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EARLY CHILDHOOD PRE-SERVICE TEACHERS' READINESS FOR USING DRAWING AS A SCIENCE TEACHING STRATEGY

Ainara Achurra,
Teresa Zamalloa,
Araitz Uskola

Abstract. *The use of drawings for science learning helps students to develop communication, modelling, and reasoning skills. Teachers should be trained to use them. This study addresses the readiness (knowledge, confidence and awareness of the importance and usefulness of drawings) of 120 preservice teachers (PSTs) for using teacher-made drawings as a strategy for teaching science, after participating in activities in which they used drawing as a way to represent scientific knowledge. The knowledge of how to draw was analysed by evaluating the presence of interrelated components, mechanisms and phenomena in drawings of the digestive system. Open questions were used to examine three aspects: confidence, awareness of the importance and awareness of the usefulness. Exploratory cluster analyses were also conducted. 69% scored low in knowledge, more than 90% scored high in awareness of the importance and of the usefulness. 28% showed high confidence. No PSTs with high knowledge and low confidence were found. All PSTs with high knowledge showed high awareness of the importance. It is concluded that in order to prepare teachers for using drawings in science teaching, teacher education programs should include the development of drawing skills that could enhance their confidence and awareness of its importance.*

Keywords: *early childhood education, drawing science, teachers' readiness, science education*

Ainara Achurra, Teresa Zamalloa, Araitz Uskola
University of the Basque Country, Spain

Introduction

Drawings can be a useful strategy for teaching and learning science, but are teachers ready for using drawings in science teaching? The use of drawings for science learning brings multiple benefits for the students not only in terms of visual skills (García Fernández & Ruiz-Gallardo, 2017), but also in the development of communication, modelling, and reasoning skills (Ainsworth et al., 2011). Few studies have focused on the teacher's role in the use of drawings in science teaching (Areljung et al., 2021a; Areljung et al., 2021b; Monteira et al., 2022), even though the teacher is the key factor for the success or failure of putting any curricular innovation into practice (Mitchener & Anderson, 1989; Tobin et al., 1994). According to the literature, teachers should know how to draw scientific phenomena (Wilson & Bradbury, 2016); and they should be aware of and value the importance of drawing in science education (Areljung et al., 2021a). Moreover, given that the deployment of strategies in class depends, to a large extent, on the degree of the teacher's confidence (Garbett, 2003; Holroyd & Harlen, 1996), teachers will need to develop not only the ability to draw pictures about scientific phenomena, but also their confidence in that ability, and, in that way, acquire the view that drawings are useful strategies for learning science. This study examined the readiness of a cohort of early childhood PSTs to use drawing for science teaching, in terms of their knowledge, confidence and beliefs about its use.

Use of Drawing to Learn Science: Teacher's Role

Making visualisations is integral to scientific thinking (Ainsworth et al., 2011). Drawing can develop one's visualisation as it involves the integration of nonverbal representational modes in terms of constructive learning processes (Van Meter & Gardner, 2005).

Effective learning strategies help students to integrate new and existing understanding, organise their ideas, construct new inferences and overcome difficulties in presented material (Chi et al., 1989; Kombartzky et al., 2010). Drawing can be an effective strategy in science education because it helps to

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understand the natural world (Dempsey & Betz, 2001), contributes to the reorganisation of ideas and the integration of new knowledge (Gómez & Gavidia, 2015) and has a great communicative potential. Besides, the majority of science learning requires visual-spatial demands that cannot be provided by other constructive strategies such as summarising or providing oral explanations (Ainsworth et al., 2011). Consequently, drawing is a common strategy for modelling in the science class, where students represent their mental models as drawings, which are then evaluated and revised (Schwarz et al., 2009). For example, drawing in anatomy (Borreli et al., 2018), histology (Balemans et al., 2015) and biology (Edlund & Balgopal, 2021) has indeed been proven to improve students' knowledge.

With respect to the teacher's role, Monteira et al. (2022) have specifically analysed both the drawings produced by a group of early childhood education students in Spain during three years and the type and intensity of the scaffolding given by the teacher. Researchers have found that the children included more details in their drawings and used symbolic and iconic modes in an increasingly autonomous way; and that the teacher lowered the intensity in some forms of scaffolding, although not in all of them. Wilson and Bradbury (2016) have compared drawings and written explanations given by elementary students in the United States of America about structure and functions in carnivorous plants and have observed that structural elements were better represented by the students in the drawings, while functions were better represented in the explanations. They have also observed that the children received scaffolding about how to explain the model, but not about how to draw; this has led them to suggest that perhaps the children did not represent the actions because the teachers did not help them to internalise the accepted conventions for representing those actions in drawings. Although the scaffolding offered by teachers has been found to be key, it should be mentioned that, according to Eilam et al. (2014), teachers lack training in visual representation. This may well be a problem for using drawing as a science teaching strategy.

Teachers' Readiness to Use Drawings as a Science Teaching Strategy

Being ready for the teaching profession is known in the literature as "teaching readiness" (Manasia et al., 2020). The term is used to indicate teachers' competence in doing both the whole job or just certain aspect/s of the job (Mohamed et al., 2016), and it is considered a significant predictor of change in practice (Lang, 1992). Today, specific elements of teachers' readiness are still under-study, with researchers being interested in measuring beliefs about knowledge, confidence, importance, usefulness, attitudes, and interest, among others (Lang, 1992; Mohamed et al., 2016; Nadelson & Nadelson, 2010; Paik et al., 2011; Park et al., 2017).

Beliefs about teaching make up an important part of teachers' thought processes (Fang, 1996), and, consequently, they influence teachers' practice by guiding their behaviours and decisions in the classroom (Vartuli, 2005). Specifically, it has been shown that beliefs in the value of a certain teaching practice support and predict the implementation of that practice in the class (Charlesworth et al., 1991; Nathan et al., 2010; Pajares, 1992; Parker & Neuharth-Pritchett, 2006; Stipek & Byler, 1997), and ultimately affect his/her students' learning (Fang, 1996).

In respect to the drawing strategy, several studies have analysed the use of drawings related to teachers' beliefs and practice. Areljung et al. (2021a) have examined 45 science class sessions of 11 early childhood and primary school teachers in Sweden, focusing on the 15 sessions in which the children drew pictures. These researchers have found that the teachers' beliefs about the role of drawing in science learning seems to be a key factor in enabling children to benefit from the pedagogical potential of drawing for learning science. Indeed, the few teachers who, in the interviews, related drawing to science teaching and learning, were the ones who made explicit use of drawing for science learning in the classroom. In another paper from the same project (Areljung et al., 2021b), it has been highlighted the importance of the drawings produced by teachers. The researchers have found that when a teacher draws a schematic drawing on the blackboard about a plant growth experiment to be conducted, all the children draw it in the same way. It has been interpreted that the teacher conveys the conventions of how to draw in teaching science and helps the children to foreground the scientific content.

Confidence can be defined as "the strength of one's beliefs in one's capabilities" (O'Neill & Stephenson, 2012). It has been shown that teachers' confidence influences their practice. For example, when confidence to teach science concepts is low, teachers offer limited and unbalanced opportunities to students for learning science and technology (Holroyd & Harlen, 1996) and do not fully engage students in science (Symington, 1980).

As far as we know, teachers' confidence in drawing has not been addressed in science teaching specifically. However, several studies in other disciplines such as art have shown that teachers lack both drawing skills and confidence in drawing, which may detract from their effectiveness as teachers and from their students' achievements. For instance, when the experience and readiness of the primary school teachers to teach the national curriculum

https://doi.org/10.33225/jbse/22.21.911

in art has been assessed in England and Wales, very few have expressed that they felt confident in teaching; most of them referred to the importance of developing greater knowledge, skills, and confidence in teaching art (Clement, 1994). Actually, teachers acknowledge limiting themselves to only encouraging children to draw, rather than evaluating their drawings, because they do not feel able either to do such assessment (Rose et al., 2006) or to teach specific drawing skills (Richards, 2003). This could be due to the limitations of their own drawing ability, which has been described as the most frequently cited obstacle for teachers when it comes to helping children draw (Burkitt et al., 2010). In fact, in Great Britain, the Office for Standards in Education, Children's Services and Skills (Ofsted, 2009) has made a report that points out that the teacher's own artistic competence is an important success factor, and that teachers who use their own materials teach more effectively. However, many primary school teachers lack confidence in drawing, which influences their effectiveness as teachers as well as their students' achievements (Ofsted, 2009). Concerning the digestive system (DS), a previous study has shown that teachers' drawings of the DS (when asked to draw what they thought was inside the human body) were similar to those made by school and university students (Patrick & Tunnicliffe, 2010). These researchers have pointed out that it is necessary to check the level of the teachers´ content knowledge; however, it is also possible that the low level of their drawings could be attributed to a lack of drawing tools and strategies.

Research Aim and Research Questions

Reviewed literature shows a lack of studies that explore teachers' readiness for using drawing as a science teaching strategy in early childhood education. This study therefore aimed to address this issue with a sample of preservice teachers (PSTs), paying particular attention to various chosen elements: knowledge, self-perceived confidence and awareness about the importance and usefulness of drawing. Moreover, this study examined whether the study population is homogeneous or heterogeneous according to their responses. The research question was the following: To what extent are the PSTs ready to use drawing as a strategy for teaching science in the early childhood classroom according to certain dimensions (knowledge, confidence, and awareness of the importance and of the usefulness of drawing)? This research question was addressed by exploring each of the dimensions individually, for the one hand, and in combination, for the other.

Research Methodology

General Background

This qualitative study explored and described the readiness to use drawings as a science teaching strategy for PSTs at the Faculty of Education of Bilbao (Spain) after participating in activities in which PSTs used drawing as a way to represent scientific knowledge –in this case, the DS- in 2019. In qualitative inquiry, the purpose is not to generalize to a population, but to make an in-depth exploration of the phenomenon addressed in the study (Creswell, 2012).

Readiness was analysed according to four dimensions: knowledge, confidence, awareness of the importance of drawing and awareness of the usefulness of drawing. These were selected following the literature review in the section *Teachers' Readiness to Use Drawings as a Science Teaching Strategy*. Knowledge data were gathered from drawings, and beliefs (confidence and awareness of importance and usefulness) from open-ended responses to a questionnaire. Levels for each dimension were established and qualitative data were quantitatively coded. Descriptive statistics and cluster analysis were undertaken to better understand the results.

Participants

To explore the phenomenon of teachers' readiness using drawings as a science teaching strategy in early childhood education, purposeful sampling was undertaken. That is, researchers intentionally selected the participants that could help them to understand the phenomenon (Creswell, 2012). For selecting participants, convenience (participants willing and available to be studied) was also taken into account. Thus, the participants consisted of 120 PSTs (in four classes) studying a Degree in Childhood Education (third year), taught by two of the researchers (each in two classes) at the Faculty of Education of Bilbao (Spain). All participants gave informed consent to participate in the research. It was clearly stated that participation was voluntary and anonymous. PSTs in the data collection process were coded as "PST1, PST2, ... , PST120".

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Teaching Sequence

The sequence was structured in several stages as described before by the researchers (Uskola et al., 2022). First, participants were asked to write and draw on an image of a human body silhouette of about 15 cm tall, the elements and processes involved in the case of milk intolerance. PSTs then searched for information in groups (3–5 people) and, guided by the teacher, reviewed and reconstructed their original model. The groups then represented their consensus model in a three-dimensional and dynamic physical model, which was then presented to the rest of the groups. After that, the groups made drawings of the DS. Next, participants reflected on the importance and usefulness of the drawings for the representation of mental models through the reading of two scientific articles given by the teacher. The most common errors when drawing the DS were also discussed. Finally, each PST was asked to write and draw again the elements and processes involved in the case of milk intolerance.

Data Collection and Analysis

In order to address participants' knowledge, the final individual drawings were analysed. To assess the ability to draw the different dimensions related to the functioning of the DS from a systemic perspective, the CMP (Components-Mechanisms-Phenomena) framework and the levels of systems thinking proposed by Hmelo-Silver et al. (2017) was adapted. For this purpose, an analysis of the drawings was first carried out, evaluating each drawing for each of the established dimensions. 0-3 levels for Components (C) were adapted from Reiss and Tunnicliffe (2001), based on the number of organs drawn and whether the drawings represented the system. Thus, level 0 corresponded to drawings that did not illustrate any internal organs, whereas drawings illustrating 1-3, or more than 3 internal organs corresponded to levels 1 and 2 respectively. As with Reiss and Tunnicliffe (2001), the idea of system (level 3) was considered to be present only if there was an uninterrupted connection between the mouth and the anus, and if there were more than three organs represented. Mechanisms (M) were scored according to the number of digestive processes (Snapir et al., 2017) in the context to which they referred (e.g., digestion of food, absorption of nutrients, and fermentation in the large intestine). Drawings were scored on the Phenomena (P) dimension based on the presence of the outcomes of the mechanisms (Snapir et al., 2017), i.e., the regulatory, plastic, energetic functions performed by the absorbed nutrients, as well as the symptoms in the case of intolerance.

A second step was to assign to each drawing a level (Table 1) in a category that reflected the representation of the system as a whole, for which the proposal by Hmelo-Silver et al. (2017) was adapted through the constant comparative method (Lincoln & Guba, 1985) with the data. Thus, for evaluating knowledge, these levels were set: level 0 corresponded to blank or erroneous answers. Level 1 indicated that Components were identified in the drawing but not interconnected. Level 2 was set for PSTs with level 3 in Components, but who had not related them to Mechanisms or Phenomena. Level 3 and 4 corresponded to establishing relationships between Components and Mechanisms, level 4 being for those who drew the organ system. Level 5 matched the highest level of Hmelo-Silver et al. (2017) and included the drawings that represented all the interrelated dimensions of systems thinking.

Table 1
Levels Established for the Analysis of the DS in the Drawings Made by the PSTs From a Systemic Perspective

Level	CMP relation	Explanation
5	C:M:P	Draws interrelated organs in relation to mechanisms and phenomena
4	(C:C):M	Draws interrelated organs in relation to mechanisms
3	C:M	Draws organs in relation to mechanisms
2	C:C	Draws the organs in an organ-system
1	C	Draws organs without connecting to other organs or mechanism
0	No answer or erroneous answer	

Note: Adapted from Hmelo-Silver et al. (2017).

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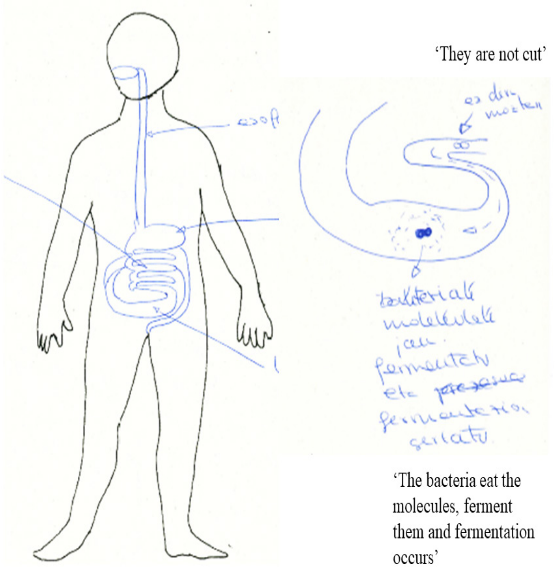
The following example (PST71) (Figure 1) shows a drawing in level 4, with a system of interconnected organs and the representation of two processes: the "non-digestion" of lactose in the case of intolerance (represented as a molecule with two parts connected and a label describing it) and the fermentation (represented as a colour change in the molecule that appears surrounded by bacteria).

Figure 1
Example of Drawing in Level 4 (PST71)



Regarding the teachers´ beliefs, their written responses to a questionnaire (Table 2) were taken into account. The PSTs were asked about their beliefs (confidence, importance, and usefulness) for using drawings as a science teaching strategy.

Table 2
Questionnaire Filled by the Students in the Beginning and at the End of the Sequence

Element	Question
Confidence	In your opinion, what is your ability to draw scientific content? Explain what you are capable of, what you are not capable of and what your needs are.
Importance	In your opinion, what is the importance of being able to draw for teaching natural sciences in early childhood education? Justify your answer explaining what an early childhood education teacher should be able to draw in relation to scientific content.
Usefulness	In your experience, did you find drawings useful for learning?

Note: The question about usefulness was only answered once (at the initial questionnaire).

Three levels (0-2) were established based on how categorical PSTs were in their answers. Thus, level 2 in confidence, importance and usefulness corresponded to PSTs that were sure of being confident in drawing science content, or PSTs that said that it is important for teachers to be able to draw, or PSTs that stated that drawing is useful for science learning, respectively. Level 0 for the three constructs was for PSTs that answered "no" categorically. Level 1 was given to intermediate answers (in the case of confidence, level 1 was given when PSTs set conditions to achieve it).

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Most of the answers were the same at the beginning and at the end of the sequence, but when the answer was not exactly the same, the responses were individually examined by the researchers. For example, after participating in the sequence, some PSTs changed their perception of their own confidence because they had become aware of their difficulties; in regard to the importance, some PSTs gave more importance to the strategy. In those cases, the final answer was taken into account. For example:

> *PST3. Before: 'I think I am capable of drawing scientific content. For example, I am able to draw various parts of the human body as well as other living beings and elements of nature' (level 2). After: 'I have difficulty drawing scientific concepts, especially when I do not properly identify the elements necessary for the explanation' (level 1).*

In the cases of PSTs that justified or explained one answer better than the other, the better explained answer was chosen. For example:

> *PST37. Before: 'In my opinion, I am able to draw animals, plants, trees or the solar system, that is, I think I am able to draw scientific content. However, I think that in early childhood education more importance should be given to drawing, in order to better develop this competence' (level 2). After: 'I think I draw animals and plants better than the body' (level 1).*

In this case, researchers considered the confidence assessment to be level 2.

Descriptive Statistics and Cluster Analysis

Measures of central tendency (mean, median and mode), variability (standard deviation, minimum and maximum) and frequency distribution were calculated for the four variables: knowledge, confidence and awareness of the importance and usefulness of drawing.

Cluster analysis was conducted to find groups of similar students based on their knowledge, confidence, awareness of importance and awareness of usefulness. Before computing the results, several analyses were performed. First, outliers were detected, which led to the exclusion of one student. Then, association between variables was determined by means of the Spearman correlation analysis; no correlation was found, indicating that selected variables may well reflect different underlying constructs. Then, the clustering variables were reduced from four to three (knowledge, confidence, and awareness of importance), as all students scored 2 in awareness of usefulness. Finally, all scores were transformed into standardised *z*-scores to ensure that different scales in variables did not influence the K-means cluster results.

The K-means clustering method was used because of its simplicity and efficiency in application (Han & Kamber, 2006). The clustering algorithm was performed iteratively from 2 to a maximum number of 8 clusters. The optimal number of clusters was selected in accordance with the number of iterations needed until convergence, final cluster centre values and high and significant F values. That led to the conclusion that 3 clusters were the optimal solution.

After the cluster analysis, separate Kruskal Wallis tests were conducted to identify differences across the three clusters (non-parametric analyses were selected due to the small size of the samples in one of the clusters). All analyses were performed in SPSS 27.

Research Results

PSTs' Readiness for Using Drawings as a Science Teaching Strategy

In order to provide basic information about the variables in the dataset, Table 3 presents measurements of central tendency (mean and median), variability (standard deviation, minimum and maximum) and frequency distribution.

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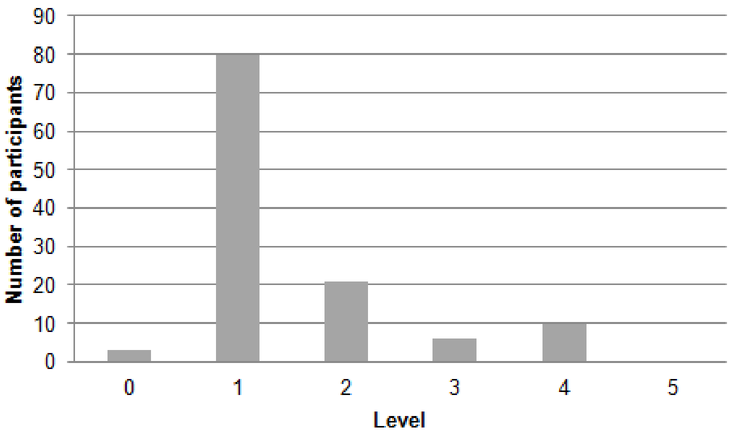
Table 3
Results From Descriptive Statistics (Mean, Median, Standard Deviation, Minimum and Maximum and Frequency Distribution) for Knowledge, Confidence, Importance and Usefulness

	Knowledge	Confidence	Importance	Usefulness
Values	0,1,2,3,4,5	0,1,2	0,1,2	0,1,2
N	120	120	120	120
M	1.50	1.08	1.92	1.98
Mdn	1.00	1.00	2.00	2.00
SD	0.95	0.69	0.33	0.18
min	0	0	0	0
max	5	2	2	2
f				
0	3	24	2	1
1	80	63	6	0
2	21	33	112	119
3	6			
4	10			
5	0			

Figure 2
Frequency of PSTs' Drawings in Each Level of Knowledge



As can be seen in Table 3 and Figure 2, the majority of PSTs (67%) were at knowledge level 1, i.e., they drew only components, and these were not interrelated as a system. Only 13% reached levels 3 and 4, i.e., they drew, in addition to components, how components participate in the mechanisms of the system. Since the fact of situating the interrelated components as a system defines levels 2 and 4 (compared to levels 1 and 3), it is noteworthy that while there were more PSTs in level 1 than in level 2, there were more in level 4 than in level 3; this indicates a certain relationship between representing the system interrelated and representing its mechanisms. Indeed, among those PSTs that drew unrelated components, only 7% represented mechanisms; and among those PSTs that drew the organ system, 32% did represent mechanisms.

In regard to confidence, 27.5% of the PSTs were fully confident in drawing scientific content; more than half of the PSTs (52.5%) were confident in drawing but specifically indicated that this was only true as long as they were simple contents that had been previously studied; 20% of the PSTs indicated that they were not confident

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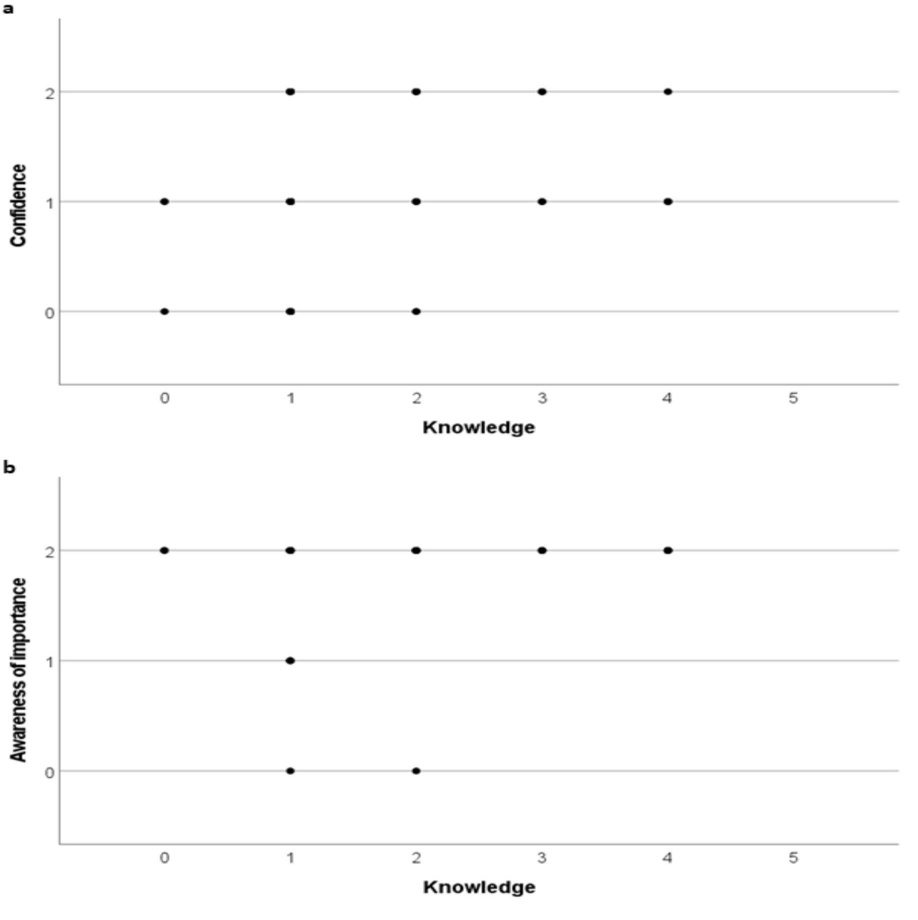
in drawing scientific contents (levels 2, 1 and 0 in confidence, respectively). Figure 3a shows the dispersion plot for knowledge and confidence. It is interesting to note that PSTs that reached levels 3 and 4 in knowledge, always reached at least level 1 in confidence, indicating that, although no correlation was obtained, higher levels of knowledge may be associated with a certain degree of confidence. In the same way, no PST at level 0 of knowledge reached level 2 of confidence.

Concerning the importance of drawing in the early childhood education classroom, the majority of the PSTs had no doubts that drawing is important, and very few thought that it was only important in certain cases or that it was not important at all (93.3%, level 2; 5%, level 1; 1.7%, level 0). However, as can be seen in Figure 3b, in the few cases in which importance was level 0 or 1, the level of knowledge was never high. Finally, when PSTs were asked whether they found drawings useful for learning, 99% stated that they did. The sample was therefore heterogeneous in terms of knowledge and confidence, and homogeneous in terms of awareness of importance and usefulness.

Figure 3

Dispersion Plot for (a) Knowledge and Confidence of PSTs; and (b) Knowledge and Awareness of Importance of PSTs



Description of Clusters According to PSTs' Readiness for Using Drawings as a Science Teaching Strategy

PSTs were classified into three clusters. Table 4 shows the results from the descriptive statistics of the clusters, Figure 4 shows a 3D representation of the clusters and Figure 5 shows the distance for each PST from its cluster centroid derived from the cluster analysis. Below, descriptions of the clusters are given with reference to the input variables: knowledge, confidence and awareness of importance and usefulness.

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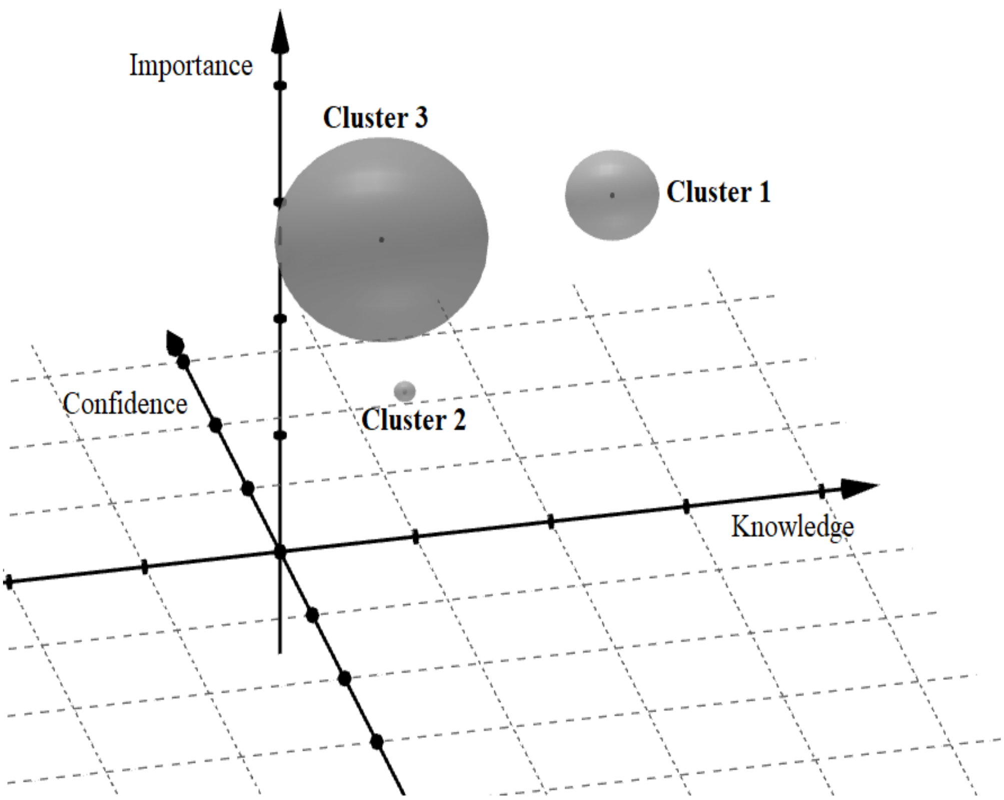
Table 4
Results from Descriptive Statistics of the Three Clusters

Variable	Cluster 1 N= 34				Cluster 2 N= 8				Cluster 3 N= 77			
	M	z	SD	R	M	z	SD	R	M	z	SD	R
Knowledge	2.76	1.32	0.89	2-4	1.13	-0.40	0.35	1-2	0.99	-0.54	0.26	0-2
Confidence	1.29	0.31	0.46	1-2	0.88	-0.31	0.84	0-2	1.01	-0.10	0.73	0-2
Importance	2	0.25	0	2-2	0.75	-3.49	0.46	0-1	2	0.25	0	2-2
Usefulness	2		0		2		0		2		0	

Note: Standardised *z* scores ($M = 0$; $SD = 1$) are also given.

Figure 4
3D Representation of the Three Clusters (Mean Values) According to the PSTs' Knowledge, Confidence and Awareness of Importance



Note: Awareness of usefulness was not included as all participants scored the maximum value. Volume of the bubbles represents the relative size of the clusters. A video showing the figure from all sides is available in https://doi.org/10.6084/m9.figshare.20338698

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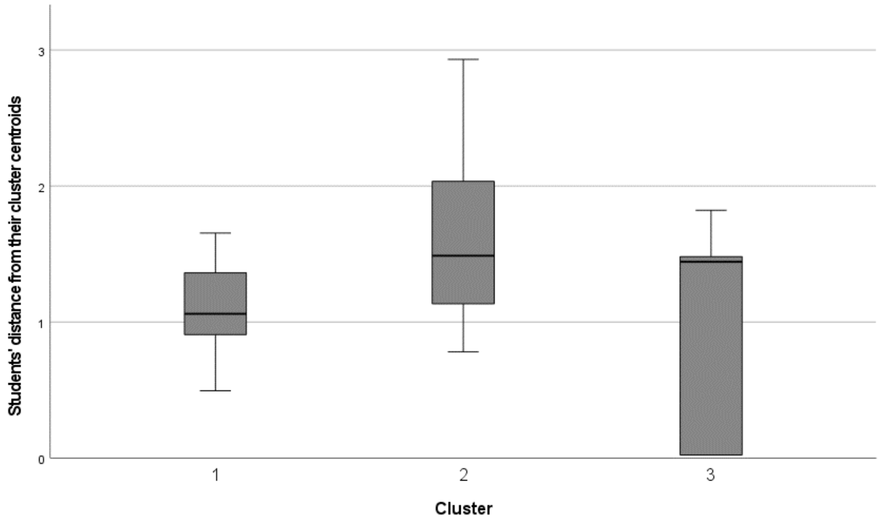
Figure 5
Boxplot of Distances for PSTs from their Cluster Centroids

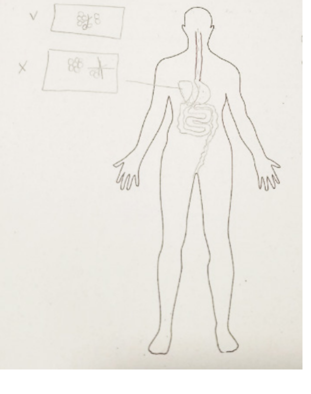


Note: Horizontal line = median, box = 25th and 75th quartiles, whiskers = the highest and lowest values, excluding outliers. Outliers were absent and thus, they were not represented.

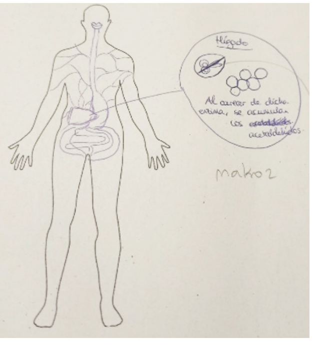
Cluster1: The Most Ready PSTs for Drawing

Cluster 1 (*N* = 34) is characterised by moderate-to-high drawing knowledge and confidence, and high awareness of importance and usefulness (Table 4, Figure 4). The PSTs with the highest scores in knowledge are included in this cluster. All PSTs scored the maximum value (2) in awareness of importance and usefulness. This is the most homogeneous cluster, as shown by the distances of the PSTs from the cluster's centroid (Figure 5). The following table (Table 5) shows examples of PSTs from cluster 1.

Table 5
Representative Examples of PSTs Profiles From Cluster 1

PST	Knowledge	Confidence	Importance	Usefulness
PST114		I think I am good at drawing although I have to improve certain aspects such as knowing what I want to draw. I see myself able of drawing although I lack content.	Drawing is very important to teach natural sciences [...].	Yes, drawings have been useful, especially to understand certain processes [...].
	Level 4	Level 2	Level 2	Level 2

https://doi.org/10.33225/jbse/22.21.911

PST	Knowledge	Confidence	Importance	Usefulness
PST109		I see myself able to draw simple shapes. […] I am aware that I am more able of drawing scientific […].	In my opinion, knowing how to draw moderately well is of great importance in early childhood education to explain science, since it facilitates explanations. […].	Yes, I find drawing useful […].
	Level 3	Level 2	Level 2	Level 2

Cluster 2: Being Able to Draw is Not Important

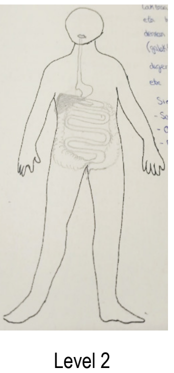
Cluster 2 is a small (*N* = 8) and more heterogeneous group (Figure 5), including all the PSTs that scored 0 and 1 in awareness of importance, where the internet was cited by some PSTs as a source of drawings to be used to teach science (Table 4, Figure 4). The variability comes mostly from confidence, as these PSTs scored from 0 to 2 (the whole range). Regarding knowledge, the score was low, but this cluster did not include the PSTs with the lowest knowledge. Awareness of usefulness was scored 2 by all PSTs.

Answers such as 'drawing is important to teach natural sciences, but nowadays, as there are lots of photos on the internet, they fulfil the same function' (PST43) or 'drawing is not important to teach natural sciences because, in the end, different methods can be used' (PST49) are what define the PSTs from these clusters.

Cluster 3: Lacking Knowledge of How to Draw but With Positive Beliefs

Cluster 3 is the biggest in terms of the number of individuals (*N* = 77), which may explain its heterogeneity (Figure 5). PSTs in this cluster have low values in knowledge. Note that it includes the PSTs with the lowest knowledge (0 value). As in cluster 2, confidence values (*R* = 0-2) show high variability. However, as in cluster 1, PSTs scored the maximum value (2) in awareness of importance and usefulness (Table 4, Figure 4). The following table (Table 6) shows examples of PSTs from cluster 3.

Table 6
Representative Examples of PSTs Profiles from Cluster 3

PST	Knowledge	Confidence	Importance	Usefulness
PST78		I am very bad at drawing pictures, and I am not able to do practically anything.	Knowing how to draw is important to respond to children's questions and needs […].	Yes, drawings have been useful to understand better the basic concepts […].
	Level 2	Level 0	Level 2	Level 2

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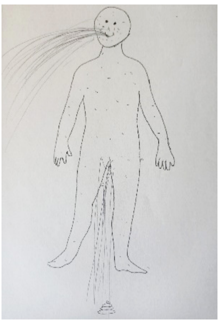
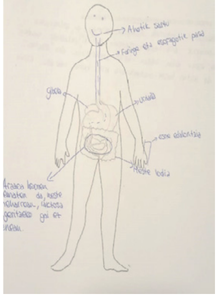
PST	Knowledge	Confidence	Importance	Usefulness
PST48		I have small capacity. I am not very skilled at drawing, but if I have a model, I am able to copy it.	It is very important because seeing things visually makes it easier to internalize them.	Yes, studying the theory through drawings is easier for me [...].
	Level 0	Level 1	Level 2	Level 2
PST51		At the moment, I don't like drawing, and I think I draw badly [...]	I think that knowing how to draw or at least knowing how to draw what is going to be explained is important [...]	It is very useful. Many times, we have our mental models, but they are not realistic and through drawings and physical models, we improve those mental models.
	Level 1	Level 0	Level 2	Level 2

To validate the clusters, differences between them were examined by means of the Kruskal Wallis test. Significant differences were found in knowledge ($H(2) = 99.590$, $p < .001$) and awareness of importance ($H(2) = 117.893$, $p < .001$). Pairwise comparisons after Bonferroni correction showed significant differences between clusters 1 and 2 (knowledge, $p < .001$; importance, $p < .001$); between clusters 1 and 3 (knowledge, $p < .001$); and between clusters 2 and 3 (importance, $p < .001$).

Discussion

This study aimed to address the readiness of a group of PSTs for using drawing as a science teaching strategy in their future professional life, with a focus on their knowledge, confidence and awareness of usefulness and importance of the strategy.

One of the contributions of this work is the way knowledge was assessed. Previous studies on teachers' readiness have usually evaluated knowledge as a self-perceived factor in a broader sample of beliefs (e.g., Park et al., 2017). However, knowledge data in this work were not obtained from PSTs' self-perception but through the analysis of their drawings (following criteria described in the literature). Methodologically, the fact of analysing drawings instead of self perceptions of knowledge improves the validity of the research methods. Furthermore, regarding the DS, it is well known that several misconceptions are persistent (Reiss et al., 2002). In fact, the drawings from the PST population in this study still presented misconceptions (e.g., a non-continuous tube). Consequently, it was assumed that self-perceived knowledge would be overrated. In that sense, our methodological approach is a proposal for teachers and researchers to avoid under- and overrated self-perceptions when measuring knowledge as one of the dimensions of readiness, specially in the case of topics for which persistent misconceptions have been described in the literature.

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PSTs' Readiness for Using Drawings as a Science Teaching Strategy

The results show that PSTs´ drawing knowledge was indeed quite low, and that most PSTs limited themselves to drawing a few loose organs and only a few PSTs drew mechanisms. These results are consistent with previous studies (Oren & Ormanci, 2014; Prokop & Fanèovièováp, 2006) where preservice students showed problems when drawing functions and connections between DS organs. This fact could be attributed to the low knowledge about the DS on the one hand, and to low drawing skills on the other. In fact, looking at the written explanations offered by these PSTs, they denoted a lack of knowledge about the mechanisms and the processes that the organs perform (Uskola et al., 2022), which points to the hypothesis of low knowledge on the DS. However, the PSTs scored higher in the written explanations than in the drawings (Uskola et al., 2022), which is in accordance with the low drawing skills hypothesis. Similarly, Havu-Nuutinen and Keinonen (2010) have found that Finnish students from primary school demonstrated higher knowledge about human anatomy in interviews than in drawings; thus, it was concluded that they did not draw all they knew.

With respect to the other dimensions, all PSTs were aware of the usefulness of drawing as a teaching strategy and almost all of them were aware of its importance. These overall positive beliefs could have a beneficial effect on teachers' practice (Areljung et al., 2021a; Vartuli, 2005). Regarding confidence, in contrast, only one quarter of the PSTs showed a high level of confidence. According to Ofsted (2009), this can have a negative impact on their effectiveness when using the strategy in their future teaching practice.

PSTs with the highest knowledge on drawing science content and low confidence were not found in our sample. That is, all the PSTs with the highest knowledge score were moderate to highly confident in their science drawing skills. That may well point to an association between knowledge and confidence in the sense that a high level of knowledge brings confidence. One may think that if the PST is able to draw science content for teaching, then the PST will have the confidence to do so. Moreover, PSTs with the lowest knowledge and high confidence were not found in our sample. In this sense, it has previously been suggested that weakness in science content can negatively affect the confidence of the teacher, causing him or her to avoid teaching science or to teach it strictly from the textbook (Grossman et al., 1989). The same occurs in the opposite case, when asked to describe their knowledge levels about the DS, and to state their perceptions of the adequacy of their knowledge levels and of their ability to teach the subject, PSTs who defined themselves as successful scored better values than those who defined themselves as unsuccessful (Ormancı & Ören, 2011). Therefore, to improve the readiness of these PSTs to draw in science teaching, reinforcing their knowledge could influence and also improve their confidence, making them more ready PSTs.

On the other hand, in the present study some PSTs with low knowledge have intermediate or high confidence. This profile of "not being able to" but being confident has emerged previously in the literature in teaching science, where teachers who show high confidence present low-level conceptual understanding in the subject itself (Holroyd & Harlen, 1996; Stevens & Wenner, 1996; Tekkaya et al., 2004); thus, they are optimistic and believe they will be good science teachers in the future even though they misunderstand certain concepts of science. However, it has also been described that there are teachers whose confidence is somewhat misplaced, that is, their confidence is low although their understanding of science is good (Holroyd & Harlen, 1996). This is not the case, because, as described before, there were no PSTs with high knowledge and low confidence.

Finally, related to the importance of the ability to do drawings to use in teaching, it is interesting to note that there were no PSTs with high knowledge that gave little importance to drawing skills. That is, all of them were aware of the importance of drawing.

PSTs´ Clusters and Educational Implications

The results revealed that the PSTs fell into three clusters. This heterogeneity in PSTs' knowledge and beliefs indicates that it would be misleading to define a general pattern for readiness.

The clusters found in the sample are specific to this case study. However, the conclusions and reflections on their educational implications may be of interest to the educational community. Thus, Cluster 1 represents a group of the trainee teachers who are quite well prepared, having scored high on the dimensions analysed. However, there is still room for improvement in the drawing knowledge of this cluster, as well as in the confidence of some of them. This cluster could respond well to the strategy of increasing their drawing knowledge and, as a consequence, also increase their confidence to draw. In terms of improving their knowledge of the

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DS, participating in modelling activities using different modes of representation has been found to be effective (Uskola et al., 2022). To improve their drawing skills, specifically with regard to drawing mechanisms, PSTs should be scaffolded so that they internalise the accepted conventions and symbolic tools for representing actions in drawings, such as arrows (Prain & Tytler, 2012; Wilson & Bradbury, 2016). The same could be applied to part of the numerous and heterogeneous Cluster 3, specifically to those with low knowledge and low confidence. Nevertheless, with those PSTs in Cluster 3 who have low drawing knowledge and high confidence, the aim and approach should be different. In this case, in addition to the need to improve their knowledge, they need to be made aware of their limitations in drawing. This could be addressed by making them auto-evaluate and co-evaluate their drawings. Cluster 2 represents a minority of PSTs that are not aware of the importance of the ability for doing their own drawings for teaching purposes. They think that images are available in textbooks, on the internet… and they are not aware of the different educational role that an image can play in the science classroom. For example, many images and physical models representing the DS show it just from an external view, and, although these images can be realistic, they do not allow the learner to see the system as a tube, in the way that self-made drawings or physical models can (Uskola et al., 2022). Although this cluster was a minority, the importance of purposefully doing their own drawings in science teaching should be addressed in the training of future teachers, as the importance they give to the strategy could determine their use in science classes (Areljung et al., 2021b).

Limitations of the Study

The sample was limited to a concrete number of participants in a specific context. Regarding the items analysed, confidence and awareness of the importance and usefulness were measured as believes; and what participants believe may align or not with the actual practice. One should also notice that there could be a ceiling effect when it comes to measure the awareness of the usefulness of the strategy, as all participants scored the maximum value.

Conclusions and Implications

This study explored the readiness of 120 PSTs for using drawing as a strategy in science teaching, aiming to fill the research gap on teacher readiness for this specific strategy. Four items were considered: PSTs' knowledge, confidence, awareness of the importance and awareness of the usefulness. 69% of PSTs scored low in knowledge, drawing no organs or only separate ones. The scores in awareness of the importance and usefulness of drawing were high for 93% and 99% of the PSTs, respectively. Only 28% of the PSTs showed high confidence in drawing scientific issues. No PSTs with high knowledge and low confidence were found. All PSTs with high knowledge showed high awareness of the importance of drawing. Three clusters emerged: PSTs in Cluster 1 ($N = 34$) had the highest scores in the evaluated items (they are the most prepared ones in the sample); eight students were in Cluster 2, who thought that drawing is not important and that they could use images from other sources; the majority of students were in Cluster 3 ($N = 77$) and scored low in knowledge but high in beliefs.

As far as we know, this is the first study exploring the readiness for using drawing as a science teaching strategy in PSTs. Results indicate that PSTs need to improve their readiness, specifically in terms of representing their knowledge through drawing (where the main difficulty is related to drawing processes and phenomena). Results also point to the fact that improving knowledge in drawing may enhance both confidence and awareness of drawing importance and therefore, readiness. Nevertheless, more studies are needed to better understand the underlying factors in readiness.

It is relevant for everyone involved in teaching science to know to what extent pre- and in-service teachers are ready for using drawing as a teaching strategy in science. In this sense, it is important to identify the main difficulties that teachers present. Consequently, in order to prepare teachers for using drawings in science teaching, teacher education programs should develop the drawing knowledge of the pre- and in-service teachers. Given that difficulties are usually related to drawing functions, processes, relationships or phenomena, the focus should be placed on developing the capacity to use science-specific symbolic tools to represent actions.

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Declaration of Interest

The authors declare no competing interest.

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Ainara Achurra *(Corresponding author)*
PhD, Professor, Faculty of Education and Sports, University of the Basque Country UPV/EHU, Vitoria-Gasteiz, Spain.
E-mail: ainara.achurra@ehu.eus
ORCID: https://orcid.org/0000-0001-8055-6057

Teresa Zamalloa
PhD, Professor, Faculty of Education of Bilbao, University of the Basque Country UPV/EHU, Leioa, Spain.
E-mail: teresa.zamalloa@ehu.eus
ORCID: https://orcid.org/0000-0001-8050-496X

Araitz Uskola
PhD, Professor, Faculty of Education of Bilbao, University of the Basque Country UPV/EHU, Leioa, Spain.
E-mail: araitz.uskola@ehu.eus
ORCID: https://orcid.org/0000-0003-0621-3085