Plastics: a literature review in science education (2010–2019)

Plásticos: revisión bibliográfica en Didáctica de las Ciencias Experimentales (2010-2019)

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Abstract

Although plastics form part of everything that surrounds us due to their excellent properties, they also represent an environmental problem that requires an educational response. This paper presents an exploratory and descriptive study of the educational research published in this field, both nationally and internationally, over the past decade using the PRISMA declaration for systematic reviews. The analysis was performed using a selection of journals with confirmed quality indices in science education (six Spanish and four international). For each study, the authorship, nature (research or innovation), plastics-related content, educational level (infant, primary, secondary or university), methodology used (quantitative, qualitative or mixed) and teaching focus (propedeutic or competence-based) were analysed. The review shows that such studies are in the minority in the literature analysed, not exceeding 3.4% nationally or 2.3% internationally, with educational research accounting for the majority of studies. With regard to the content covered, the composition and properties of plastics

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predominate, with studies related to environmental awareness or solutions to the problem, which are considered to be key, receiving relatively little attention. It is also seen that the authorship of non-university teachers is relatively low and that qualitative methodologies are used most often. Moreover, the transmission of content rather than competence-based teaching predominates. The above suggests that the problem of plastics remains a challenge in teaching.

Key words: plastics, literature review, educational research, educational innovation

Resumen

Los plásticos forman parte de todo lo que nos rodea por sus excelentes propiedades, pero también suponen un problema ambiental que demanda una respuesta educativa. Este trabajo presenta un estudio exploratorio y descriptivo sobre la investigación didáctica publicada sobre este tema en el contexto nacional e internacional en la última década empleando la declaración PRISMA para revisiones sistemáticas. El análisis se realizó en una selección de revistas con índices de calidad contrastados en Didáctica de las Ciencias Experimentales (seis españolas y cuatro internacionales). Para cada trabajo se analizó la autoría, su naturaleza como investigación o innovación, los contenidos tratados sobre plásticos, el nivel educativo (infantil, primaria, secundaria o universidad), la metodología empleada (cuantitativa, cualitativa o mixta) y el enfoque de enseñanza (propedéutico o competencial). La revisión muestra que estos trabajos son una minoría en el conjunto de la bibliografía analizada no superando el 3,4% en el ámbito nacional y el 2,3% en el internacional, acaparando investigaciones educativas el mayor número de trabajos. Respecto a los contenidos abordados predominan la composición y propiedades de los plásticos teniendo poca presencia trabajos relacionados con concienciación ambiental o soluciones al problema, considerados aspectos clave. Se observa también que la autoría de profesorado no universitario es relativamente baja y que la metodología cualitativa es la más usada. Asimismo, predomina la trasmisión de contenidos, en lugar del desarrollo competencial. Todo ello sugiere que el problema de los plásticos sigue siendo un desafío para los docentes.

Palabras clave: plásticos, revisión bibliográfica, investigación educativa, innovación educativa

Introduction

The first synthetic plastic, namely Bakelite, was synthesised in the early 20th century. Since the 1960s, the ever-increasing demand of an

increasingly consumer-oriented society has resulted in a significant increase in plastics production worldwide, reaching a value of 322 million metric tonnes in 2015 (Lusher, Hollman and Mendoza, 2017). Indeed, plastics have helped to preserve health, improve transport, technological development or ecological performance, integrating themselves into our society, where they form part of almost everything around us and have gradually replaced other materials (Lusher et al., 2017). Their success resides in the fact that they are cheap, lightweight and exhibit high thermal and mechanical resistance (Elías, 2015).

However, this frenetic consumption has led to the large-scale generation of waste and its presence in our oceans (Jaén, Esteve and Banos, 2019), and this is the main problem of plastics: their sustainability as they are manufactured to be long-lasting. It is estimated that 8 million metric tonnes of plastics reach the oceans every year (Smith, Love, Rochman and Neff, 2018). Their main effects are physical, such as choking, asphyxia or injury to marine organisms (Eriksen, Maximenko and Thiel, 2013). Natural forces subsequently fragment them to form microplastics (Smith et al., 2018), which enter the food chain and are incorporated into marine biomass, including food destined for human consumption (Lusher et al., 2017). Moreover, as they are degraded, their additives, some of which are able to cross the walls of the intestinal tract, leach out (Smith et al., 2018).

During the World Ocean Summit in 2017, the United Nations Environment Programme (UNEP) proposed to eliminate microplastics and single-use plastics as the main sources of marine waste by 2022, and this was followed by the prohibition of single-use plastics in Europe in 2021 (Koch and Barber, 2019). Recently, environmental activist movements worldwide (Thunberg, 2019) forced the Climate Summit 2019 to reconsider measures for waste management, eliminate single-use plastics in countries outside the European Union (United Nations, 2019) or the 17 Sustainable Development Goals (SDGs) proposed by the United Nations (Gamboa, 2015).

Plastics contamination has become an environmental problem (Torres, 2019) that requires a response from all areas, including education. The aim of scientific education is to introduce social activism to students so that they become scientifically aware and socially responsible citizens who are able to make reasoned decisions as regards personal and civic science-related actions (Skamp, Boyes and Stanisstreet, 2013).

Several authors have demanded a response from schools. Thus, for Jaén et al. (2019), educators should play a role in raising citizens' awareness to allow them to face up to these problems, whereas Marcén and Molina (2016) consider that the change of citizens' attitudes and behaviours must come from the school. Jaén and Palop (2011) consider teaching to be a generator of worries and skills that must provide a response to these environmental problems, and should encourage students to form their own opinion and understand that their actions, however small, may affect their environment.

In conclusion, this is an urgent educational challenge to achieve a prepared and active population that is aware of, and takes measures against, this environmental problem. As such, we should ask ourselves whether the Science Education (SE) research published nationally and internationally is covering and contributing to resolving this problem. The following questions need to be asked:

- What proportion of research and innovation in SE over the past decade has covered the problem of plastics?
- To what extent do non-university science teachers participate in specialised SE publications covering this topic?
- Is there a frequent collaboration between specialist SE teachers and non-university science teachers in these studies?
- What plastics-related content is covered in these studies, and using what methodology and teaching focus?

Objectives

To answer the questions posed above, an exploratory and descriptive study of the current state of SE research in the field of plastics, published both nationally and internationally, was performed. The following objectives were established:

- To identify and describe the teaching research and innovation in the field of plastics published in the past decade in a selection of Spanish and international SE scientific journals.

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- To analyse the influence of this research on the set of publications considered.
- To examine the degree of participation of non-university science teachers in those studies.
- To determine the proportion of articles published by university and non-university SE teachers, the contents covered and the methodologies used.
- To critically assess to what extent current national and international educational research is contributing to a response to this environmental problem.

Method

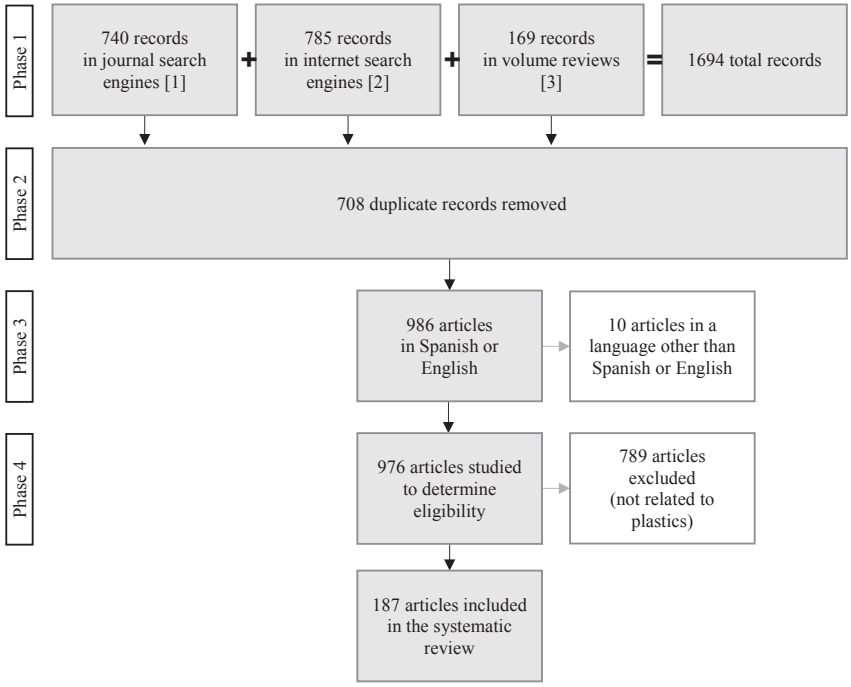
A literature review was performed using the journals listed in Table 1. The selection thereof was justified by the fact that they are all specialised SE journals. The selection criteria for the international journals was being in the first or second quartile of the JCR and SJR for several years of the decade studied. With regard to national SE journals, this criterion is very strict and none of them comply with it, therefore those journals that best reflect the state of the art in SE, with a marked influence in an Ibero-American context and which had been used in other reviews (Manchón and García-Carmona, 2018), were selected. Many of these national journals have the FECYT quality seal and are indexed in the JCR, SJR, ESCI WOS or Latindex.

TABLE I. Journals selected and scientific quality indicators (highest position in the decade)

Journal	JCR-SSCI SJR Quartile (Impact Factor)		FECYT Quality Seal	Latindex Characteristics Met	IN-RECS-Education
National					
Enseñanza de las Ciencias (*EC*)	Q3 (1.183)	Q2 (0.52)	Yes	34	Q1
Revista Eureka sobre Enseñanza y Divulgación de las Ciencias (*REEDC*)	ESCI WOS	Q2 (0.48)	Yes	35	Q1
Revista Electrónica de Enseñanza de las Ciencias (*REEC*)	-	-	No	26	Q1
Alambique, Didáctica de las Ciencias Experimentales (*ALB*)	-	-	Yes	32	Q1
Investigación en la Escuela (*IE*)	-	-	No	30	Q1
Didáctica de las Ciencias Experimentales y Sociales (*DCES*)	ESCI WOS	-	No	32	Q1
International					
Science Education (*SE*)	Q1 (3.50)	Q1 (5.31)			
Chemistry Education Research and Practice (*CERP*)	Q1 (2.09)	Q1 (1.03)			
International Journal of Science Education (*IJSE*)	Q1 (1.51)	Q1 (1.94)			
Journal of Chemical Education (*JCE*)	Q2 (1.75)	Q2 (0.47)			

The review covered the period 2010 to 2019, both inclusive, which should give an overview of current SE research. The phases proposed in the PRISMA Declaration (Urrútica and Bonfill, 2010) for systematic literature reviews were followed (FIGURE I). Phase 1 involved the search for articles with *plásticos/plastics* in the title, abstract, key words or text of the manuscript. The journals' own search engines were used [1], and for those for which all results were not available or not shown, search engines such as Google Academic or university databases were used [2], always using boolean operators. To ensure that the search was complete, the electronic version of all publications were reviewed [3]. Duplicate publications were eliminated in phase 2, and articles in languages other than Spanish or English were discarded in phase 3. The suitability parameters for articles were decided in phase 4 based on the premise that they must be related to some aspect of plastics.

FIGURE I. Literature review according to the PRISMA Declaration (Urrútica and Bonfill, 2010)



The frequency of the articles selected was determined by journal and the percentage corresponding to the total number of studies published in that journal.

After reading the studies, the lead author of this study proposed a categorisation of each article based on the following:

- Authorship of the study. The number of authors, their educational level, contributions by each author and mix thereof were analysed.
- Nature of the study: They were categorised as educational research, educational innovation or other, based on the section of the journal in which they were published, and if this was not available, the characteristics of the study presented.

- Topics covered: The categories proposed in a previous study with secondary-school students (López-Fernández, González and Franco-Mariscal, 2021), which showed that they would like to learn about plastics, were used (Table II).

TABLE II. Categories for analysing plastics-related content

Category	Content
Composition and properties of plastics	Synthesis, manufacture, origin, degradation physicochemical properties of plastics.
Contamination of the environment by plastics	Environmental aspects due to contamination by plastics, final destination, consequences, biodiversity, etc.
Solution to the problem	Possible solutions, collection of plastics, recycling, etc.
Environmental awareness	Attempts to produce changes of attitude or behaviour with regard to plastics

- Educational level. The categories were infant, primary, secondary or university education, or not known.
- Methodologies used. As a large number of educational innovations did not follow the structure of a research project, for studies related to educational research the methodology (quantitative/qualitative/mixed), study type and instruments used were analysed.
- Teaching focus. The scientific teaching approaches were categorised as propedeutic or competence-based.

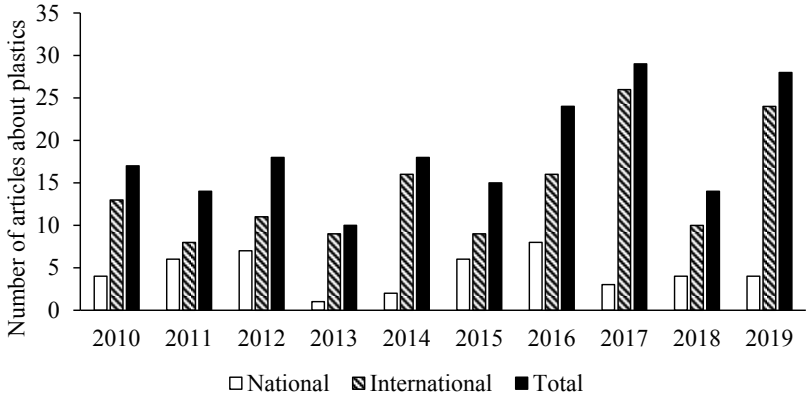
On the basis of that proposal, the other two authors performed their own assessment, indicating their agreement, doubts or disagreement. Studies for which there was no agreement were discussed until a consensus was reached.

Results

Plastics-related publications in the past decade

With regard to the plastics-related articles published between 2010 and 2019 (187), a clear difference was observed between those published nationally (45) and internationally (142). The distribution per year is shown in FIGURE II.

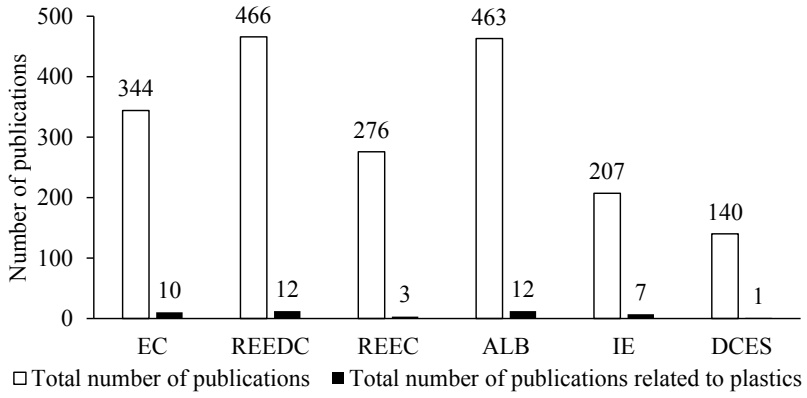
FIGURE II. Distribution of plastics-related publications by year (2010–2019)



No clear trend in the evolution of the number of articles published was observed in either context, with the largest number of articles being published internationally in 2017 and 2019 and nationally in 2016.

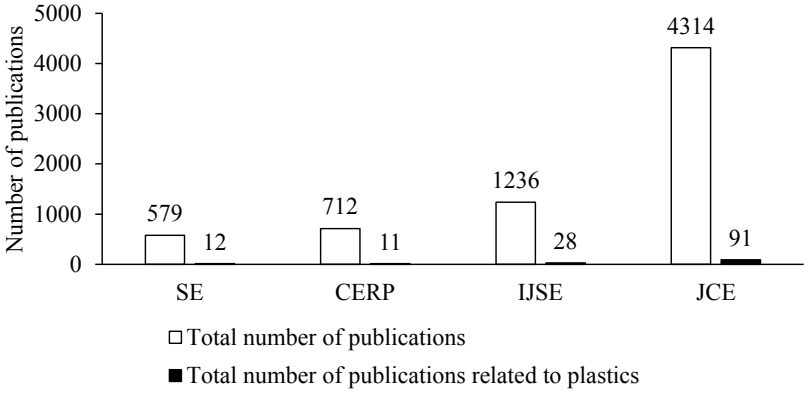
To determine whether this number was high or low, it was compared with the total number of articles published in each journal. The national study (FIGURE III) showed that *REEDC* and *ALB* published the most articles, with *DCES* publishing just one.

FIGURE III. Articles published in each national journal (2010–2019)



Internationally (FIGURE IV), almost all the journals selected published at least the minimum number of articles (12) found in Spanish journals. The highest number of plastics-related studies (91) were published in a chemical education journal (*JCE*), followed by *IJSE* (28).

FIGURE IV. Articles published in each international journal (2010–2019)



The percentage of articles reviewed with respect to the total (Table III) shows that, irrespective of their context, all journals analysed were in the range 0.7–3.4%.

TABLE III. Plastics-related publications with respect to all articles in the journal

Journal	Title	Frequency	Percentage
National (N=45)	EC	10	2.9
	REEDC	12	2.6
	REEC	3	1.1
	ALB	12	2.6
	IE	7	3.4
	DCES	1	0.7
International (N=142)	SE	12	2.1
	CERP	11	1.5
	IJSE	28	2.3
	JCE	91	2.1

The journals with the highest percentage of plastics-related articles published were *IE* nationally (3.4%) and *IJSE* internationally (2.3%). In addition, it is noteworthy that, with the exception of *REEC* and *DCES*, Spanish journals made a greater contribution to this field than their international counterparts over the period studied.

Authorship of publications

Table IV presents various authorship-related aspects.

TABLE IV. Characteristics of authors

		National Journals (N=45)		International Journals (N=142)		Total (N=187)	
		Frequency	%	Frequency	%	Frequency	%
Authors	One	11	24.4	25	17.6	36	19.3
	Two or three	30	66.7	62	43.7	92	49.2
	More than three	4	8.9	55	38.7	59	31.6
Educational level of teacher	Primary	3	3.0	2	0.4	5	0.8
	Secondary	21	20.8	23	4.7	44	7.4
	University SE	40	39.6	59	12.0	99	16.7
	University, other speciality	33	32.7	388	79.0	421	70.9
	Others (research centre, healthcare centre, foundation)	4	4.0	21	4.3	25	4.2
Contributions	One article	76	87.4	443	95.3	518	94.0
	Two or three	11	12.6	21	4.5	32	5.8
	More than three	0	0.0	1	0.2	1	0.2
Mix	One author*	11	24.4	26	18.3	37	19.8
	Same educational level	23	51.1	86	60.6	109	58.3
	Different educational level	11	24.4	30	21.1	41	21.9

*Mix not considered for articles submitted by a single author

Publications with two or three authors predominate both nationally and internationally (49.2%). Publications with a single author are less common in international journals (17.6%) but not in Spain (24.4%). Studies with more than three authors are more common internationally (38.7%).

The majority of authors are university lecturers (87.6%) and usually from areas unrelated to SE (70.9%), therefore the didactic treatment applied to the problem may differ from approaches in the SE field. Fortunately, the Spanish context is an exception as authorship is shared more evenly between SE university lecturers (39.6%) and those from other subjects (32.7%).

The participation of secondary school teachers is low (7.4%) even though their contributions are essential. However, a marked difference is seen between national (20.8%) and international journals (4.7%), thus highlighting the implication of Spanish secondary school teachers.

In addition, 94% of authors published just one paper, with those appearing on two or more publications being essentially non-existent. With regard to the mix of authors, the collaboration between authors from the same educational level, mostly university-based (58.3%), should be noted. A substantial collaboration between university lecturers and lower educational levels is not seen (21.9%).

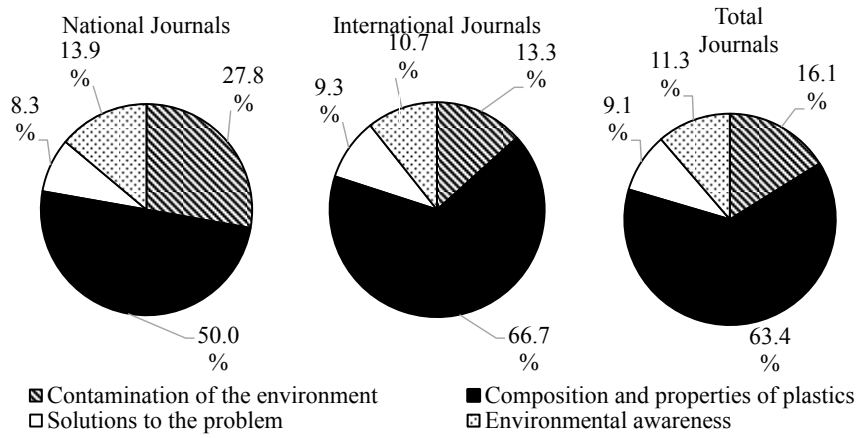
Nature of the studies

The nature of the studies is very similar both nationally and internationally. Thus, educational research accounts for the majority of studies (55.5% national and 54.2% international), followed by educational innovations (31.1% national and 32.4% international) and other studies (highlight, literature review or essays; 13.3% national and 13.4% international).

Content covered

FIGURE V shows the percentages for each category of content (Table 2) covered in the studies. The distribution of topics is similar both nationally and internationally, with the category *Composition and properties of plastics* clearly representing the largest number (63.4%). This category is somewhat more popular internationally (66.7%) than nationally (50%). The limited number of studies concerning *Environmental awareness* (10.7–13.9%) and *Solutions to the problem* (8.3–9.3%) should be noted.

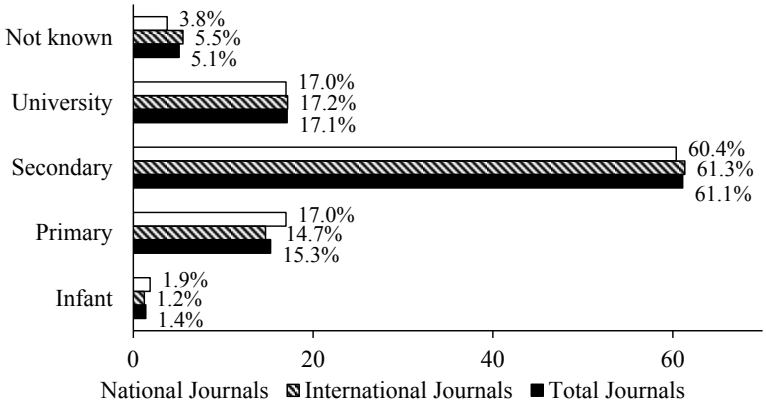
FIGURE V. Percentage of publications by content



Educational level

Our analysis showed that 61.1% of publications concern the secondary level, followed by university level (17.1%, FIGURE VI). Two types of study are found for the latter: teachers undergoing initial training (students taking a Degree in Primary Education Teaching or a Masters in Secondary Education Teaching), and those with professional futures in which plastics play an important role (students taking a Degree in Environmental Science, engineering degrees, etc.). The limited number of studies involving children aged less than 12 years is noteworthy.

FIGURE VI. Percentage of articles by educational level.



Methodologies used

The main type of research in national educational research studies is qualitative (60%), compared with quantitative (24%) or mixed (16%). In contrast, internationally, there is a better balance between the use of qualitative (39%), quantitative (31.2%) and mixed (29.8%) methodologies (FIGURES VII, VIII and IX).

The most common studies are descriptive (52.8%), followed by exploratory (25.9%), case studies (13%) and correlational (4.6%). Other minority studies are explanatory (2.8%) and interpretative (0.9%).

The most widely used instrument is any type of knowledge test (54%; open or closed questions, mixed, exams, etc.), of which 18.1% are pre-/post-test. Although tests are commonly used in combination with other instruments (71.2%), they were used alone in 23.8% of cases and combined with others in 33.3%. The second most widely used instrument is direct observation (20%), including daily observation (27.9% for this instrument), audio and/or video records (18%) or others. Interviews, productions by participants, portfolios, focal groups or educational curricula and text books are used in less than 11% of articles.

FIGURE VII. Methodology in qualitative studies.

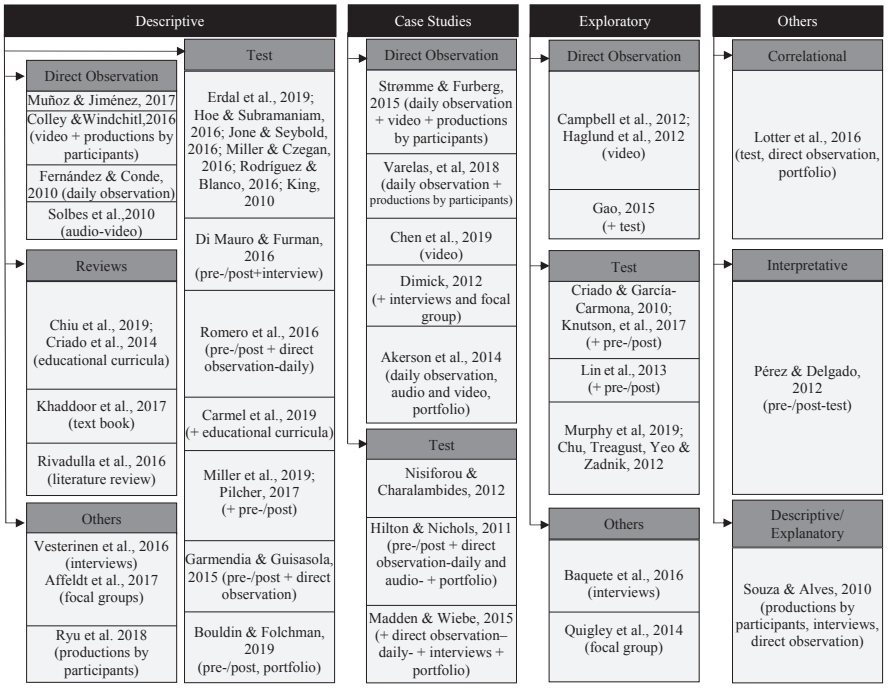


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FIGURE VIII. Methodology in quantitative studies.

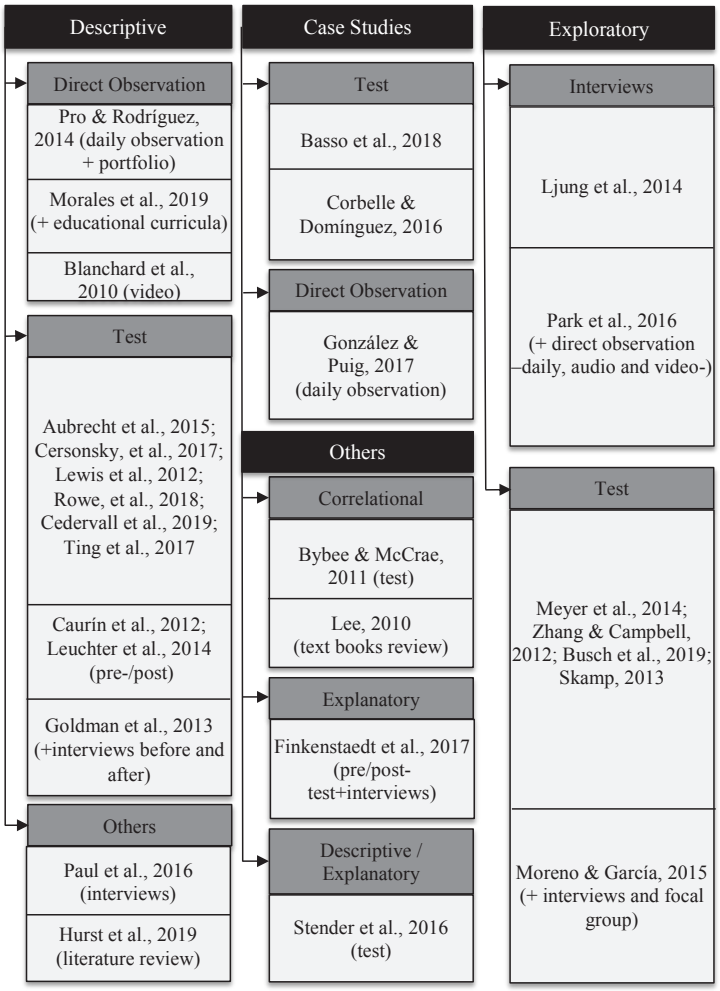
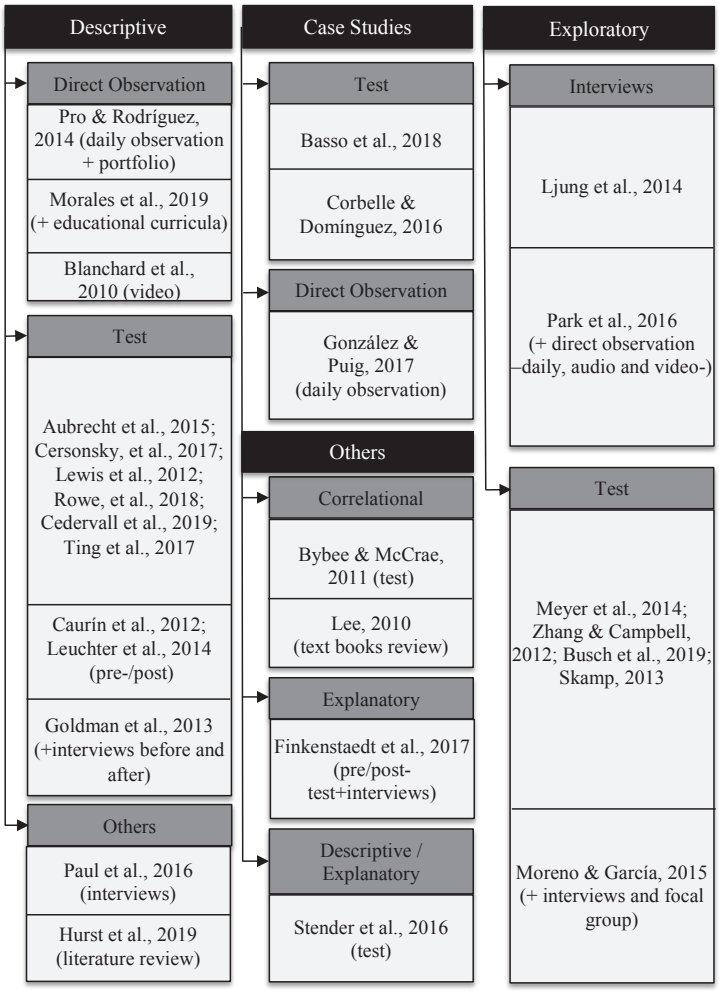


FIGURE IX. Methodology in mixed studies.



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Teaching approaches

Two teaching approaches are detected. The main approach is propedeutic (64.7%), which is based on learning knowledge and scientific processes, without taking into account the interests of students and society (Furió et al., 2001), whereas the remaining 35.3% involve a competence-based approach involving the development of skills by application of knowledge.

Innovations are based on experiences that highlight learning of some properties of plastics (80.9%), with thermal or electrical conductivity being the most common. Another recurring topic concerns polymers, considered to be essential chemical compounds in plastics. Other, less-common proposals cover contamination by plastics and their environmental impact (6.3%).

Conclusions

Despite the importance of plastics and their contamination, the results found do not appear to suggest a school that generates environmental awareness and sensitivity, thus allowing citizens to give effective responses and resolve environmental problems, at least as regards the number of research studies published. Initial evidence for this is provided by the limited number of publications concerning plastics in SE in the past decade, with this number being somewhat higher nationally (3.4%) than internationally (2.3%). These values are in agreement with those from other reviews (Fernández, 2008), which highlighted the shortage of studies in environmental education or contamination. Another worrying aspect is the evolution of the number of publications over the past few years. Thus, whereas there appears to be an increase internationally due to activist actions (Koch and Barber, 2019), this is not seen in Spain.

The reason that 79.2% of studies are published by university lecturers is probably due to the fact that high-impact journals, such as those selected, tend to focus on studies in an academic setting. Similarly, effective collaboration between university-based researchers and those from other educational levels, such as secondary education, where a significant number of studies are performed, at least in Spain (18.8%), appears to be lacking. This type of collaboration between authors could

represent a major advantage as regards resolving the problem from a school viewpoint as these teachers are in direct contact with students and can see the effects of such studies, therefore they should be the ones who are involved in raising citizens' awareness (Jaén et al., 2019). The very limited number of studies in pre-secondary settings, which are essential to reinforce environmental education from an early age, should be noted (Corraliza and Collado, 2019).

The composition and properties of plastics are presented as the main contents, highlighting their importance in our lives, although there is a clear lack of practical studies regarding contamination, environmental awareness and the proposal of solutions. Indeed, studies regarding the direct relationship between plastics contamination and health are lacking (Cersonsky et al., 2017; Miller and Czegan, 2016), thus suggesting that this aspect of the problem is being essentially ignored even though increasing numbers of studies demonstrate the effects of plastics on our bodies (Smith et al., 2018).

The majority of contents are based on a propedeutic approach, which tends to be the main approach used in standard teaching practice by science teachers (Furió et al., 2001). This approach does not benefit from the contextualised and competence-based learning required for the development of scientific literacy (Pedrinaci et al., 2012). As noted by Corraliza and Collado (2019), dissemination of information and knowledge tends to be insufficient on its own, therefore the promotion of significant experiences is necessary. From our viewpoint, the teaching-learning of plastics should be oriented towards resolving a socio-scientific issue by way of scientific practices that allow all the perspectives, environmental repercussions and measures to be adopted to be understood. This will allow the development of critical thinking skills in students.

Similarly, improvements to some methodological aspects may contribute to progress in the teaching-learning of plastics. For instance, the use of quantitative and mixed methodologies, which are less widely used in Spain than internationally, and the use of more competence-based instruments, may help in that regard.

This study is not free from limitations. One of these is that an attempt has been made to limit the studies analysed to a national or international context, which is somewhat complicated given that many national journals also publish studies from overseas authors, many of whom are based in Ibero-America, and Spanish authors also publish in international journals.

Another important limitation is that the majority of proposals made in schools are never published, therefore supposing that the content of the studies published reflects what is actually happening in classrooms is risky, although it may give an initial insight into this topic.

Although the reality of educational research into plastics presents numerous aspects that can be improved, the question of contamination with plastics has begun to receive attention in the past few years, although the teaching of such topics remains a challenge for teaching staff. For the reasons presented above, we believe that it is essential to continue to study this aspect in research and educational centres at all levels.

Acknowledgments

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