TÜRK FEN EĞİTİMİ DERGİSİ
Yıl 17, Sayı 3, Eylül 2020

Journal of
TURKISH SCIENCE EDUCATION
Volume 17, Issue 3, September 2020

http://www.tused.org

Physics Education: Systematic Mapping of Educational Innovation Articles

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Received: 09.07.2019 **Revised:** 11.04.2020 **Accepted:** 06.05.2020

The original language of article is English (v.17, n.3, September 2020, pp.315-331, doi: 10.36681/tused.2020.29)

Reference: Campos, E., Armenta, I. H., Barniol, P. & Ruiz, B. (2020). Physics Education: Systematic Mapping of Educational Innovation Articles. *Journal of Turkish Science Education, 17* (3), 315–331.

ABSTRACT

This article presents a systematic mapping review on educational innovation in the area of physics education. We identified 508 articles published in journals from 2015 to 2019 from the *Web of Science* and *Scopus* databases. We found that research in educational innovation in the teaching of physics has focused on the analysis of didactic proposals and their evaluation. The analysis reveals areas of opportunity for the area of educational management, where we found some of the most cited articles, as well as for the study of innovative extracurricular activities related to the teaching of physics. There is an inconsistency between the large proportion of articles focused on teacher education and the absence of this kind of study at the basic levels. In general, the study of educational innovation in physics takes place at the high-school and university levels. The mapping provides information that supports researchers, professors and managers interested in educational innovation.

Keywords: Physics education, educational innovation, systematic mapping.

INTRODUCTION

Educational innovation is defined as a change involving the improvement of an aspect of education that implies the emergence of a situation resulting from innovation that has been internalized on a personal level and institutionalized at the organizational level. Innovations are subject to constant and flexible review regarding characteristics such as novelty, intentionality, internalization, creativity, systematization, depth, relevance, orientation to results, permanence, anticipation, culture and diversity of agents (Ortega et al., 2007). Teachers, researchers and managers interested in improving seek to implement educational innovations that adapt to the needs of their institutions.

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© ISSN:1304-6020

Physics education research (PER), however, is a relatively new area of research, emerging approximately 40 years ago (Docktor & Mestre, 2014). Research in this area tries to reduce the gap that exists between what is intended to be taught in physics and what the student really learns. Docktor and Mestre (2014) identify six thematic areas that capture most of the research done in physics education: conceptual understanding, problem solving, curriculum and instruction, assessment, cognitive psychology, and attitudes and beliefs about learning and teaching. In this article, we seek to conduct a systematic mapping of the studies carried out in the area of educational innovation in physics education in recent years, which may give an account of the form of research development in this area.

The systematic mapping of literature offers a broad review of primary studies in a specific area with the purpose of identifying the evidence that is available on the subject (Kitchenham y Charters, 2007). Following the method of Petersen et al. (2008), a systematic mapping of 508 articles published in journals between 2015 and 2019 was carried out in the *Web of Science* (WoS) and *Scopus* databases. We analyze the distribution of the publications by: (1) database and type of study, (2) first author and citation, (3) country of affiliation of the first author, (4) context and educational level in which they develop the studies and (5) thematic fields of educational innovation in physics. The importance of the present mapping is that it provides data on educational trends in the area of physics education that can serve as a reference for researchers, professors, managers and training communities of public and private entities that are interested in supporting educational innovation in physics and other related areas.

Physics Education

We searched for previous systematic literature reviews in the area of physics education using the search string described in Table 1. The expressions B1–B7 were taken from the expressions recommended by Calderon and Ruiz (2015) for this type of search. The expressions "literature review" (B8) and "resource letter" (B9) were included to specify the area of study. The first, "systematic review," is the term most used to refer to literature reviews, while the second, "resource letter," is used in articles that provide an integrated view of previous research conducted on a specific topic.

Table 1. *Search string for previous systematic reviews in physics education*

(A1) "*Physics education*" AND	(B1) "*Systematic review*" OR
	(B2) "*Research review*" OR
	(B3) "*Systematic overview*" OR
	(B4) "*Systematic literature review*" OR
	(B5) "*Systematic mapping*" OR
	(B6) "*Mapping study*" OR
	(B7) "*Systematic mapping study*" OR
	(B8) "*Literature review*" OR
	(B9) "*Resource letter*"

In the *Scopus* and WoS databases, no previous systematic review was found, but a study was found that presented a thematic review of studies in physics education between the years 2013 and 2015 by Çepni, Ormanci and Kacar (2017). In this study, the authors analyzed the studies published in the six journals that they considered the most relevant in physics education: *Journal of Research in Science Teaching*, *Science Education*, *Studies in Science Education*, *International Journal of Science Education* and *Journal of Science Education and Technology*. The authors reported that the analyzed studies focused on the concept of energy with undergraduate students but found few studies that analyzed the effects of teaching approaches (such as context-based learning, research-based learning, etc.)

Besides the study of Çepni, Ormanci and Kacar (2017), we found two reviews of literature on the use of computers in physics education (Cardona & Lopez, 2017; Velasco & Buteler, 2017), a qualitative meta-synthesis of science education studies (Küçükaydın, 2019), and two thematic analyses on different areas of science education (Ormanci & Çepni, 2019; Ormanci, 2020). Studies of the type "resource letter" were also identified. Table 2 shows the five most important studies of this type in recent years. The first focuses on the whole area of physics education, while the others focus on problem solving (article 2), demonstrations used in the education of physics (article 3), active learning (article 4) and research-based assessment instruments (article 5). This type of article provides a list of bibliographic resources with some annotations and suggestions to guide teachers and non-specialists in the field of physics to understand and teach a specific topic.

Table 2. *Description of the five most important "resource letter" studies carried out in the field of physics education in recent years*

Title of the article	Citation
1. Resource Letter: PER-1: Physics Education Research	McDermott & Redish, 1999
2. Resource Letter RPS-1: Research in problem solving	Hsu, Brewe, Foster & Harper, 2004
3. Resource Letter PhD-2: Physics Demonstrations	Berg, 2012
4. Resource Letter ALIP-1: Active-Learning Instruction in Physics	Meltzer & Thornton, 2012
5. Resource letter RBAI-1: Research-based assessment instruments in physics and astronomy	Madsen, McKagan & Sayre, 2017

Çepni, Ormanci and Kacar (2017) highlight the importance of systematically analyzing the publications in academic journals and publishing the results to ensure a clear visibility of the state of a relevant field, such as physics education. They also indicate that the last bibliographic review on research in physics education prior to theirs was conducted in 1984. In this study, we conducted a systematic review of educational innovations in the area of physics education between the years 2015 and 2019 in the *Scopus* and WoS databases.

Systematic Literature Review

This study follows the method of Petersen et al. (2008) to perform systematic mappings. The five steps defined by these authors are illustrated in Figure 1. Subsequently, each of these steps is described.

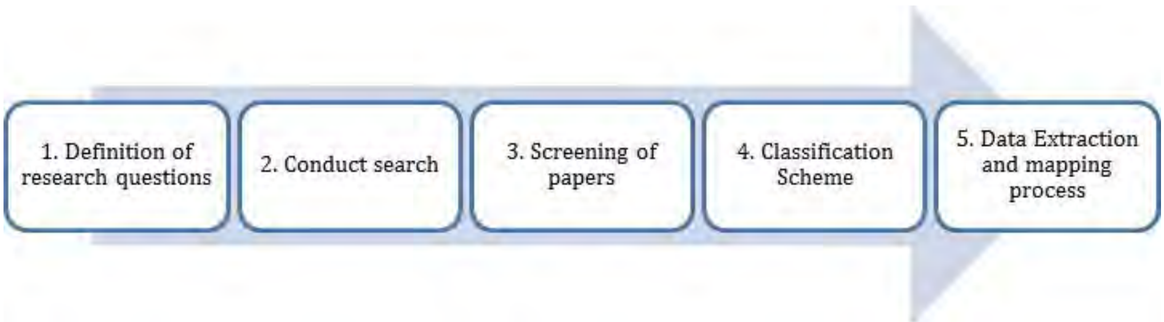

Figure 1. Process followed to perform the present systematic mapping

Step 1. Definition of research questions

In this step, the problem was defined through research questions that directed the subsequent analysis. The five questions are detailed in Table 3.

Table 3. *Research questions*

	Question	Description
RQ1	How are publications on innovation in physics education distributed in the period between 2015 and 2019 in the databases?	1. Database (*Scopus* y *WoS*) 2. Type of study (theoretical and empirical)
RQ2	Which publications have had the greatest impact in the area?	1. First authors who have published the most 2. First most-cited authors 3. Most cited publications
RQ3	Which are the countries that carry out research in the area?	1. Publications by country of affiliation of the first author
RQ4	In what context and educational level have the studies been carried out?	1. Context 2. Educational level
RQ5	What are the most frequent research lines in the articles on innovation in physics education?	1. Most frequent thematic fields

Step 2. Conduct search

In this step, we defined the criteria that were followed to perform the search in the *Scopus* and WoS databases from January 2015 to December 2019. We conducted several pilot searches to test and adjust the search string. The final string consisted of the Boolean expression composed of the terms mentioned in Table 4.

The term "physics education" (A1) was included to delimit the area. The terms "educational innovation" (B1) and "instructional innovation" (B2) were taken from the Education Resources Information Center (ERIC) thesaurus. The term "innov*" (B3) was applied for the truncated search of all keywords related to innovation. The terms B4–B16 are the synonyms of "educational innovation" found in the thesaurus. The search was restricted to studies cataloged as articles (classified as "article" or "article in press" by the same databases).

Table 4. *Terms of the final search string*

(A1)	"*Physics education*" AND	(B1)	"*Educational innovation*" OR
		(B2)	"*Instructional innovation*" OR
		(B3)	"*Innov**" OR
		(B4)	"*Educational change*" OR
		(B5)	"*Educational development*" OR
		(B6)	"*Educational environment*" OR
		(B7)	"*Educational improvement*" OR
		(B8)	"*Educational technology*" OR
		(B9)	"*Experimental colleges*" OR
		(B10)	"*Experimental curriculum*" OR
		(B11)	"*Experimental schools*" OR
		(B12)	"*Experimental teaching*" OR
		(B13)	"*Nontraditional education*" OR
		(B14)	"*Research and development*" OR
		(B15)	"*School restructuring*" OR
		(B16)	"*Theory practice relationship*"

Step 3. Screening of papers

For the screening of the works compiled under the search criteria of step 2, we used the following exclusion criteria:

- Articles related to medical education (e.g., "medical physics").
- Articles related to sports education (e.g., "physical education").

- Articles of opinion and scientific dissemination without any degree of theoretical or empirical research.
- Articles whose central research topic was related to other disciplines such as environmental and chemical education.

We reviewed the abstracts of the works collected in step 2 to indicate which were candidates for elimination under the criteria established above. We directly removed the articles in which we had agreement. Where we had disagreement, we discussed until reaching a consensus on elimination or retention. In this way, we identified 508 articles on educational innovation in physics education in the *Scopus* and WoS databases between 2015 and 2019.

Step 4. Classification Scheme

Categorization schemes are widely used in literature reviews. The categorization schemes of the present study were constructed taking as reference categorizations already defined or seeking to identify categories that emerged when analyzing the abstracts of the works. The categories used are summarized in Table 5.

Table 5. *Categories used*

Question	Construction Criterion	Categorization
RQ1-1, RQ2, RQ3 y RQ4	Contexts of publications and implementations	They were categorized by their respective contexts.
RQ2-2	Kumar categorization (2008) on types of study	Empirical: studies based on experience or observations. Conceptual: studies focused on abstract aspects or theory.
RQ5	Categories that emerged from the analysis taking as reference Beichner (2009), and Docktor and Mestre (2014) in the area of physics education.	(1) Didactic proposal (2) Evaluation of didactic proposals (3) Teacher training and preparation for future teachers (4) Curriculum reflection (5) Social aspects of learning in the classroom (6) Students' conceptual understanding (7) Educational management in physics education (8) Studies on research in physics education

The thematic fields (RQ5) that emerged from the analysis were based on Beichner (2009) and Docktor and Mestre (2014). Beichner (2009) recognizes eight categories: (1) conceptual understanding, (2) epistemology, (3) problem solving, (4) attitudes, (5) social aspects, (6) technology, (7) evaluation of specific instructional interventions and (8) instructional materials. Docktor and Mestre (2014) identify six areas that capture most of the research conducted in physics education: (1) conceptual understanding, (2) problem solving, (3) curriculum and instruction, (4) evaluation, (5) cognitive psychology and (6) attitudes and beliefs about learning and teaching. These fields were adapted to the area of innovation in physics education from the review and analysis of the articles in the database.

Step 5. Data Extraction and mapping process

The final step consists of extracting the data and the mapping the articles. The database was created in Excel. The link to the database is https://tinyurl.com/y2526nes. In this database we present the 508 articles with identification keys A1 to A508 and the categorizations necessary to answer the research questions.

RESULTS AND DISCUSSION

In this section, we present the systematic mapping in the order of the research questions.

a) RQ1. Distribution in the Databases

We identify the studies that are in *Scopus*, in WoS and in both, then categorized the studies as empirical or theoretical/conceptual, identifying a total of 377 (74%) empirical and 132 (26%) theoretical/conceptual studies. In *Scopus* exclusively, there are 102 articles, of which 73 are empirical and 29 are theoretical/conceptual (Figure 2). The total number of articles found exclusively in WoS is 346; of them 261 are empirical and 85 theoretical/conceptual. The number of articles found in both *Scopus* and WoS is 61, of which 43 are empirical and 18 theoretical/conceptual. As shown in Figure 2, the relationship between empirical and theoretical/conceptual articles (74:26) remains very close in all classifications. This ratio is 72:28 for *Scopus*, 75:25 for WoS and 70:30 for those articles found in both.

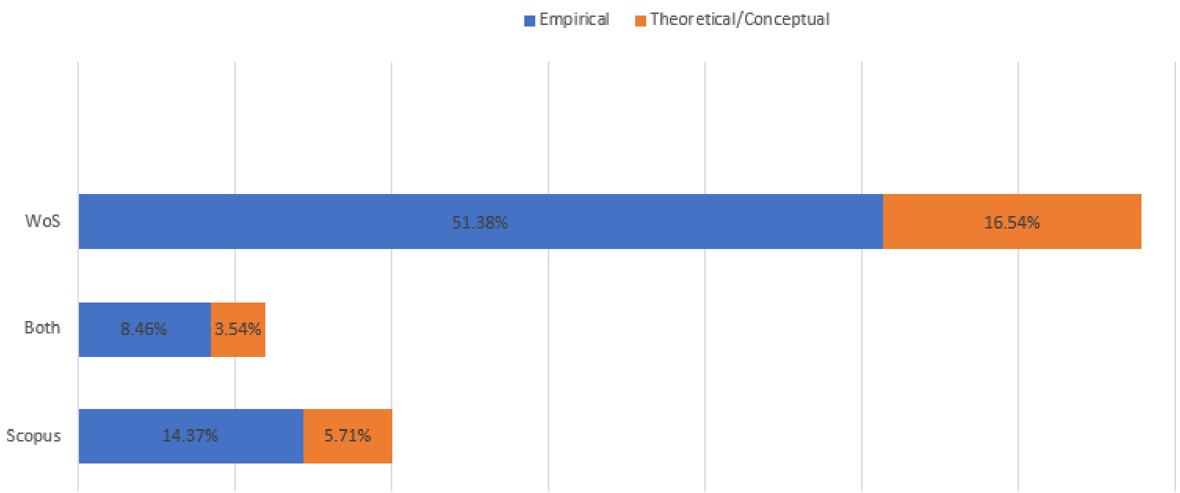

Figure 2. Distribution of publications by database and type of study

b) RQ2. Impact of the innovation in physics education

We identified the first authors who had two or more publications in the time range covered by the database (2015 to 2019). There is a tendency to publish more than one article in WoS more than in Scopus (Table 6). The first authors who published the most are Foote, K. T.; Imashev, G.; Marshman, E.; Viennot, L.; and Wang, J. Y., each with four articles. They are followed by Haglund, J.; Li, J.; and Tiruneh, D. T., each with three articles. Most of their publications were in WoS journals. This could be an indicator that WoS indexes more educational innovation journals than Scopus.

We also identified the 10 most cited publications in Scopus and in WoS separately, since both databases use different citation indicators. We used the “cited by” feature from the Scopus database and the “total times cited count” from the WoS database. The 10 most cited publications in Scopus are shown in Table 7 and those of WoS in Table 8. Each table presents the identifier from the database, the authors, citations, and thematic field in which they are categorized (RQ5) and their academic level (RQ4).

Table 6. *First authors with the highest number of publications in the different databases*

Author	*Scopus*	WoS	Both	Total
Foote, K. T.	1	1	2	4
Imashev, G.	2	2	0	4
Marshman, E.	0	4	0	4
Viennot, L.	0	4	0	4
Wang, J. Y.	0	3	1	4
Haglund, J.	0	2	1	3
Li, J.	0	2	1	3
Tiruneh, D. T.	0	3	0	3

Table 7. *Most cited articles in Scopus, their thematic fields and academic levels*

Identifier	Authors	Citations	Thematic field	Educational level
A237	Sun et al.	41	Evaluation	Open education
A152	Madsen et al.	34	Investigation	Extracurricular
A50	Daineko et al.	25	Didactic proposal	University
A204	Reeves et al.	20	Investigation	Not explicit
A117	Johnson-Glenberg et al.	19	Evaluation	University
A149	Liu et al.	18	Didactic proposal	High school
A130	Khatri et al.	18	Management	Not explicit
A23	Battista et al.	17	Didactic proposal	Extracurricular
A71	Gabdulchakov et al.	17	Teacher training	University
A43	Corbo et al.	16	Management	University
A39	Chasteen et al.	16	Management	University

Table 8. *Most cited articles in WoS, their thematic fields and educational levels*

Identifier	Authors	Citations	Thematic field	Educational level
A102	Holmes et al.	51	Didactic proposal	University
A103	Hou	44	Evaluation	University
A203	Redish et al.	39	Social aspects	High school
A152	Madsen et al.	36	Investigation	Extracurricular
A155	Marshman et al.	31	Conceptual understanding	Not explicit
A24	Baxter et al.	29	Didactic proposal	Elementary
A27	Cai et al.	25	Didactic proposal	High school
A112	Izutani et al.	25	Didactic proposal	Postgraduate
A407	Lo et al.	24	Didactic proposal	High school
A248	Tiruneh et al.	24	Conceptual understanding	University

c) RQ3. Countries with research in the area

We used the country of the first author's university to identify the geographical distribution of the affiliations of the first authors (RQ3) of the 508 articles. The total of the publications is distributed in 67 countries. The United States is the country with the highest number of publications (98), followed by Spain (38) and Turkey (34), Indonesia (24), China (22) and Germany (22). The rest of the countries have less than 20 publications in the five-year period included in this study (Figure 3). It is important to emphasize that only the origin of the affiliated institution of the first author was taken into account, so that collaboration between countries cannot be appreciated.

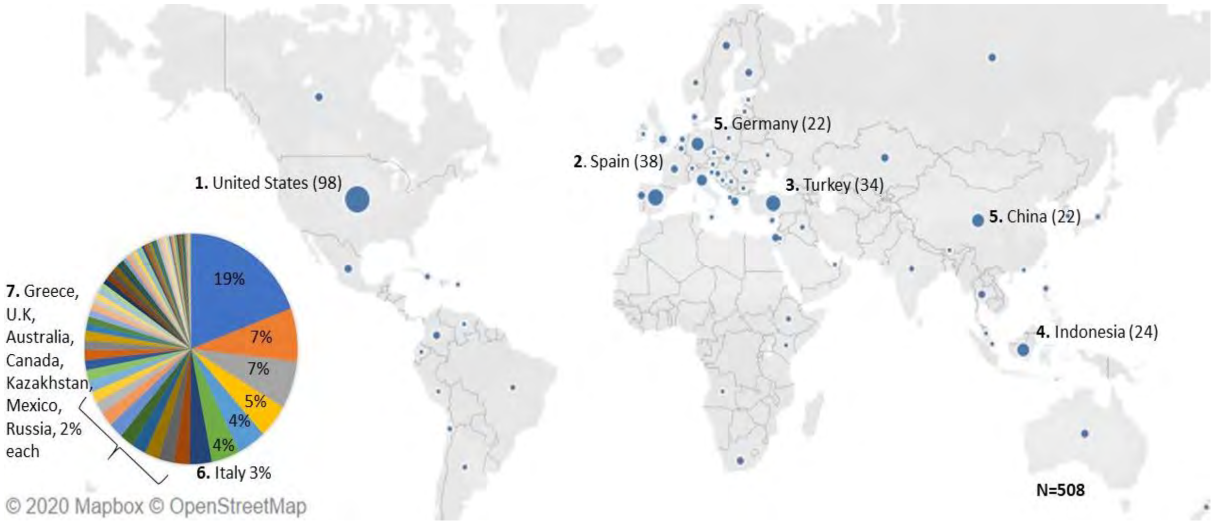

Figure 3. Geographic distribution of affiliation of first authors

d) RQ4. Educational level and Context

Most of the articles (94%) were located in a school context, while 32 articles were developed in an extracurricular context (6%). Within the extracurricular contexts, those that are located within the industry or research stand out (Table 9 and Figure 4). In the category of others, research was found in museums, observatories, competitions, library work, programs that promote science and surveys of graduates about their energy culture.

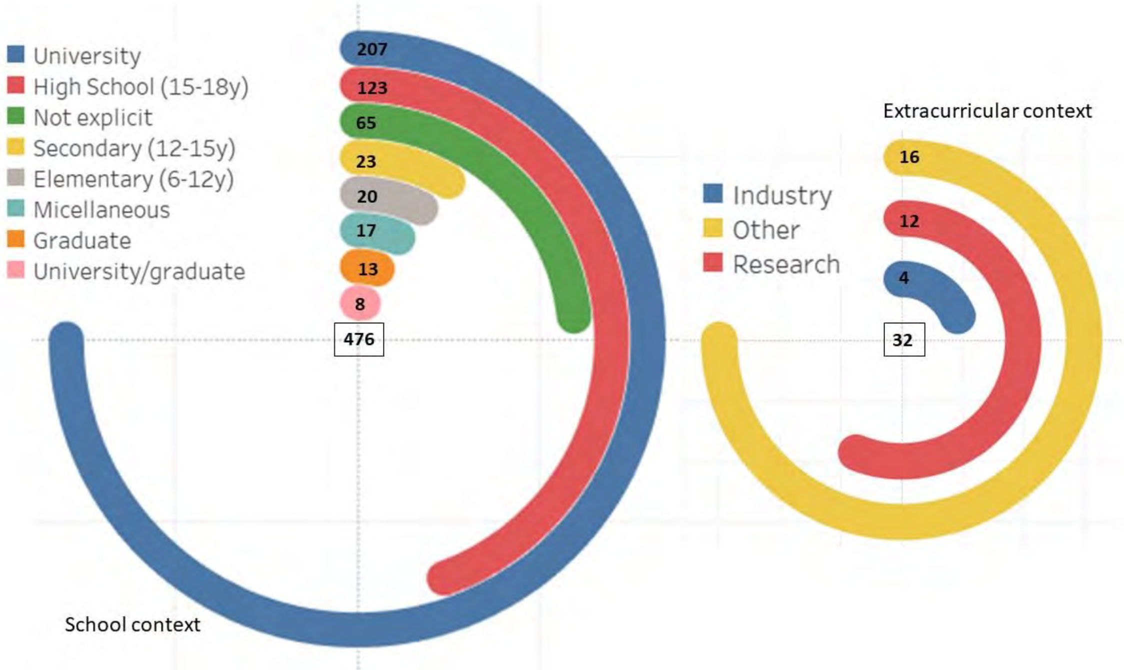

Figure 4. Articles per context

Table 9. *Distribution of articles according to their context*

Context		Articles	Percentage
Extracurricular	Industry	4	13%
	Research	12	38%
	Others	16	50%
	Total Extracurricular	**32**	**6%**
School	Primary (6 to 12 years old)	20	4%
	Secondary (12 to 15 years old)	23	5%
	High School (15 to 18 years old)	123	26%
	University (over 18 years old)	207	43%
	University / Graduate	8	2%
	Graduate	13	3%
	Miscellaneous	17	4%
	Not explicit	65	14%
	Total School	**476**	**94%**

Studies in the context of the industry make suggestions of content that can be used for teaching. The studies in the research context are focused on research analysis or some characteristics of researchers in physics education. In the school context (476 articles), we identified and categorized the educational level and the school context in which the research was developed. Most of the studies are located at the university level (43%), followed by the high school level (26%). Fourteen percent do not specify the educational level, but there were indications of school context.

Of the articles of studies carried out in school contexts, more than half focus on the teaching of physics (274, 57.56%), while the other half focus on teacher training (21.43%), interdisciplinarity (linking physics with other subjects such as mathematics, chemistry, reading), transversal contents (attitudes, gender, motivation, preference factors), links with other sectors and others. Studies devoted to the teaching of physics focus on physics courses. They analyze student conceptions or teaching proposals at different levels and with different emphasis. One hundred eighty-six are located at a university or high-school level.

In the context of teacher education and training (104 articles), most of the studies are concerned with university (59) and postgraduate education (24). Most teacher education studies (56) are located in these two levels, and only two are in high school and one did not specify the level. The studies on current professors are 48, of which, 22 are located in high-school level and 10 in university level. Only four of these studies is at the basic level.

Thus, not only are there few articles in extracurricular contexts but very few suggest links to extracurricular contexts or interdisciplinary links with other subjects. The reported works on teacher training are abundant compared to other contexts; however, few works focus on the basic level.

e) RQ5. Identification of thematic fields

Eight categories were identified that emerged from the titles, keywords and abstracts of the publications. In Figure 5 and Table 10, the fields and the percentage of presence of each are shown.

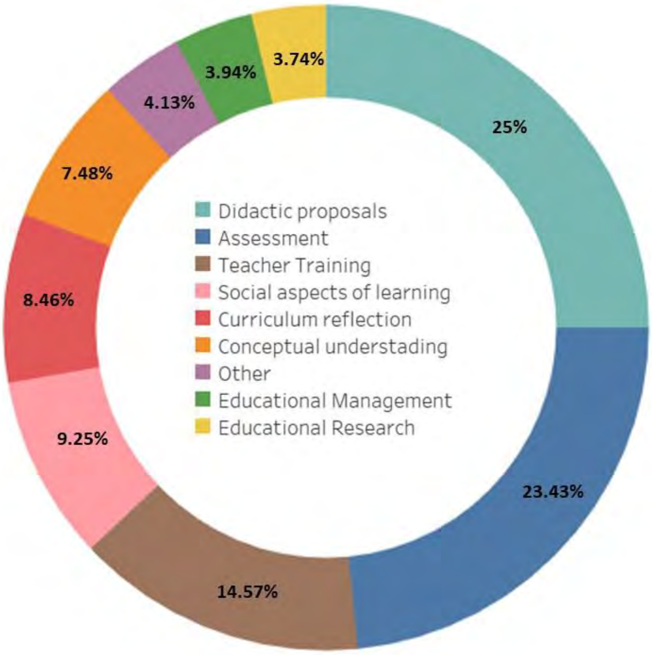

Figure 5. Thematic fields of mapping on physics education (508 articles)

(1) Didactic proposal. We identified the publications, both empirical and theoretical/conceptual, in which didactic activities or conceptual models are proposed to improve the teaching/learning processes on various physics topics for different educational levels. This field has been identified before by other authors as the instructional materials (Beichner, 2009) and curriculum and instruction in physics fields (Docktor & Mestre, 2014), which indicates that it has been an important area of research in education in physics in the last decade. For example, the A3 publication is located in this field, since the performance of students is explored when they use an interactive course module in the understanding of electrical circuits (Akdemir, 2015).

(2) Evaluation of didactic proposals is a category identified by Beichner (2009) as the “evaluation of specific instructional interventions”. In this category, we grouped the publications whose purpose is to evaluate the effectiveness or the impact that any specific instructional intervention can have, for example, on the learning of physics. The instructional interventions evaluated can be designed by the authors themselves or by others. Publication A6 illustrates this category as an example. The authors study the efficiency of the physics module of the PTechLS model, previously developed by one of the authors, with students from a rural high school in Malaysia (Alias et al., 2015). This publication is placed in this category because even though the model was proposed by one of the authors of the publication, the article focuses on its evaluation and not on its presentation.

(3) Teacher training and preparation for future teachers. In this field, we included publications in which teachers are prepared to improve the teaching of physics or in which strategies are implemented to prepare future physics teachers. Although this category has not been named in the same way, Docktor and Mestre (2014) highlighted a similar field, “Attitudes and beliefs about teaching and learning”, in which they locate the beliefs and values of the teaching staff when teaching physics, as well as the preparation of teaching assistants. For example, publication A28 studies the role of mentoring in the construction of the professional identity of physics teachers who are beginning their career as teachers (Cameron & Grant, 2017).

Table 10. *Thematic fields of the articles and their identifiers.*

Thematic field	N	Identifiers of the articles	Educational level
Didactic proposals	127	A100, A102, A107, A110, A112, A121, A122, A129, A139, A14, A144, A146, A149, A151, A156, A158, A16, A165, A172, A178, A183, A188, A192, A196, A197, A198, A2, A20, A205, A207, A208, A21, A210, A215, A216, A228, A23, A233, A239, A24, A241, A242, A244, A246, A247, A25, A255, A257, A260, A261, A262, A267, A27, A271, A295, A297, A299, A3, A30, A301, A302, A304, A307, A311, A319, A32, A321, A323, A33, A336, A337, A338, A343, A344, A345, A351, A352, A357, A36, A361, A363, A365, A370, A375, A386, A395, A399, A405, A407, A413, A42, A421, A422, A425, A431, A432, A441, A444, A451, A453, A456, A463, A471, A478, A480, A491, A493, A494, A495, A496, A499, A50, A500, A508, A52, A56, A61, A62, A63, A68, A72, A76, A79, A8, A82, A83, A94	Primary: 2% Secondary: 6% High school: 28% University: 43% Postgraduate: 4% Miscellaneous: 2% Extracurricular: 2% Not stated: 18%
Assessment of didactic proposals	119	A103, A109, A113, A117, A120, A124, A125, A13, A131, A135, A136, A140, A141, A145, A148, A154, A160, A162, A17, A173, A19, A200, A201, A202, A217, A222, A223, A227, A229, A232, A235, A236, A237, A240, A243, A245, A249, A250, A251, A252, A26, A266, A269, A274, A285, A293, A294, A303, A305, A306, A308, A309, A310, A312, A315, A316, A318, A320, A324, A331, A335, A349, A356, A359, A368, A371, A374, A376, A377, A378, A38, A383, A384, A385, A388, A389, A392, A394, A397, A398, A409, A412, A414, A420, A423, A424, A430, A439, A44, A442, A445, A449, A450, A454, A455, A458, A46, A461, A465, A479, A48, A482, A485, A489, A498, A505, A506, A507, A54, A55, A6, A60, A64, A65, A75, A78, A88, A89, A90	Primary: 5% Secondary: 6% High school: 30% University: 40% Postgraduate: 3% Miscellaneous: 1% Extracurricular: 1% Not stated: 14%
Teacher training and preparation for future teachers	74	A115, A119, A12, A126, A127, A128, A133, A138, A157, A159, A163, A166, A170, A184, A185, A191, A194, A211, A213, A220, A225, A234, A238, A253, A256, A268, A270, A273, A276, A279, A28, A284, A286, A287, A298, A327, A328, A334, A34, A340, A342, A354, A360, A364, A37, A372, A373, A382, A393, A400, A426, A429, A434, A436, A437, A452, A459, A468, A469, A47, A472, A475, A488, A492, A503, A53, A57, A58, A66, A71, A74, A81, A84, A9	Secondary: 3% High school: 18% University: 57% Postgraduate: 8% Miscellaneous: 4% Extracurricular: 1% Not stated: 9%
Social aspects of learning in the classroom	47	A104, A108, A118, A132, A142, A164, A167, A171, A175, A179, A180, A181, A199, A203, A214, A226, A265, A281, A300, A330, A332, A339, A341, A362, A367, A369, A387, A390, A391, A4, A404, A406, A410, A411, A415, A418, A427, A428, A435, A448, A460, A477, A483, A484, A497, A59, A93	
Curriculum reflection	43	A1, A105, A106, A143, A161, A169, A176, A18, A182, A189, A190, A193, A206, A218, A219, A221, A230, A275, A280, A283, A288, A290, A291, A296, A322, A325, A346, A348, A438, A440, A446, A457, A464, A473, A5, A501, A7, A73, A77, A80, A85, A95, A97	
Students' conceptual understanding	38	A111, A116, A123, A134, A147, A15, A150, A153, A155, A168, A174, A177, A212, A248, A259, A263, A264, A277, A289, A29, A313, A314, A329, A347, A353, A355, A396, A40, A408, A433, A462, A486, A487, A490, A502, A86, A96, A99	
Educational management	20	A130, A209, A272, A278, A326, A358, A379, A380, A381, A39, A419, A43, A447, A45, A466, A481, A51, A69, A70, A92	
PER	19	A10, A137, A152, A204, A22, A254, A258, A292, A35, A401, A402, A403, A417, A443, A474, A476, A49, A87, A91	
Others	21	A101, A11, A114, A186, A187, A195, A224, A231, A282, A31, A317, A333, A350, A366, A41, A416, A467, A470, A504, A67, A98	

(4) Curriculum reflection. In this field, we grouped those theoretical/conceptual publications in which the authors reflect on the need for innovations or curricular adaptations in the area of physics and in related areas. For example, in publication A7, the authors reflect on the importance of the laws of physics as part of curricular development to empower society and face the needs of the future (Alizoti et al., 2016). The problem is presented based on the curricular needs identified by UNESCO. In publications in this field, the authors refer to literature or educational authorities to highlight the area of physics within the school curriculum.

(5) Social aspects in learning within the classroom. This category includes publications that focus on social aspects that influence the teaching and learning of physics, such as language. This field has also been identified by Beichner (2009) as "social aspects." In publication A4, the authors found that students in Saudi Arabia have difficulty understanding physics textbooks in English, which hinders their learning of physics (Albadi et al., 2017).

(6) Conceptual understanding of students. This category has been one of the main interests of the research area in the education of physics since its inception, so it has been identified in the literature as "conceptual understanding" (Beichner, 2009, Docktor and Mestre, 2014). This field includes research that studies how students understand certain physics topics, through various tools. For example, in publication A29, the authors studied how high-school students use representations to understand the concept of an electric field (Cao and Brizuela, 2016).

(7) Educational management in physics education groups studies that refer to the management of innovation processes in the area of educational institutions. For example, in publication A43, the authors present a framework for transforming the departmental culture and supporting educational innovation (Corbo et al., 2016).

(8) Studies on research in physics education refer to those studies on the characteristics of the research carried out in the area. For example, publication A10 analyzed how the research area of physics education has evolved since its inception (Anderson, Crespi and Sayre, 2017). They focused mainly on the collaborative networks that have emerged among researchers in the area. Other publications in this field focus on the processes of carrying out research in the education of physics, such as possible methodologies or meta-analysis.

ANALYSIS AND DISCUSSION

Most frequent thematic fields

The three most frequent thematic fields are didactic proposals (25%), evaluation of didactic proposals, (24%) and teacher training and preparation for future teachers (15%). It is interesting to study the trends observed in the most cited articles within each of these fields.

In these three fields, there are more studies focused on the university level (Table 10), followed by the high-school level. Teacher education and training have an even higher percentage of studies dedicated to the university level than the distribution of the university level in all articles of the database (57% vs 43%; Table 9). However, the didactic proposals or their evaluation are little reported or investigated at the basic levels, and no studies were found on teacher training and preparation at these levels.

We found eight articles to be the most cited in the area of didactic proposal: Daineko et al. (2017), Liu et al. (2017) and Battista et al. (2015) in *Scopus* (Table 7), and Holmes et al. (2015), Baxter et al. (2017), Cai et al. (2017), Izutani et al. (2016) and Lo et al. (2018) in WoS (Table 8). We can observe that several studies focus on innovations in laboratories. Daineko et al. (2017) propose virtual laboratories to teach natural sciences and present an example in physics courses. Liu et al. (2017) implemented the use of mobile devices for scientific modeling in high school physics laboratories. Battista et al. (2015) analyze the contribution of an interdisciplinary laboratory to promoting research and education. Holmes et al. (2015) propose a didactic structure of good laboratory practices that increase the capacity to make decisions based on data. Izutani et al. (2016) present a laboratory program as a teaching aid for the characterization of materials. The other studies focus on technological innovations; Baxter et al. (2017) used social peer-robots to support child learning and identified that personalization of the social behavior promotes learning, Cai et al. (2017), used augmented reality for the teaching of magnetic fields, and Lo et al. (2018) applied the meta design theory first principles of instruction to design their flipped classroom approach

In the second most frequent field, evaluation of didactic proposals, two articles were the most cited in either *Scopus* or WoS (Tables 7 and 8): Johnson-Glenberg et al. (2016) and Hou (2015). These studies evaluate different didactic proposals focusing on different variables related to student learning. Johnson-Glenberg et al. (2016) studied the effects that embodied learning and the digital platform have on the retention of physics concepts, specifically of centripetal force. Hou (2015) analyzed the learners' flows and behavioral patterns in game-based learning activities that utilize a role-playing simulation game. It is interesting to note that these two studies are related to the evaluation of modeling proposals at the university level through different methods, pre-test and post-test design (Johnson-Glenberg et al., 2016) and a cluster analysis of video-taped interactions between students (Hou, 2015).

The third most frequent field is teacher training and teacher preparation. In it, only one article is most cited in the Scopus database (Table 7): Gabdulchakov et al. (2016). This study presents new strategies for teacher training at the university level. Gabdulchakov et al. (2016) propose a reform in the strategy for training university science teachers based on a personal approach. The approach of the article is theoretical, and its main goal is to identify the main components of the new strategy of teacher training.

Thematic fields and most cited articles

Tables 7 and 8 show the ten most cited articles in *Scopus* and WoS. Figure 6 shows the distribution in the thematic fields of the 17 most cited articles in both databases and in the total number of articles.

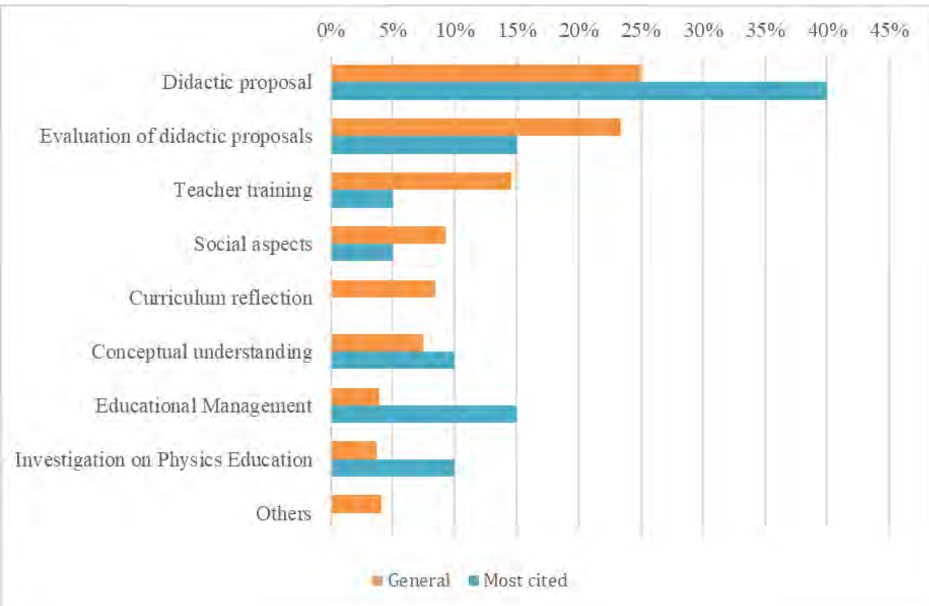

Figure 6. Articles within the most cited by thematic field

Two thematic fields are observed that are not very frequent in the database (Figure 6) but are among the most cited: educational management (15% in the most cited, versus 4% in general) and research (10% in the most cited, versus 4% in general). This shows the relevance of these thematic areas for researchers. We present a general analysis of the most cited articles of these two thematic fields.

The three most cited articles in educational management are the articles by Chasteen et al. (2015), Khatri et al. (2016) and Corbo et al. (2016). These articles have in common that they present general recommendations for researchers who wish to manage educational innovations at the institutional level. The study by Chasteen et al. (2015) presents the effect of a change model at departmental level, the study by Khatri et al. (2016) presents a model for designing instructional material for successful propagation and the study by Corbo et al. (2016) provide a research-based framework for promoting institutional change in higher education.

The two most cited articles in research, meanwhile, are those by Madsen et al. (2015) and Reeves et al. (2016), which show results and/or general recommendations related to the investigation. The article of Madsen et al. (2015) is one of the most cited articles in both databases. They present a meta-analysis of studies related to the impact on students' beliefs about the learning of physics (Madsen, 2015). The study by Reeves et al. (2016) presents a contemporary perspective of the social sciences on the validity and validation process of tests.

CONCLUSIONS

In this study, a systematic literature mapping (Petersen et al., 2008) was carried out on educational innovation in the area of physics education in the Scopus and WoS databases from 2015 to 2019. This represents the first systematic mapping of academic publications that relate directly and in a generalized manner the topics of physics education and educational innovation without focusing only on particular topics of the teaching of physics. In this way, a link is presented between the results of educational research and its application in teaching practice, as well as the identification of emerging topics in research on educational innovations in the teaching of physics.

The main findings of the study indicate that (1) in both Scopus and WoS, there is a greater presence of empirical articles (74%) compared to theoretical/conceptual ones (26%); (2) the first authors who published the most did so mainly in journals of the WoS database; (3) the countries in which the most has been published on educational innovation in physics education in Scopus and WoS are the United States, Spain, Turkey, Indonesia, China and Germany; (4) most of the studies are located in a school context of the physics class and at the university level, with few studies suggesting the link with extracurricular contexts; and (5) the three main thematic fields in educational innovation in the education of physics are didactic proposals (25%), evaluation of didactic proposals (24%) and teacher training (15%).

We identified that educational innovations in the teaching of physics have focused on didactic proposals and their evaluation (49% as a whole). This reveals an area of opportunity for the area of educational management, where some of the most cited articles are found, as well as for the area of research on social aspects of learning within the classroom in specific contexts and the study of innovative extracurricular activities related to the teaching of physics. Likewise, in accordance with the results of Çepni, Ormanci and Kacar (2017), the opportunity to direct the research of didactic proposals towards an integrating character of knowledge is perceived, since most of them retain a disciplinary approach within physics, avoiding their relationship and integration with other areas of knowledge. In particular, there is an opportunity in the evaluation and analysis of educational proposals at the basic level, but above all in the training of teachers at the basic levels. Due to the number of articles published and the citation index, the thematic field of didactic proposals is the most relevant regarding educational innovation in physics education. The citation index in the fields of research and educational management indicates that the scope of these areas is relevant, even if the number of articles is small.

The main limitations for this systematic review are circumscribed in the units of analysis (metadata and abstracts) and the sources in which the searches were conducted (Scopus and WoS). These limitations did not make it possible to recognize publications that have not been identified with the word "innovation" or its derivatives in the keywords, abstract, title or in the body of the document, even when the work could provide an educational innovation. The present mapping provides a general overview of educational trends that can enhance deepen literature exploration routes for researchers, professors, managers and training communities of public and private entities interested in specific research topics in the area of educational innovation in physics. Potentially, it is also a guide to trace investigation routes according to the interests of the instances and areas of opportunity reported, as well as in the construction of theoretical frameworks for research in educational innovation in physics education.

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