate the usual and desirable teaching model in order to improve university teaching adequately and coherently. Thus, the literature contains two contrasting models that act as references: *the subject- and teacher-centred model* (MCM), which is the majority (Borte et al., 2023), and the *learning- and student-centred model* (MCA), which is the minority (Gargallo et al., 2007). The latter is considered desirable from a research point of view (Chocarro-de-Lus et al., 2013; Montes & Suárez, 2016; Pundak & Rozner, 2008). These two models differ in how the contents are treated, the teaching methodology used, and the type of evaluation conceived and practised. In the first case (STCM), the contents are usually approached in an additive and encyclopaedic manner; the methodology is based on the direct and unidirectional transmission of information, and the evaluation is understood exclusively as qualification based on exams. The second (LSCM) is based on problems, cases, or projects, focused on better organisers (Porlán, 2018), and adjusted to students' mental schemas. The methodology focuses on student learning, and the evaluation is progressive, participatory, and formative (Porlán, 2017). When analysing actual teaching practices, intermediate models also appear, with a clear predominance of those closest to the STCM (Gargallo et al., 2007). From previous studies (Crawford & Capps, 2016; Duschl et al., 2011) and experience with the FIDOP Program, we know that the necessary evolution from the STCM to the LSCM is a gradual and difficult process that requires formative strategies based on the design, application, and evaluation of classroom experiences, in collaboration with colleagues and with the support of expert educators in the intended model (De-Alba-Fernández & Porlán, 2020). Batista and Batista (2002) suggest that these changes may present even more difficulties for science teachers. In this case, epistemological beliefs lead to change by overvaluing conceptual and theoretical knowledge about intellectual abilities and actions.

In describing the patterns of good university teaching and based on an ambitious investigation into the characteristics of the best teachers, Bain (2006) suggests that every university professor must ponder over what the best do: work with problems, with research, as a team, and with formative assessments. The author also points out that using these strategies consistently makes students feel confident that they are learning valuable material. Finkel (2008), in turn, invites us to reflect on the few times we have learned something so deeply during our schooling that we have retained it for years. The author indicates that teachers capable of motivating their students and *giving meaning* to learning make it lasting, but he concludes that a new teaching model is necessary. In the same sense, Bruner (1978) had already stated that to achieve *deep learning*, students must live a process of conscious self-regulation promoted by a teacher with suitable *scaffolding strategies*.

Refining even more on the guidelines of good university teaching, various studies on the changes that innovative teaching causes in learning (Baepler & Walker, 2014; Park & Choi, 2014; Salter et al., 2013) tell us that cases where students' ideas are valued and form the starting point of teaching improve students' engagement, participation, and academic outcomes. In the same sense, authors such as Trigwell et al. (1994) and Trigwell and Prosser (2014) propose that the key to teaching improvement is to encourage students' autonomy to construct knowledge as the main actors in the process. More specifically, Postareff et al. (2008a and 2008b) propose that the type of interaction of students with the content is the key to recognising in practice the two teaching models we have been mentioning. To these authors, teachers who organise their classes so that students interact with the content in an investigative, reflective, and critical manner are well aligned with the required teaching change.

In the case of university science and technology classes, Metzger (2015) and Pundak and Rozner (2008) consider that the genuinely innovative ones are those that promote student learning through experiences that overcome the barrier between the teacher (who knows everything) and the student (who knows nothing), favouring a constructive interaction.

From our point of view, and aligned with the contributions of the didactics of sciences, we consider that one of the keys to the teaching change is to conceive students as *epistemic subjects* possessors of meaning schemes from which they can face relevant, novel, and interesting challenges. Although low-level schemes include errors and simplifications, they can evolve autonomously and significantly with teachers' appropriate *scaffolding* (Porlán, 2020).

From a standpoint focused on teachers' attitudes, Enricone (2001) proposes a set of characteristics that favour good university teaching: a) Disposition towards change (not being afraid to experiment); b) Reflective attitude about the designed and applied activities (Toni & Makura, 2015); c) Update in significant knowledge for teaching and d) Evolution of teacher learning through continuing education.

Thus, acknowledging students as active subjects and having a professional and reflective vision of the teaching activity seem to be two critical guidelines in evolving from the STCM to the LSCM (Grillo, 2001).

Teacher education aligned with change

Zabalza (2004) considers the institution crucial in promoting good teaching by stimulating formative and teaching-innovation programs. In our opinion, these programs should focus on fostering the change of model, guiding and supporting teachers in experimenting with the desirable model because, if specific strategies –for example, those aimed at participatory and formative evaluation– are not protected adequately from the weight of tradition, the innovative teacher will have challenges focusing teaching on learning, since there are variables, such as the one we mentioned about evaluation, that greatly condition students' (more passive or active) responses, trained as they were for years to mobilise only before traditional exams.

In our case, the University of Seville's FIDOP Program is clearly aligned with the change towards a learning-focused teaching model. In science and technology education, the main principles described by Feria (2017), a participant in the program, are:

- Relate the contents to key scientific problems (Couso et al., 2020), integrating the conceptual, procedural, and attitudinal dimensions.
- Go from the concrete to the abstract and vice versa, promoting a *basic outline of the subject* for students (Porlán, 2018).
- Incentivise methodologies that prioritise student research and reflection (Lederman et al., 2013).
- Promote student participation, making them protagonists and co-responsible for their own learning (Mellado, 1999).
- Recognise students' mental models and learning difficulties, evaluate the initial and final state and the intermediate processes, know their progress and blockages, and be able to judiciously make the necessary adjustments in the didactic design (Delord, 2020).
- Promote formative, continuous, and participatory assessment (and qualification) (Sanmartí, 2007).

In short, it is necessary to experiment with institutional university teacher education programs that foster the described teaching model and evaluation projects that analyse its actual impact on the demanded change. In this sense, and as part of a broader study carried out in the FIDOP Program to analyse its impact on participants' practices, this work provides the perspective of science and technology students on the classroom improvement cycles applied by their teachers, thereby highlighting the necessary role students must play in these evaluation processes (Duart & Martínez, 2001; Giné, 2008).

Students' opinions on teaching improvement

Juárez-Jerez (2012) maintains that the evaluation of teaching education and innovation must aim to improve experiences and that, for that, classic student satisfaction surveys are not enough; we must go further. The challenge is to create adequate instruments that describe classroom events from students' points of view using quantitative and qualitative data that are useful for providing feedback to teachers and the program.

According to Duart and Martínez (2001), an evaluation strategy must integrate three sources of information: external information collected by the students, internal information collected by the teacher, and academic results. In our case, we decided on students' external assessment as one of the indicators, along with others, of the impact of the FIDOP Program (Ricoy & Fernández-Rodríguez, 2013), combining quantitative and qualitative data through the C-Renoves questionnaire (Student Beliefs about Innovations in Higher Education) (Pérez-Robles & Delord, 2022).

Gómez and Valdés (2019) criticise the aspects that university leaders ask students to evaluate their teachers since they do not usually include what merits to be assessed, such as the direct processes of the classroom (the characteristics of the contents addressed, the methodological approach followed, the type of activities, the evaluation criteria, etc.). Thus, the results are of little use for teachers. The authors suggest that the evaluations be carried out in the context of innovation and to provide information for teaching improvement.

Another critical factor in teacher evaluation strategies by students is the rejection they cause in many teachers. Stroebe (2016) indicates that this type of evaluation has prioritised its role in promotion processes instead of the desirable objective of improving teaching. To avoid this, our research has focused on knowing the students' opinions about what happened during the CIMA regarding content, methodology, and evaluation. The answers have been available to each teacher from the first moment, without any repercussion on their promotion and with the sole objective of providing valuable contrasting information for their improvement and that of the program.

With this guidance of knowing students' opinions about the experimentation of new didactic proposals based on active learning, Abdel and Collins (2017) analysed an *inquiry-based teaching* model through the opinion of 197 students attending biology and medicine subjects. The results show that 84% confirmed that they worked from the resolution of questions, valuing this teaching model very positively; 69% stated that they had learned more than in traditional classes; and, especially, 89% declared that working with questions had motivated them to learn and get involved in the classroom. These results are similar to those of the study by Gil-Galván et al. (2021), in which most of the 1,065 students who lived a *problem-based learning (PBL*) experience stated that it had provided them with a high level of learning and had helped them develop methodological and participatory competencies. Also, in Pozuelo et al.'s (2021) study on *research-based* classes, the opinions of 640 students were analysed through a questionnaire; 70% valued the experience positively compared to traditional teaching, highlighting the teamwork outside the classroom, the scripts for investigating problems, and the evaluation rubrics. In a study focused on the opinion of 142 science students about the model of *flipped classes,* Gilboy et al. (2015) indicated that 76% of the students stated that they had learned more than in transmissive classes and 64% that they had become more committed to the subjects. Finally, Dawson et al. (2019) analysed the point of view of 400 science and technology students on an *assessment model based on feedback* that kept students in permanent interaction with their ideas, content, and teachers' contributions. The most notable result is that 90% stated that they had learned much better than preparing for the exams since they could control their progress and obstacles and developed pleasant feelings towards the assessment in a way they had never experienced before.

In an extensive and fascinating study on physics classes in engineering majors, Dos Santos et al. (2022) analysed students' experiences and opinions regarding a teaching model based on *interdisciplinary projects with solid social projections* carried out by student teams. The analysis used various instruments, highlighting the *written reports.* This model aimed to promote active learning, constructive communication, development of reflection, creativity, intellectual freedom, and the fusion between theory and practice, understanding that theoretical contents are not an end but intellectual tools to address real-world problems (Porlán, 2018). From the analysis of the reports, it is clear that the students described the classes as a rich and profound experience that developed their critical and reflective thinking, their ability to solve problems with rigour, their learning of theory in action, their capacity for dialogue and communication, and their freedom and responsibility with the task.

In a study on students' thoughts on how to improve university teaching in content and methodology, Giné (2008) analysed the opinions of 96 law, education, chemistry, and pharmacy students through *discussion groups*. The results show a great wealth of nuances. The students highlight that the contents must be connected to reality and the profession, valuable and applicable, and related to each other. According to them, the methodology should promote reflective and critical thinking, relate theory to practice based on challenges, projects, and cases, and promote students' participation and autonomy.

With a biographical approach, Wolffenbuttel (2006) studied the life story of a physics professor recognised as an exemplary teacher. His students described him as someone close, loving, optimistic and empathetic, highlighting the emotional bonds he used as pillars of a good class environment. Regarding its methodological characteristics, they stated that it followed a model based on classroom research, group work, project development, and experimentation. Regarding the contents, they mentioned that the teacher always presented them with links to phenomena and real-world problems, which aligns with the desirable LSCM.

Finally, Giménez (2007) investigated the opinions of his students during a Microbiology course in which he used three teaching strategies to promote active learning: practical case studies, teamwork, and guided debates. The students stated that these strategies favoured contact with reality, student involvement and participation, and better learning. Regarding the teacher, they highlighted that she constantly adapted to the students' process, attending to them and helping them, even individually, and that she created a pleasant and well-being environment. At the same time, some students highlighted that the innovations required excessive work and dedication, especially outside of class, which was incompatible with the rest of the subjects.

In short, we can affirm that, in the analysed studies, most students confirm the active teaching put into practice by their teachers and their high valuation of it, considering having learned more and better than in traditional classes and having developed competencies and attitudes that are not usually promoted such as participation, commitment, reflective thinking, and control of one's own learning. Moreover, the following aspects of the new model stand out: work with problems or projects, teams, research, communication, meaningful interaction, theory in action, etc. Finally, some studies highlight the importance of emotional factors and a good atmosphere in the classroom.

METHODOLOGY

The methodology used in this study is qualitative in nature, and its design is framed by a descriptive-interpretive and categorical analysis of the content.

Instrument

This study has been carried out based on the C-Renoves questionnaire, which includes closed and open questions about teachers' application of the classroom improvement cycles (CIMA) as participants in the FIDOP Program. In this work, we analysed the answers of science and technology students to open questions. The analysis of closed questions has been the subject of another previous study (Pérez-Robles & Delord, 2022). As indicated, CIMAs imply for teachers an analysis of preexisting practice and the design, application, and evaluation of a practice improved through cyclical and progressively broader processes until they cover an entire subject (Delord et al., 2020).

The instrument, based on previous work (De-Alba-Fernández & Porlán, 2020; Rivero et al., 2020), has been validated in the following three phases (Pérez-Robles & Delord, 2022): a) An evaluation carried out by seven experts in university teacher education in scientific-technical fields, to assess the suitability and clarity of the closed and open items and their classification in the category system, and a pilot test with 58 students from these areas, whose teachers were part of the program, although not of this study, to confirm the understandability of each item. The evaluation and the test allowed us to improve the writing of many items in the questionnaire; b) A first application of the construct and an exploratory and descriptive-interpretive factor analysis of the answers, with a sample of 414 students of STS subjects from teachers participating in the program, which led to a series of modifications that culminated in the final version of the instrument and c) A second confirmatory application of the validity of the instrument, similar to the previous one, which was carried out with 235 students of STS subjects, also by teachers of the program (Pérez-Robles & Delord, 2022).

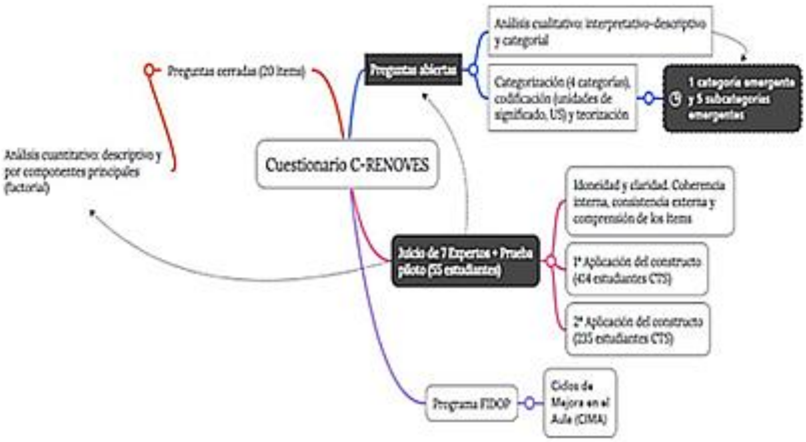
Students' instruments for assessing their teachers' teaching models are usually exclusively quantitative questionnaires that ask them to indicate the degree of agreement with specific statements (Gómez & Valdés, 2019). According to Alterio and Pérez-Loyo (2009) and Cortés et al. (2014), the exclusive use of this type of items may reflect ambiguous opinions that distort the results. For this reason, the C-Renoves questionnaire incorporates 20 closed items and presents six open questions, following the criterion of using various data sources (Madaus & Kellaghan, 2000) and enabling the birth of emerging categories (Figure 1) (Aguilera, 2017). The questions are as follows:

- *Write and argue for the characteristics of the classroom improvement cycle experienced in the subject that have been most valuable for your learning (P1).*
- *Write and argue for the characteristics of the teacher that have been most valuable for your learning (P2).*
- *Write and argue for the characteristics of the classroom improvement cycle experienced in the subject that should be improved (P3).*
- *Write and argue for the teacher characteristics that should be improved (P4).*

- *Use this section to make other reasoned comments in relation to the classroom improvement cycle (P5).*
- *Use this section to make other reasoned comments in relation to the teacher's characteristics (P6).*

Figure 1

Analysis and research methodology of the C-Renoves questionnaire



Participants

The sample was formed by 86 students of scientific-technical subjects whose teachers had completed a CIMA during the 2021-2022 academic year within the framework of the FIDOP Program. Of the total sample, 61 subjects were women (70.9%) and 25 men (29.1%), with a mean age of 22. The sample was chosen due to the possibility of accessing them, being non-probabilistic and intentional.

Ethical considerations

The study followed the basic principles for people's protection in research processes as per the Belmont report. Specifically, we requested the students' informed consent. As per the policy of protection and processing of personal data of the University of Seville (EU GDPR, art. 89.1), their anonymity, the exclusive use of the answers by the researchers and teachers, and permission to use them were guaranteed.

Obtaining the Units of Meaning (UM)

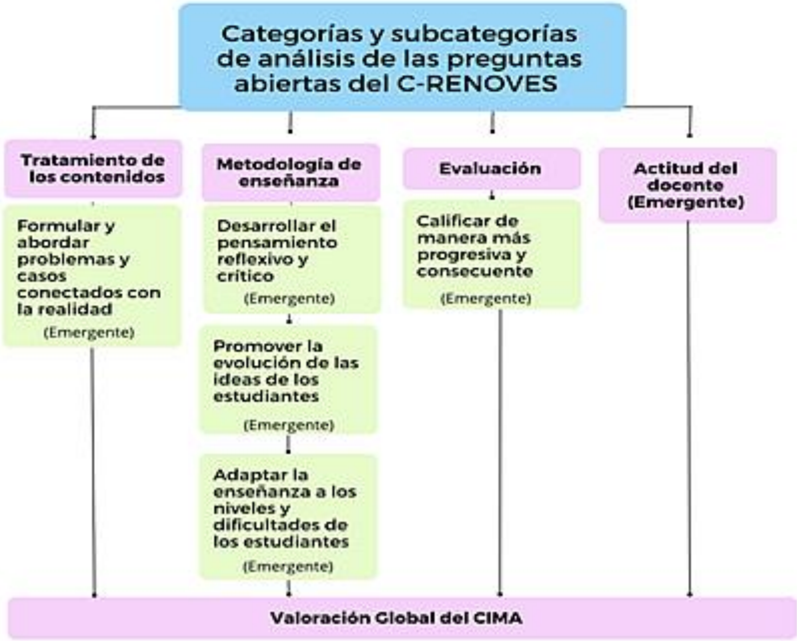
To analyse the responses to the open questions of the questionnaire, we have extracted the UM and classified them into categories and subcategories, taking into account the criteria of Krippendorff (1990) and Bardin (2002) of observing a text rigorously and systematically, looking for information that provides answers to the researcher's previous questions and grouping them according to the similarity of their meanings, but also being attentive to other information, not initially foreseen, that enters the domain of the research. Specifically, two authors independently carried out the selection and categorisation of the UM. Subsequently, they compared the results and discussed the discrepancies with the third researcher, discarding those UM on which there was no agreement (11%).

Categories and subcategories

In this descriptive and categorical content analysis process, we have questioned students' texts based on three categories that represent the most relevant curricular elements: *treatment of contents, teaching methodology* and *assessment,* and one more about the *overall assessment of CIMA* (Figure 2). During the analysis process, a category linked to the objective of the research emerged (*teacher's attitude),* and several subcategories representing some of the critical guidelines that differentiate the LSCM from the STCM emerged: *Formulate and address problems and cases connected to the real-world*; *Develop reflective and critical thinking; Promote the evolution of students' ideas; Adapt teaching to the levels and difficulties of the students and grade more progressively and consistently.* Finally, each UM obtained and categorised has been classified into LSCM or STCM based on the orientation that emerges from its particular content regarding the CIMA applied by the teacher.

Figure 2

Analysis Categories and Subcategories



Coding

The identification of the UM has been carried out with a three-digit code, which contains the subject number, the number of the open question of the questionnaire and the identification of the unit with the learning-centred model or with the subject-centred model, as seen in the example "S19P1-LSCM", which corresponds to a UM of subject 19 (S19), obtained in the first open question of the questionnaire (P1) and which is identified with the learning-centred model (LSCM).

RESULTS

In the analysis, we obtained 118 units of meaning (UM). Regarding LSCM and STCM models, we have calculated the frequency of the UMs that denote an orientation of teachers' improvement cycles towards one or the other, resulting in 74.58% indicating an orientation towards LSCM and 25.42 % towards the STCM (Figure 3). The distribution of the UMs in the categories and subcategories and, in each of them, the orientation of the units towards the two reference models has also been calculated (Table 1).

Figure 3

Frequency of units of meaning regarding the LSCM and the STCM

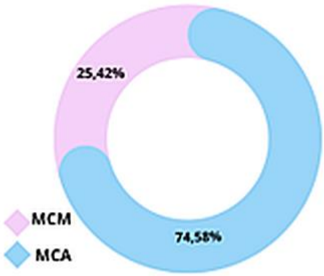


Table 1

Units of meaning by categories and subcategories and frequency of orientation towards the LSCM and the STCM models

Categoríes and subcategories:	LSCM Model US	%	STCM Model US	%	Total (US)
Treatment of content	19	**65,10%**	10	34,90%	29
Formulate and address problems and cases connected to reality	19	**65,10%**	10	34,90%	29
Teaching Methodology	36	**73,47%**	13	26,53%	49
Develop reflective and critical thinking	11	**68,75%**	5	31,25%	13
Promote the evolution of students' ideas	5	**62,50%**	3	37,50%	14
Adapt teaching to students' levels and difficulties	20	**80,00%**	5	20,00%	22
Evaluation	1	25,00%	3	**75,00%**	4

Qualify more progressively and consistently	1	25,00%	3	**75.00%**	4
Teacher's Attitude	10	**100%**	0	0%	10
CIMA Global Rating	22	**84,61%**	4	15,39%	26
Total	88	**74,58%**	30	25,42%	118

In the following paragraphs, we will describe the results based on the previous categories and the emerging subcategories that came up in the analysis and present examples of the representative UMs.

Formulate and address problems and cases connected to the real world

Regarding the treatment of the contents, as can be seen in Table 1, 65.10% of the UMs describe and value positively that they have been worked on in connection with problems and practical cases connected to the real world in a way that –agreeing with Dos Santos et al. (2022)– the contents have not been explained directly but have been progressively presented as intellectual tools to solve the challenges presented, as can be seen in these units:

- "*When we investigated the problems, the contents were understood very clearly…*" (S29P2-LSCM).
- "*The teacher has given us practical problems that have helped us understand the topics better*" (S17P2-LSCM).
- "*The content has been very close to the reality problems of our future jobs*" (S153P5-LSCM).
- "*The teacher has asked us to help in solving questions about problems that address real situations*" (S26P2-LSCM).
- "*We have investigated cases as a group to have more insight into how to solve them, which has been very satisfactory*" (S16P1-LSCM).

On the other hand, 34.90% of the units reflect that some teachers have either not worked with problems or have done so in a poorly contextualised manner in the current and professional reality, which has not promoted the necessary connection between theory and practice:

- "*...it is necessary to dedicate more time to current problems*" (S117P4-STCM).
- "*...we should have worked with content and problems more focused on our professional career*" (S126P3-STCM).
- "*Students must be involved in classes through questions*" (S45P6-STCM).
- "*Put more real cases... to know how to connect theory with practical situations*" (S81P4-STCM).

Develop reflective and critical thinking

Regarding teaching methodology, 68.75% of the UMs reflect, in coherence with the LSCM, that during the CIMA, they have worked with a methodology that promotes the development of one's own reflective and critical thinking, which is valued satisfactorily by the students, as it focuses and motivates them in the task:

- "*The teacher has made us reflect on the different cases, developing our critical thinking*" (S25P2-LSCM).
- "*... various studies have gone a lot deeper in learning, in making us think and develop ideas*"(S54P6-LSCM).
- "*It has managed to make reflection, change, and action penetrate our minds...*" (S122P6-LSCM).
- "*I think it's very good because it has helped me work on the topic myself, with my ideas and reflections, and see what I understand and don't... it's an incentive to motivate you and work hard*" (S176P5-LSCM).
- "*...since the classes are very participatory, they force you to pay attention and think, so many of the usual distractions disappear*" (S21P2-LSCM).

On the other hand, 31.25% of the units reflect the opinion of students who are dissatisfied with particular aspects of the methodology of some CIMA, demanding more dynamic, participatory, and coherent classes, with fewer transmissive components:

- "*I think less theory should be explained... there was almost no participation on our part*" (S69P3-STCM).
- "*As a teacher, you can't say one thing and do another. The classes were too dense and monotonous, I had the feeling that there was a lack of motivation on our part and the teacher's*" (S86P4-STCM).

Promote the evolution of students' ideas

In methodology, 62.50% of the UMs confirm that most teachers have implemented a sequence of activities to evolve the students' ideas, first by asking questions, problems, or cases so that they formulate their ideas and subsequently helping them improve them through activities that confirm, expand, or question them:

- "*The teacher first asked us for our opinion to resolve the questions, and then we worked on them in a broader way*" (S26P2-LSCM).
- "*There was an attempt to make students give their personal points of view on various topics to improve them*" (S41P2-STCM).
- "*The methodology we used seemed very correct to me… the new is critically related to our previous ideas*" (S52P1-LSCM).
- "*It is valuable how the teacher has paid more attention to students' ideas and questioned them little by little*" (S23P2-LSCM).

On the contrary, 37.50% of the units reflect the opinion of students who are dissatisfied with the type of activities and their role in them, demanding more problematised activities in which they can test their own opinions:

- "*It should have been worked on with real practices. It is impossible to understand the theory if I do not practice with my own ideas and real examples*" (S167P3-STCM).
- "*When we finish the theoretical-practical activity, a new topic begins without asking us our opinion about the previous activity and whether or not we have changed our point of view*" (S86P3-STCM).

Adapt teaching to the levels and difficulties of the students

Finally, regarding the methodology, 80% of the UMs show that teachers have adapted their methodology to the levels and obstacles of their students, considering their ideas, resolving doubts, modulating the pace, and adjusting the tasks, even at the individual level:

- "*I would highlight how the teacher has been able to adapt to each student*" (S34P2-LSCM).
- "*Each student has different knowledge, and it has been necessary to adapt to each one's previous knowledge*" (S12P2-LSCM).
- "*During the topic, the teacher asked us about our knowledge of what was being discussed, knowing how to adapt the speed of the topic to our difficulties*" (S32P2-LSCM).
- "*The teacher has adapted exceptionally to the learning pace of the group of students*" (S36P2-LSCM).
- "*The teacher has perfectly understood our ideas and the doubts that have arisen and has clarified them*" (S15P2-LSCM).
- "*…the teacher asked us for our ideas about what we would work on, adapting the following tasks to our difficulties*" (S32P1-LSCM).

At the same time, 20% of the UMs reflect opinions of students dissatisfied with the non-adaptation of teaching to their level, reflecting the inevitable disconnection that is established when the complexity of the content is far from students' *zone of proximal development* (Vigotski, 1979):

- "*Many times, the contents were too complex to be addressed in a way that was easy to understand for our level*" (S73P3-STCM).
- "*The teacher should have been informed about our theoretical status. It was the first time that I saw those concepts. We did not understand what the teacher was passing on, and it was increasingly difficult to follow*" (S75P4-STCM).

Grading more progressively and consistently

Only four UMs appear in the students' answers regarding evaluation, probably because when the CIMA was carried out in the middle of the academic year, they did not yet know the repercussions it would have on their grading. In these UMs, a conceptual differentiation between assessing and grading is not identified. One of them shows an orientation of the teacher towards the LSCM:

- "*When evaluating with assignments, the teacher rated students' learning in a more continuous and fair manner*" (S47P1-LSCM).

The other three show an orientation towards the STCM and an evident contradiction between the activities carried out during the CIMA (more innovative, problem-based...) and the fact of not considering them when grading or having taken a rote-learning test not based on practical problems like those of CIMA:

- "*I think the teacher should have assessed us weighting more on innovative activities*" (S17P5-STCM).
- *"Although we have had the notes for the exam, the teacher should have contemplated other types of activities*" (S125P6-STCM).
- "*In the test, they evaluated us with theoretical questions that we had to memorise, I don't understand why there were no practical problems like the ones we did during the innovation*" (S69P5-STCM).

Even though they are not very representative, the data show that the tendency towards STCM is stronger than towards LSCM, which only occurs in this category.

Teacher's attitude

In this category, all UMs (100%) show very positive opinions about the teachers' attitude. Students highlight teachers' passion, vocation, and wit, highlighting the enormous importance that teachers' commitment to teaching has for the improvement of teaching:

- "*The teacher has shown her willingness and vocation when teaching*" (S34P2-LSCM).
- "*...the passion with which the teacher has approached the subject is very gratifying*" (S48P2-LSCM).
- "*The teacher has done all the work very well, I have learned a lot in this subject, and I wish more teachers would innovate*" (S125P6-LSCM).

- "*A good and clear teacher, for me, it has been a good choice of subject*" (S128P6-LSCM).
- "*My opinion… is completely positive, because I am satisfied with the teacher's work, he sparked my interest in the classes*" (S104P6-LSCM).

They also highlight the closeness and help of the teacher and show how students detect and value it:

- "*The teacher…does great, he is very involved, he wants us to really learn,… he helps us…*" (S157P6-LSCM).
- "*In addition, he is a teacher willing to help students. Committed to his subject*" (S122P6-MCALSCM).

Finally, some show the teachers' respect for their beliefs and the positive assessment they make of this fact:

- "*The teacher does not impose his vision... which I appreciate. He has made us understand the agenda without imposing an ideology* " (S121P6-LSCM).

Overall assessment of the CIMA

Regarding global opinion on the CIMA, 84.61% of respondents' UMs indicate that the experience has been very positive, that they liked it, that it has been pleasant, interesting, and has made learning less tedious and easier. They even put the emphasis on the fact that lived experience demonstrates that it is possible to design content and methodologies in a way that breaks the monotony of traditional teaching and, ultimately, highlights the importance of emotional aspects in teaching (Porlán et al. 2020):

- "*I found it to be a very pleasant, fun, and innovative experience*" (S128P5-LSCM).
- "*Assimilating and understanding a subject like this is much easier*" (S6P1-LSCM).
- "*Subject worked well, in an interesting and very dynamic way given how boring the syllabus is*" (S52P6-LSCM).
- "*It is one of the first subjects I have really enjoyed in my degree*" (S153P5-LSCM).

- "*Despite being one of the most complex subjects of the degree, it has been very enjoyable for us*" (S23P6-LSCM).
- "*The teacher shows that there are contents and ways of working on them that are not monotonous*" (S13P2-LSCM).

Some students also indicate that the classes guided by the LSCM have provided a more dynamic and interactive environment:

- "*I liked the more dynamic and not so unidirectional classes*" (S45P5-LSCM).
- "*It seemed to me that the innovative classes are more dynamic and attractive*" (S72P5-LSCM).

Some have emphasised that CIMA has led to more significant learning and a better understanding of the contents:

- "Innovation has made us learn significantly" (S19P5-LSCM).
- "Innovation has made it easier for us to understand the subject" (S146P5-LSCM).
- "It has been very beneficial to learn and pass" (S31P1-LSCM).

However, 15.39% of the UMs in this category show that, for some students, the innovation has been carried out hurriedly, covering too much content and requiring much effort. Some teachers may have wanted to make an innovative methodology (LSCM) compatible with an oversised vision of the contents of the syllabus (STCM), which usually generates contradictions and conflicts:

- "*I consider the workload excessive, fewer content should be addressed*" (S152P5-STCM).
- "*…it developed very quickly and in a way that was not easy to understand*" (S73P4-STCM).
- "*The jobs were too close together, without time, there were many tasks to do…*" (S78P3-STCM).
- "*Some aspects must be improved for better understanding and smoother development*" (S41P5-STCM).

DISCUSSION AND CONCLUSIONS

The results obtained in the open questions of the C-Renoves questionnaire of the FIDOP Program reveal a clear and majority orientation of science and technology teachers towards the LSCM (74.58% of all UMs). Particularly highlighting their *attitude and commitment*, as evidenced in all the UMs referring to the teaching attitude and their ability *to adapt to students' levels and difficulties* (80% of the UMs in that subcategory). The results also indicate a positive overall assessment of the students about the CIMA (84.61% of the UMs in this category). These results confirm all the studies consulted on the opinions of university students regarding innovative experiences, both in the case of science and technology and in other areas, in the sense that they support and value them very positively (for example, Abdel & Collins, 2017; Dawson et al., 2019; Dos Santos et al., 2022; Gilboy et al., 2015; Gil-Galván et al., 2021; Pozuelo et al., 2021). However, in a few studies, students emphasise the need for the methodology used to contemplate adapting to the students' levels and difficulties (Giménez, 2007), as in our case. This fact highlights the excellent use of the essential concepts of scaffolding (Bruner, 1978) and *zone of proximal development* (Vigotski,1979), which are especially addressed in the FIDOP Program (Feria, 2017).

About the contents, the results show most UMs (65.10%) highlight as the most notable characteristic that during the CIMA, *teachers have related problems and cases connected to reality*, stating that this formative principle of the FIDOP Program, aligned with the LSCM, has impacted most participants' innovative practice. At the same time, the content of these UMs, and those that, in the opposite direction, reflect a tendency closer to the LSCM in some teachers (34.90%), also clearly shows the positive assessment students make of this fruitful connection between contents and problems, coinciding with the results of other studies, many of them in the field of science and technology since, according to the students, it *engages and commits them to learning* (Abdel & Collins, 2017; Gilboy et al. 2015; Gimenez, 2007), *promotes their participation* (Gil-Galván et al., 2021; Giné, 2008), *teaches* them to *investigate and solve problems* (Dos Santos et al., 2022; Pozuelo et al., 2021), *connects them with current reality and profession* (Dos Santos et al., 2022; Giménez, 2007; Wolffenbuttel, 2006) and, ultimately, *helps them learn more and better* (Gilboy et al., 2015; Giménez, 2007; Dawson et al., 2019).

Concerning methodology, the results indicate that the UMs that show teachers' orientation towards the LSCM (73.47%) and those that are critical of the teachers' methodology (26.53%) highlight three essential aspects of the said model: *the development of reflective and critical thinking*, *focus teaching on promoting the evolution of their ideas and mental schemes,* and *adapt teaching to their levels and difficulties,* which evidences the impact of the FIDOP Program in the change in the methodological model of the participants and in the development of a *know how to teach* and of a *knowledge in action*, consistent with teaching focused on students' active learning and, again, with the already mentioned foundations of *scaffolding* and the *zone of proximal development*.

The positive and negative evaluations of the students in this category show how their opinions on a good teaching methodology are aligned with the proposals of the LSCM, coinciding with other research close to ours in relation to the importance they give to the development of their reflective and critical thinking (Dos Santos et al., 2022; Giné, 2007). However, as we have indicated, very few studies have been found (Giménez, 2007) showing students' evaluations of the importance of the methodology focusing on promoting the evolution of their ideas, adjusting to them and taking into account their learning difficulties. For this reason, we consider these to be relatively novel contributions from this work.

Concerning assessment, we have mentioned the lack of relevance of the results as there are only four UMs in this category. Three of them reflect a type of finalist qualification inconsistent with the approach followed in the contents and methodology during the CIMA, contravening the idea of the necessary *constructive alignment* of the curricular elements proposed by Biggs (2005). Students value this fact negatively and propose that the tasks carried out throughout the innovation be taken into account, questioning the hegemony of exams, a phenomenon described by Eisner (1999) when he states that there is a belief that exams are unquestionable tests for the true revelation of individual knowledge.

Regarding the teachers' attitudes, 100% of the UMs show and exemplify ones close to the LSCM: involvement, help, closeness, passion, respect, etc., which may have been influenced by the FIDOP Program, where the negative stereotyped image many teachers have of students or teachers' personality, or both issues are worked on at the same time. Nonetheless, the UMs also reflect the enthusiasm with which students value these types of attitudes, the influences they have on their learning, and the desire for more teachers to also develop them, coinciding with other similar studies (Gímenez et al., 2007; Wolffenbuttel, 2006). Along these lines, Lara-Díaz et al. (2016) indicate that teaching practices that are not based on dialogue and participation do not stimulate students' interest in getting involved. In the same sense, Gordon (2004) and Bixio (2995) propose that a bad relationship in the educational setting, especially when the teacher exercises power over the students, causes low self-esteem, frustration, and lack of motivation to get involved. In short, here, we allude to the importance of the human and emotional dimension in didactic communication and its powerful influence on students' and teachers' behaviours. Students who feel recognised and valued because of their ability to construct knowledge multiply their involvement, motivation, and learning capacity (Porlán, 2018).

As for the overall assessment of the CIMA, we also found a very significant number of UMs (84.61%) that reflect a clear orientation of most teachers towards the LSCM and, therefore, some evidence of the influence of the formative program. The students' opinions are enormously positive and highlight emotional aspects (*satisfaction, enjoyment, pleasant sensation, not boredom...*) and others related to learning improvement (*ease, interest, significance, not unidirectionality*…).

Regarding the improvements proposed for the CIMA, some UMs highlight the *excessive workload* they have assumed, the *comprehension difficulty of* the task, the *lack of time*, or the *excessive content*. Coinciding with these results, in Torres-Gordillo's (2010) study on *project-based learning*, some students considered the experience quite demanding and lacking in time. The author states that innovative classes require good organisation and time management, which is not always achieved. Similarly, in Gargallo et al.'s (2015) investigation, also based on student-centred teaching, some students made similar assessments, pointing out that teachers' better planning was necessary to alleviate the effort. For Taplin (2000), this teaching model requires a significant change in the students' roles, which generates anxiety in some, as they do not have constant work habits. To overcome this, the author proposes to develop well-structured *work scripts* (Finkel, 2008). Finally, in the study by Pozuelo et al. (2021) about *project-based investigations*, students pointed out as valuable aspects research scripts, workbooks, and rubrics, which confirms the importance of well-planned classes and that resources are necessary to guide and support student activity.

In conclusion, the students have shown that most teachers in training in the FIDOP Program have applied classroom improvement cycles with a clear orientation towards the LSCM. However, a minority sector remains in practices closer to the STCM or combines elements of both models, which confirms our hypothesis that changes in teaching are slow and difficult that undergo gradual and sometimes incongruent transitions (Crawford & Capps, 2016; Duschl et al., 2011). This orientation is manifested in all the categories analysed, except in the evaluation, which highlights *the teacher activity*, *the overall assessment of the CIMA*, and the *adaptation of teaching to learning*. For evaluation, the low number of UMs obtained does not allow us to value this result, which requires new studies on this specific variable. These findings, together with those from the quantitative data of the C-Renoves questionnaire, have provided better knowledge of the impact of the program on its improvement and provided each teacher with direct and helpful feedback based on their students' opinions. At the same time, the results show a high appraisal by the students of the CIMA in which they have participated and a notable coincidence between their opinions and the orientation of the LSCM, even when their opinions were critical of their teachers' model. As novel contributions of this work, we can mention the results related to the need for *the LSCM to promote the evolution of students' ideas, adjusting them, and considering students' learning difficulties*. More contributions are also the students' improvements regarding *the need for adequate guidance for developing innovative activities, a better time adjustment* that allows in-depth work, and *an evaluation and qualification consistent with the LSCM.*

This work presents the limitations inherent to a study focused on a single context in which a single inquiry instrument has been used; the results, therefore, must be taken with due caution. As indicated, this study is part of a broader project where other strategies and resources have been used to evaluate the FIDOP Program and whose results have already been published (De-Alba-Fernández & Porlán, 2020).

Finally, we consider, following Stufflebeam and Shinkfield (2007), that the most important thing when evaluating a formative project is not so much to demonstrate its degree of goodness but rather to seek its improvement by identifying the necessary adjustments in the complex process that is the teaching change. Consequently, the results of this particular study and the general evaluation project of the FIDOP Program are serving for the review of its formative activities and especially for the design of exemplifications and work guides, in this case for teachers so that they better guide the design, application, and assessment of the classroom improvement cycles.

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AUTHORSHIP CONTRIBUTION STATEMENT

APR was responsible for the literature review, formal analysis, research, and methodology. GD and RP provided study management, resources, and supervision. All the authors actively discussed the results and reviewed and approved the final version of the paper.

DATA AVAILABILITY STATEMENT

Data supporting the results of this study will be available from the corresponding author GD upon reasonable request.

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