Master of Science in Physics Education at The University of Guadalajara: The Curricular Design Process

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Abstract

Based on several educational needs related to Physics Education in Mexico, the University of Guadalajara began the curricular design of a Master's Program in Physics Education. The work for the curricular design of the Master of Science in Physics Education at the University of Guadalajara was developed through nine phases. This paper presents the generalities related to the curricular design process of the Master of Science in Physics Education program at the University of Guadalajara. As a result, we have obtained a program creation project with 21 Learning Units integrated under a competency model and two research lines. Currently, while we are writing this work, the proposal is pending approval by the General Council of the University.

Introduction

Curriculum design is "a rationality that is created to organize the educational process" (Casarini, 2019). A process in which the intentions, values, beliefs, etc., of an educational institution are translated to articulate the training of professionals who meet some of the social needs of a particular group.

The MSPE proposal includes, in addition to the statement of what is intended to be learned through the courses organized in the curricular framework, the way in which the teacher's actions are expected to promote situations that favour or facilitate student learning. It also involves the processes of student-student and teacher-student interaction. This is clear in the phases of delimitation of the knowledge necessary for the development of professional activity, social impact, determination of competences and, from its articulation in the definition of problems in the professional field that give rise to the birth of the Learning Units (LU).

Although we know that the curriculum does not make sense as long as these interactions are not carried out (the curriculum as an interactive reality), the MSPE creation project presents a vision of the curriculum as an educational plan (Angulo, 1994; Casarini, 2019) due to the guidelines established in the educational model itself, the general rules for study plans (Universidad de Guadalajara, 2022a) and the general rules for postgraduate studies of the University of Guadalajara (Universidad de Guadalajara, 2022b).

In Mexico, the need for a postgraduate degree in Physics Education arises from the importance of improving science education, particularly physics, in elementary to secondary students derived from the analysis of test results such as PISA. In addition, it is relevant to train high-level human resources that generate knowledge about the teaching-learning process of Physics at any educational level (including undergraduate and postgraduate).

The problems facing contemporary society are complex. Their solution and understanding require the articulation of different skills, knowledge, attitudes, and values related to science and technology due to the constant progress of these areas. The curricular team, based on this scenario and considering what is established in the educational model of the University of Guadalajara (Castellanos et al., 2007) of focusing the activities on what students do, decided that the postgraduate training process would be based on the development of skills.

The work for the curricular design of the Master of Science in Physics Education (MSPE) of the University of Guadalajara (UDG) was developed through nine phases (Díaz-Barriga, 1990): Formation of a curricular team; Detection of Physics Education needs; Identification of potential demand; Detection of similar programs; Delimitation of the graduate's field of action; Definition of competences; Identification of knowledge necessary for the graduate’s professional performance; Definition of Learning Units (LU) and curriculum plan; Determination of a program evaluation plan (internal and external).

The curricular design process

The model adopted for the design of the program is based on competences with a constructivist approach. This is because, as we will see later, the design of the competences is based on the results of the feasibility study and the delimitation of the Learning Units is due to problems in the professional field and not to specific content (Casarini, 2019).

As mentioned above, the process was carried out in 9 phases. Each one is addressed below.

1. Formation of a curricular team; selection of the team in charge of designing the program. Under the management of the Director of the Basic Sciences Division of CUCEI and the Head of the Physics Department, a curricular team was brought together, made up of experts in both curriculum design and competence as well as experts from the disciplines themselves. The team, in the first meetings, discussed both the methodology to be followed and the way in which the work for the curricular design would be carried out.

2. Identification of Physics Education needs, which allowed to locate the postgraduate course in a reality and in a social context. After the initial agreements, the curriculum team was given the task of designing instruments that would allow identifying both the need for trained human resources trained in the area, their competences, as well as the preferences regarding the modalities of the possible postgraduate course, from the perspective of potential employers. Two questionnaires emerged from these discussions: one for employers–people who influence the recruitment of staff in schools, and another for potential users of the program (follow the link to see Appendix A and Appendix B (in Spanish)). These instruments were shared, mainly, between the schools of the Higher Secondary Education System (SEMS in Spanish) and university centres where courses related to physics are taught within the UDG; in addition to private universities within the state of Jalisco.

3. Identification of potential demand; this is done through research and analysis of potential users of the graduate program. As mentioned in the previous point, two questionnaires were obtained to identify the ideas of potential users about their preferences in terms of research lines, skills, and knowledge in the field of Physics Education. The information obtained with these forms was useful to recognize the potential demand and the possible modalities in which the master's program will be offered. These questionnaires belong to the relevance and feasibility study described below.

Pertinence and feasibility study

Considering that the Master of Science in Physics Education will favour the training of human resources to perform research and intervention tasks in various educational contexts, practicing academics who teach physics-related subjects may enrol regardless of their original training. Likewise, the master's program is expected to be an attractive training option for graduates of Physics and various engineering fields. Therefore, to estimate the relevance and feasibility of creating an educational program such as the one described in this document, two opinion surveys were designed using the Google Forms tool.

A survey was sent to the academic authorities of different Higher Secondary and Higher Education campuses of the UDG, as well as to other incorporated schools and private universities in the State of Jalisco. These authorities were asked about the teachers who make up their academic staff and who are responsible for the scientific training of young people enrolled in their educational establishments. It was called the "employer's survey" because these authorities, directly or indirectly, are key actors in the incorporation of teachers and academics into educational contexts.

A second survey was sent to students who are about to graduate and graduates of the bachelor's degree in physics from the University Centre for Exact Sciences and Engineering (CUCEI in Spanish) and to practicing professors at the University of Guadalajara who only have a bachelor's degree in science or engineering. It was called a "candidate survey" because these participants fit the profile as benefitting from the master's program. Annexes A and B, respectively, show the employer and candidate surveys as they were sent by email.

From October 9, 2020, to January 14, 2021, emails were sent to employers and candidates. In total, 35 responses were received from employers (out of the 66 applications to participate that were sent) and 107 from candidates (out of the 134 applications sent). The return rates were 53% for employers and 80% for candidates; higher values than usual for this type of online survey, which are usually below 10% according to Rocco and Oliari (2007). Their answers were analysed to calculate the Cronbach's alpha coefficient, which is a robust estimator of the reliability of the designed and applied instrument. A Cronbach's alpha of 0.896 was obtained for candidates and 0.867 for employers. This means that the surveys applied had a good level of reliability.

Characterization of respondents

Figure 1 compares the age distribution of the surveyed candidates (graph on the left) with the age distribution of the professors working in the academic units of the surveyed employers (graph on the right). As can be seen, employers report that most of their physics teachers are over 30 years old. The ages of the students and graduates who responded to the survey are concentrated between 20 and 40 years. This means that future students of the proposed master's degree will be able to join the employers' academic units.

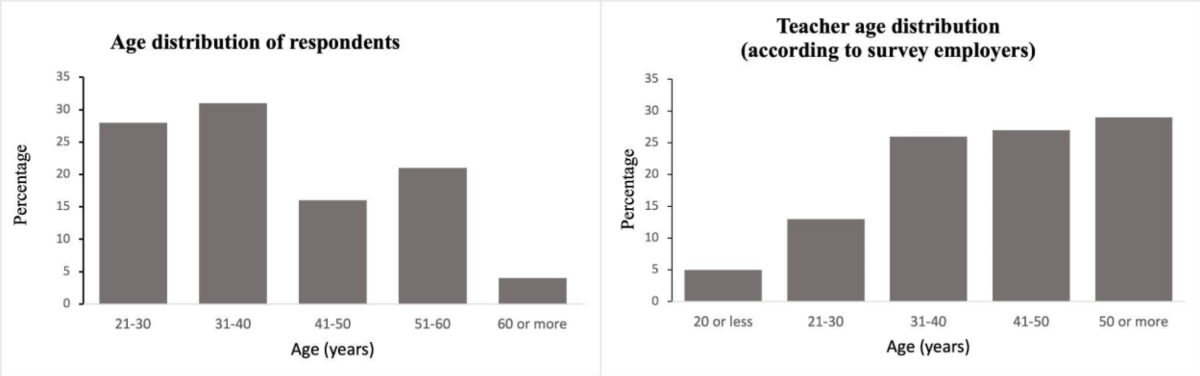

Figure 1. Age distribution of the surveyed candidates (left) and age distribution of the professors who work in the different academic units of the surveyed employers (right).

Figure 2 compares the academic qualifications of the respondents and the degrees reported by employers for the majority (60% or more) of the professors working in their academic units. As can be seen, the population of candidates surveyed can be considered representative of practicing teachers considering their level of studies. It is important to note that teachers who already have master's and doctoral degrees were surveyed, assuming that these degrees are in other areas of Physics, not in Physics Education.

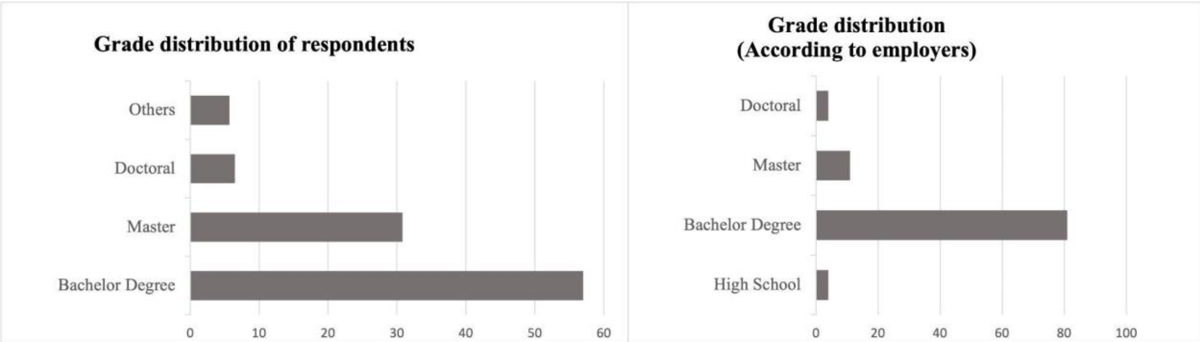

Figure 2. Distribution of academic degrees of the surveyed candidates (left) and distribution of degrees of the professors who work in the different academic units of the surveyed employers (right).

Figure 3 compares the respondents' areas of training with those reported by employers for most of their teachers (more than 60% of them). As can be seen, it is rare for physics teachers to be physics graduates. By surveying physicists and attracting them to the proposed master's program, it is hoped to reverse this trend.

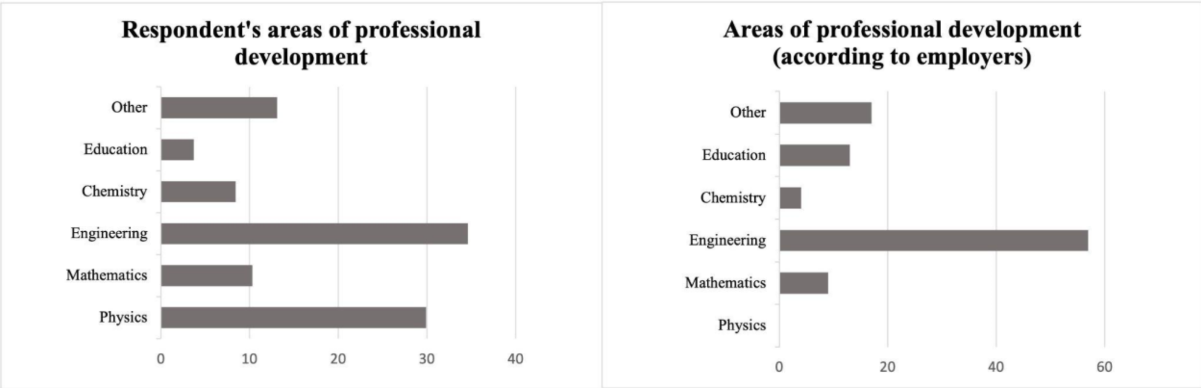

Figure 3. Distribution of training areas of the respondents (left) and distribution of training areas of the teachers who work in the different academic units of the surveyed employers (right).

In summary, most of the candidates surveyed (about 70%) are between 20 and 50 years old. Most have a bachelor's degree in some engineering and are hired in formats other than full-time (fee-based, part-time, or hourly). Half of them are dedicated exclusively to teaching and the other half combine teaching with some other activity (research, tutoring or administrative tasks). This suggests that, considering only the campuses of the UDG, there are potential users for whom a postgraduate degree in physics education may be an attractive training option.

Analysis of interests and abilities

In the questionnaires sent, 11 competences were mentioned that, desirably, a future graduate of the proposed master's degree should develop. The competences were divided into three activities: teaching, research, and management tasks. Table 1 shows these competences with respect to the referred area.

Table 1. Competences that were considered in various questions of the questionnaires sent to respondents and employers.

Scope	Competences
Teaching	1. Manages the spaces and resources necessary for the development of the teaching-learning process of Physics. 2. Uses information and communication technologies (ICT) and learning and communication technologies (LCT) efficiently as support in the teaching-learning process of Physics. 3. Knows and understands the conceptual development of Physics in historical and epistemological terms. 4. Knows the relevant aspects of the teaching-learning process of Physics, demonstrating willingness to collaborate in the training of scientists.
Research	5. Participates in the preparation and development of research and intervention projects in Physics Education. 6. Communicates the results of research in Physics Education to their peers and/or to the public in oral and written language (participates in dissemination and/or scientific dissemination projects).

	7. Proposes solutions to problems in the context of Physics Education. 8. Proposes and/or applies innovative methodologies and strategies to improve the teaching-learning process based on Physics Education Research (PER).
Management	9. Designs and redesigns parts or the whole of the curriculum based on the learning of Physics. 10. Influences issues of educational policy related to the teaching and learning of physics. 11. Proposes and/or applies methodologies and strategies aimed at improving the teacher training process in Physics Education.

The responses of the candidates and employers suggested the following: the designed postgraduate degree can contribute to their professional development, there is interest in such a program, gaps in research skills were identified and it could be useful and attractive for practicing teachers that the program is offered in an unconventional modality. Therefore, the program is attractive and necessary. Other results obtained with the questionnaire are presented below:

- Originally three lines were proposed: Management and Politics of Physics Education, which obtained lowest score; Educational technology for teaching-learning Physics; Curriculum design, teaching and learning and; educational evaluation related to Physics. One of them, Management and Politics however, was perceived as not relevant.
- Gaps in research skills are identified.
- It is useful for practicing teachers that it is offered in an unconventional modality.
- The program is attractive and necessary.

Taken together, the candidates' responses suggest that the designed postgraduate course can contribute to their professional development and that, although they do not master all the skills and assumptions required by Physics Education research, they do have a genuine interest in developing them.

4. Identification of similar programs, which helps to determine the degree of satisfaction of the demand and the impact that the postgraduate course could have. Along with the application of the questionnaires, a search was made for graduate programs with similar characteristics, among which it was found, as mentioned in the justification of the program, that there is only one specifically related to Physics Education at the National Polytechnic Institute, within the Mexican Republic. On the other hand, in countries such as Chile, Argentina, Uruguay and Brazil there are bachelor's degrees in physics and physical engineering, the first dedicated to the training of Physics teachers with a research orientation and the second to the training of physicists who are dedicated to research in that science.

Social impact

In our globalized world it is important that citizens can mobilize their learning in academic and non-academic contexts. In this regard, Gil and Guzmán (1993) mention that the learning of sciences is an essential part of the training of every individual for a satisfactory development within the current globalized context; the technological scientific component determines the way in which a country is inserted in the global commercial system.

In this sense, PISA (OECD, 2006) considers that the reading, mathematical and scientific skills of students between the ages of 15 and 16 are important for their development given that they are about to enter adult life. It should be noted that the teaching of physics contributes to the development of scientific competence and is related to mathematical competence. To illustrate, in 2018, Mexico's scientific performance on the test was 415 points for girls, below the OECD average of 490; in the case of children, it was 424, also below the average of 488 (OECD, 2021). The above evidence the need to improve the learning and performance of students in the areas of sciences, which includes physics, in this specific case in the population studying at the intermediate and higher levels. Although this test is no longer administered, the results cited indicate that it is necessary to pay attention to these aspects of the training of Mexicans.

The Institutional Program 2020-2024 of the National Council of Science and Technology mentions that, in 2016, Mexico did not have even 1 researcher for every 1000 people who carry out some economic activity, while countries like Singapore, Japan and France had at least 10 scientists for every thousand people in the Economically Active Population (EAP). In the case of Latin American countries, Mexico is below Argentina and Brazil, countries that have three and two researchers for every thousand people within the EAP, respectively (CONACYT, 2020).

In this regard, the same document points out that it is necessary to increase the quantity and quality of scientific production developed by Mexican researchers, as well as increase the importance of the role played by this scientific community in the international context and assume positions of global scientific leadership (CONACYT, 2020).

Thus, in order to comply with the 2030 Agenda for Sustainable Development adopted by the General Assembly of the United Nations Organization, Sustainable Development Goal 4 of the Sectoral Education Program 2020-2024 stipulates to guarantee inclusive, equitable and quality education and promote lifelong learning opportunities for all (SEP, 2020). Within the priority objective 3, the priority strategy 3.2 proposes, among other specific actions (SEP, 2020):

- 3.2.2 Guarantee the provision of training, training and professional updating of teachers, teaching technicians, pedagogical technical advisers, managers, and supervisors of basic and upper secondary education, with emphasis on the development of disciplinary, pedagogical, didactic and digital capacities.
- 3.2.3 Strengthen postgraduate education programs as a continuing education option for teaching staff, teaching technicians, pedagogical technical advisors, managers, and supervisors.

Similar programs

This need to cover teacher education, as will be seen below specifically in physics, is addressed through master's programs such as those summarized in Table 2 (follow the link to see the extended Table 2). The names of the educational programs and the institution that offers them are listed.

Table 2. Some master's programs focused on teacher education in National Institutions.

Institution	Program name
IPN	Master of Science in Physics Education
IPN	Master in mathematics education
UDG	Master's degree in teaching for Higher Secondary Education
UDG	Master's degree in teaching mathematics
UNAM	Master's degree in teaching for Higher Secondary Education (MADEMS) (In-person and online)
UPN	Online Master of Basic Education
UPN	Master in educational development
BUAP	Master in mathematics education
ITESM	Master of Education.

Table 2 shows that the only program completely oriented to Physics Education is the IPN. This master's degree is research-oriented and had, in the class of 2020, about 100 applicants, of which only 15 were admitted. It should be noted that it has applicants and students from Chile, Colombia, Costa Rica, the United States and even Iran, as well as from Mexico.

5. *Delimitation of the field of action of the graduate*; depending on social needs. From the identification of the ideas of employers, potential users, the detection of training needs and the review of similar programs; it became clear, therefore, the need for a research-oriented program in Physics Education with the opportunity for the developed knowledge to be applied in the classroom. The curriculum team determined that graduates of the Master of Science in Physics Education will be able to perform, both in the field of knowledge generation and application, in educational institutions from preschool to higher and postgraduate level, as well as in educational research institutions or centres.

6. *Definition of competences.* It is necessary that any educational program adapts to the pedagogical model of the institution that promotes it. Therefore, the curriculum team considered the UDG model: For the University of Guadalajara, its academic model is focused on the student and their ways of being and learning to be, know, do, live together, and undertake… (Castellanos et al., 2007).

Based on the above, three research lines and eleven related competences were initially defined. These initial competences were turned over to five experts in the area, with the intention that they provide their opinion about the relevance and consistency of both a postgraduate degree of this nature and its relationship with the competences (follow the link to see Annex C). Based on this, the results of the feasibility study and subsequent discussions and revisions, the competences were refined, resulting in a set of eight, from which the curriculum would be built (follow the link to see Annex D).

Thus, the graduate of the program will be a human resource who will develop the following competences with a sufficient level of achievement:

1. Understands the conceptual development of Physics in historical and epistemological terms.
2. Knows the relevant aspects of the teaching-learning process of Physics, demonstrating willingness to collaborate in the training of scientists.

3. Manages the spaces, resources, and tools necessary for the development of the teaching-learning process of Physics.
4. Designs or redesigns parts or the whole of the curriculum based on the learning of Physics.
5. Participates in the preparation and development of research projects in Physics Education.
6. Communicates the results of research in Physics Education to their peers and/or to the public, in various forums through different media and resources.
7. Influences issues of educational policy related to the teaching and learning of physics.
8. Proposes and/or applies methodologies and strategies aimed at improving the teacher training process in Physics Education

7. Identification of the knowledge necessary for the professional performance of the graduate. After the definition of competences, the knowledge underlying each one was identified, in such a way that they can be grouped and thus form the learning units or modules that will make up the curriculum. The conceptual knowledge was identified as: knowledge, which are the theoretical foundations that students should acquire. Procedural knowledge constitutes the skills and processes that students must master for the exercise of their work as educational physicists. And attitudinal knowledge, which constitute the attitudes and values that the science teacher in Physics Education must observe for the performance of their activity. For this, an instrument designed by the curriculum team was used (follow the link to see Annex E).

8. Definition of Learning Units and curriculum plan. Based on the identification of knowledge and its grouping by similarity or affinity, the Learning Units or Modules (LU or LM) were formed, whose articulation forms the curriculum plan of the program. Being knowledge derived from competences and these being based on real problems faced in Physics Education, the curricular team conceives the courses as LM, in this regard, Catalano, Avolio and Sladogna (2004) define a module as the articulation of competences, educational and formative actions around problems or situations in the field of action of the educational physicist. However, the regulations of our alma mater do not include LM, so the term LU will be used to name each of the courses that make up the curriculum. (For more details follow the link to see Annex E).

21 LU emerged from the knowledge integration exercise, the distribution of which by training areas can be seen in the following section. This way of conceiving the LU, since it refers to problems or situations related to the field of Physics Teaching and not to the topics as the main object, allows maintaining the validity of the master's degree as knowledge in the area advances. The order of the courses was defined based on the hierarchy of competences of the graduation profile of an educational physicist, through the application of the Morganov-Heredia matrix (follow the link to see Annex F) described by Ramírez et al. (2013).

Likewise, the type of course was identified based on the load with respect to the types of knowledge; the LU with the highest load of conceptual knowledge was identified as a course, those with the highest load towards procedural knowledge as a workshop or seminar, and those that presented a balance between both as a course-workshop.

The courses arise from the articulation of competences that an educational physicist must develop, the identification of knowledge related to each competence and its integration into the solution of problems related to exercise within the field of knowledge of Physics Education.

Next, the structure of the curriculum is presented according to the areas of training (see Tables 3-6) and their organization within the curriculum map (Table 3).

Table 3. Curricular map of the Master of Science in Physics Education.

Name of the Learning Unit Type of course / Hours-week / Credits Training area

Semester 1	Semester 2	Semester 3	Semester 4
		Historical and conceptual development of physics C/4/4 PB	Educational Physics and scientific literacy C/4/4 PB
Classical Physics Teaching CW/9/9 PB	Modern Physics Teaching CW/9/9 PB		
Technologies for Learning and Knowledge in physics CW/6/6 PB		Complementary topics of Physics Education 1 C or CW/4*/4* OE	Complementary topics of Physics Education 2 C or CW/4*/4* OE
	Physics Education Projects I W/5/5 SP	Physics Education Projects II W/5/5 SP	Physics Education Projects III W/5/5 SP
Interdisciplinary research seminar S/6/6 SP	Thesis seminar I S/6/6 SP	Thesis seminar II S/6/6 SP	Thesis seminar III S/6/6 SP
336 h/semester 21 h/week 21 credits	329 h/semester 20 h/week 20 credits	304* h/semester 19* h/week 19* credits	304* h/semester 19* h/week 19* credits

PB= Particular Basic; OE= Open Elective; SP= Specializing
C= Course; W= Workshop; CW= Course-Workshop; S= Seminar, * minimum

9. Determination of a program evaluation plan (internal and external). In this regard, Díaz-Barriga (1990) mentions that the curricular plan is not considered static, since it is based on needs that can change and disciplinary progress which makes it necessary for the curriculum to be constantly updated according to disciplinary needs and progress. As mentioned in the previous point, the LU revolves around problems or situations faced by an educational physicist during their professional practice, so the update will only require the adjustment of the activities and materials used for the development of the courses and not necessarily changes in terms of content, hours, or credits.

Thus, the evaluation will comply with the regulations of the UDG and the CUCEI, which, among the indicators, include the incorporation of the members of the academic core to the National System of Researchers (SNI in Spanish) and terminal efficiency. As far as the institution is concerned and, regarding external evaluation, incorporation into the CONACYT National Postgraduate System (SNP in Spanish) will be sought in the medium term.

The General Postgraduate Regulations of the University of Guadalajara, in its article 28, establishes that the evaluations of the master's programs must be carried out every two years. For this reason, in the case of the proposed program, the evaluation of the program will be given at the graduation of each cohort and will consider, from the internal point of view: terminal efficiency, scientific productivity, quality of the teaching-learning process, linkage with external bodies to the UDG and the availability of financial resources for the operation of the program. To do this, it will be necessary to implement a graduate monitoring plan, application of undergraduate surveys and constant review of the instructional design of the courses.

Likewise, the implementation of activities aimed at improving the infrastructure and capacity of workspaces (virtual and physical) will be sought through participation in calls for applications for resources. The above through the development of the following processes:

- The members of the academic nucleus will participate, individually or collectively through research groups and academic bodies, in calls for entities such as CONACYT, the Ministry of Public Education, the State Government or the UDG itself.
- The incorporation of all the members of the academic core to the SNI will be sought the year following the start of operations of the MSPE-UDG. In addition, visiting professors will be invited, initially national and later international.

Some teachers of the proposed Basic Academic Core are linked to the Postgraduate Program in Physics Education of the IPN, as well as with graduates of the same program who work in educational institutions in Mexico, Colombia, and Chile. This, initially, will facilitate the collaboration of students from different latitudes and will lay the foundations for the internationalization of the master's degree. This link will have to be formalized within the framework of the proposed postgraduate course.

The aim will be to promote the collaboration of students with peers abroad through the courses Physics Education Projects. This will also generate international links, both for the professors in charge of the courses and for the members of the tutorial committee.

Regarding the follow-up of graduates, participants are required who already have enough experience to identify the demands of the labour market or further studies and who have not spent too much time after graduation to forget some key issues of their passage through the program. Thus, the target group will be made up of people who graduated from the program between two and four years ago.

Discussion

The design of competences of the graduate of the master's degree is based on the results of the feasibility study, the training needs of the respondents and the need for educational researchers corresponding to the area of physics.

Every LU contributes directly to the development of competences by focusing on problem solving in the context of Physics Education and not on specific topics as is traditionally done. In addition, the sequence of the courses is based on the order in which the competencies should be developed based on the analysis carried out by the curriculum team using the Morganov-Heredia matrix. That is, the methodology followed to classify competencies is an excellent tool when the LU are based on competencies and not on content (Huerta & Heredia, 1976; Ramírez et al., 2013). The relevance of the curriculum design lies precisely in the above characteristics.

The master's degree aims to improve research skills and not just teaching skills. Its program tries to strengthen and expand the possibilities of addressing such diverse problems ranging from didactics to the management of spaces where physics could be cultivated as a tool to understand reality, all this was the result not only of satisfying the needs of the labour field but of a reflection by the curriculum team and consultation with experts in the area.

Although the program, being educational, will contribute to the improvement of Pedagogical Content Knowledge (PCK) (Townsend, 2016), which will indirectly result in aspects such as students' performance on tests such as PISA and the development of soft skills: Leadership, Human Connection, Communication, Creativity, Collaboration, Critical Thinking, Empathy, Problem Solving and Emotional Intelligence (Holubová, 2023), it is emphasized that its orientation is towards research, to train opinion leaders who generate knowledge about the reality of teaching and learning physics in different fields and educational levels. Therefore, Table 3 represents the courses that an educational physicist requires to train as a researcher and not directly to professionalize as a teacher.

Physics education is an interdisciplinary field, therefore, it should be performed by people trained in physics, not necessarily educators. However, interdisciplinarity requires skills that are not necessarily learned in physics disciplinary programs.

Physics Education in Mexico has focused on the problems of didactics; however, its field of action is much broader. For example, teacher training, the epistemology of physics, educational models, curriculum design and development and educational technology are addressed (Ramírez & Escobar, 2023). The above is based on the topics presented in their theses by graduates of the only postgraduate degree in physics education in Mexico (CICATA-IPN, n.d.). However, the Mexican Council of Educational Research A.C. (COMIE in Spanish) considers 18 thematic areas, including educational management and policy (COMIE, n.d.). The above makes evident the need to address issues related, among other things, to management and educational policy, even when they were considered of little interest in the feasibility study.

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