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Developing a research instrument to record pre-school teachers' beliefs about teaching practices in natural sciences

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In the last 30 years, 4 distinct theoretical approaches have been described for early childhood science education. The approaches are, empiricist, Piagetian, socio-cognitive and socio-cultural. Drawing on the differences among these approaches regarding the theoretical framework adopted in teaching, the role that is assigned to the teacher during the activity and the actions that are expected from the children, we aimed to serve 2 purposes with this research. Firstly, to elicit the in-service pre-school teachers' beliefs about teaching practices for natural sciences and to record the approaches that these beliefs match. To fulfil this purpose, a new instrument was developed. Secondly, to examine the instrument's validity and reliability. The participants in the study were 94 pre-school teachers who served in public schools in 2 prefectures in Greece. Research findings suggest that pre-school teachers tend to state that they mainly adopt practices that fit the empiricist approach while practices that fit the socio-cognitive approach are not used so often. Finally, they seem to rarely follow practices that fit the socio-cultural and Piagetian approaches.

Keywords: early childhood science education; Greek pre-school teacher's practice beliefs; science pedagogical approaches

Introduction

The issue of introducing children aged 3 to 8 years to natural sciences has been raised for the last 30 years, as evidenced in research in early childhood education, educational psychology and science education. This research has contributed to the formation of a distinct research field, internationally, known as early childhood science education (Canedo-Ibarra, Castelló-Escandell, García-Wehrle & Morales-Blake, 2010; Lorenzo Flores, Sesto Varela & García-Rodeja Gayoso, 2018; Ravanis, 2022). However, as the starting points and perspectives of the endeavours in the above-mentioned research areas are different, the orientations are often incompatible, as they set different research questions that arise from diverse theoretical trends.

A rather distinct category of early childhood science education research focuses on teaching strategies which enhance the development and implementation of activities that help young children take their first steps in natural sciences (Delserieys, Jégou, Boilevin & Ravanis, 2018; Elmalı & Laçin Şimşek, 2021; Mantzicopoulos, Patrick & Samarapungavan, 2013) while another broad category of the literature deals with the development of programmes and curricula that have such orientation (Adbo & Vidal Carulla, 2019; Allen & Kambouri-Danos, 2017; Baldwin, Adams & Kelly, 2009; Saçkes, Trundel & Shaheen, 2020). Moreover, a number of surveys also focuses on pre-school teachers' beliefs, opinions, and practices as they are encouraged to discuss or implement programmes and physical science activities. In particular, the exploration of pre-school teachers' practices is of particular importance in the international educational community where the issues of early childhood science and technology education are increasingly enhanced in curricula around the world (British Columbia Ministry of Health and the Ministry of Children and Family Development, 2008; Department of Basic Education, Republic of South Africa, 2019). In Greece a distinct part of the pre-school curriculum focuses on natural science teaching (Καθημερινή Ηλεκτρονική Εφημερίδα για την Παιδεία [Daily Electronic Newspaper for Education], 2017). Along this line we developed an instrument to record pre-school teachers' beliefs based on the four theoretical approaches and investigated its factorial structure. These teachers' beliefs could lead, on the one hand, to the improvement of both pre-service and in-service training of teachers and improved quality of the basic and continuing education of teachers and on the other hand, to the development of more effective science teaching activities for pre-school learners.

Theoretical Framework

Limited research exists on the pedagogical practices used by pre-school teachers in the field of natural sciences. Undeniably, developing relevant practices is not just a matter of the curriculum or the teachers' will. Institutional, social and cultural features influence in many and often implicit ways, the dominant pedagogical practices of the different periods, and the ideas about the nature and the role of early childhood education and teacher training systems (Areljung, 2019; Fleer, 2009; Lamanauskas & Augienė, 2019; Ljung-Djärf, Magnusson

& Peterson, 2014).

Limited research focuses on the distinct science teaching strategies of pre-school teachers. In a study by Kavalari, Kakana and Christidou (2012), it was found that two approaches are actually used: the empirical approach applied in the vast majority of cases and the contemporary approach. In the empirical approach in particular, learners receive information through their senses while knowledge is simplified, and the experiment stands as a simple demonstration without systematic observation. Here, a pre-school teacher asks questions and is responsible for transferring knowledge and interpreting experiments. The empirical approach also includes classified activities that originate from the Piagetian framework, where emphasis is placed on the development of thinking skills through the handling of materials. The contemporary approach is based on the systematic observation of investigations during which learners' predictions are verified, their views are discussed and recorded, and conclusions are formed. Here, the teacher facilitates learners' investigations, providing the appropriate teaching material and implementing practices that facilitate learning such as collaborative learning, symbolic representation, et cetera.

Merino, Olivares, Navarro, Ávalos and Quiroga (2014) explored the differences between kindergarten teachers' views on science and their instructional practices. A mixed teaching model was identified, both in kindergarten teachers' views on science and their instructional practices. According to them, the empiricist, Piagetian and socio-cognitive approaches could coexist:

> *a traditional epistemological concept dogmatic in the sample, characterised by a rationalist view of science – with a traditional academicist teaching model, which looks for true, definitive and unquestionable meanings or knowledge, and at the same time, believes in the existence of constructivist and evolutionary rationalities.* (Merino et al., 2014:4195)

A classification of approaches to natural sciences teaching in the context of early childhood education

The study of curricula, empirical research, and suggestions for initiating activities in the natural sciences within early childhood education has led to the creation of a framework for classifying four distinct pedagogical approaches, namely, the Science Early Childhood Pedagogical Approaches (SECPA). However, the analysis of theoretical and methodological options as well as research orientations, highlights the formation of a classification based on the following criteria (Ravanis, 2017):

1) Learning theory that dominates teaching approach either implicitly or explicitly.
2) The role that is assigned to the teacher during the activity.
3) The actions that are expected from the children.

According to the above-mentioned classification, the following four distinct pedagogical approaches were proposed in the framework (cf. Table 1).

Empiricist approach

The empiricist approach can be traced back to both traditional pedagogy development and strong influences of early behavioural perceptions of learning and ideas based on empiricism regarding intelligence development (Kerdeman & Phillips, 1993; Skinner, 1968). Unfortunately, the unregulated mixing of these influences took place without any kind of clear rules and structured discussion, and inevitably led to a widely accepted delusion: the successful initiation of young children in natural sciences favours educational environments that attempt to "transfer" scientific information and knowledge to the minds of young learners. In this context, the main aspects of the components of a teaching process have several constant and recurring characteristics. The teacher is at the centre of the process maintaining a strong leadership role. Particularly, he/she sets out the themes of the teaching activities, proposes and presents experiments, defines the boundaries of children's actions and discussions, asks questions, formulates conclusions and gives the "right" answers. In such a perspective, children adapt to the teacher's actions, participate in predefined plans for activities and answer questions. The subject of instruction and scope of activities is drawn directly from physical sciences according to subjective simplifications and estimations of what can be taught to young children (Conezio & French, 2002; Miller, 2016). The approach is summarised in the framework given in Column 1 of Table 1.

Piagetian approach

The second approach has its roots in the context of Piagetian genetic epistemology (Piaget, 1936/1952; Piaget, 1938/1954). Hence, its basic theoretical position on learning theory stands on the view that mental development is not due to "transferring" information and perceptual data from the environment to a child's thinking, but the construction of logical structures. This occurs in a context in which the child is constantly interacting with the world around him/her. Thus, for teaching pre-school children, Kamii and DeVries (1978) propose an orientation to physical-knowledge activities that focuses on children's activity with specialised interactive material. This perspective is quite different from the classical teaching of physical science in higher levels of education, which gives priority to teaching theoretical schemes and principles, models, laws and methodological elements. During physical-knowledge activities that correspond to the level of children's intellectual development, children independently handle materials and objects, test and plan, set goals, and strive to achieve them individually or in collaboration (Kato & Van Meeteren, 2008). The teachers' role during these kinds of activities is complex and demanding. Prior to the activities teachers provide the content and boundaries and set the pedagogical material in order to maximise children's initiative and ability to develop individual actions. Secondly, the teachers support, facilitate and encourage children through free experimentation, they intervene to help them manipulate teaching material and set more complex goals, and they record creative choices and insurmountable obstacles of learner's actions. At the end of the activities, teacher recordings can thirdly be used to estimate initial projections, to conclude on the successful outcome of the activities and to suggest the appropriate arrangement of the space and the use of quality pedagogical material in order to maximise the chances of successful teaching situations (cf. Column 2 in Table 1 for a summary).

Socio-cognitive approach

The socio-cognitive approach is a third distinct framework which was established in the science education framework. Along with science education, the first international academic attempt took place, which systematically studied the transition of children's thinking from everyday experiential reasoning to thought patterns compatible with scientific knowledge. In this context, the focal point lies in both recording and exploitation of mental representations of children of 4 to 8 years old (Demirba & Ertuğrul, 2014; Kampeza, Vellopoulou, Fragkiadaki & Ravanis, 2016) and the study of teaching activities during which an attempt is made to construct new representations in children's thought (Kalogiannakis, Nirgianaki & Papadakis, 2018). At this point, the teachers obtain a special role as they have to select, prepare, propose and direct activities, while being in constant interaction with their young learners. The goal of their action is to create the conditions for achieving transformations in children's thinking, and in this aspect the issue of children's intelligence lies at the heart of every activity. In the context of the socio-cognitive strategy, the teacher systematically mediates to create conditions of research and discovery in which the learner has increased chances of constructing new representations overcoming the difficulties already identified in previous research. During these teaching activities, young learners engage in situations of interaction between children and teachers or between children, discuss and investigate by exchanging arguments, formulate simple hypotheses and use multiple representations to support the construction of new reasoning (cf. Column 3, Table 1).

Socio-cultural and/or cultural-historical approach (S-C/C-H)

The fourth distinct pedagogical approach in the development of physical sciences activities in the field of early childhood education is the S-C/C-H framework. The genesis of this strategy is based on Vygotsky's fundamental assumption that learning and developmental processes emerge within the child's own environment through its natural, cultural, historical and social elements (Hedegaard, Fleer, Bang & Hviid, 2008). Thus, a S-C/C-H framework emphasises the creation of an educational environment in which children's activities highlight elements such as their ideas, imagination and creativity, as well as play, collaboration and communication. In this perspective, a holistic approach to learners' scientific thinking is important, which is relevant for both the organisation of teaching activities and their analysis at the methodological level.

> *This trend is focused on a systemic study of the procedures through which young children develop scientific thinking and the situational characteristics that act as a driving force of this development. In that framework, qualitative and flexible methodologies are replacing quantitate linear approaches of concrete functions, static elements and isolated incidents and circumstances. Integrating everyday reality and real-life phenomena, research leads to a better contextual understanding and to a deeper conceptualisation of the process of individual's development as well as of the educator's mediating role as a cultural tool.* (Fragkiadaki & Ravanis, 2016:312)

In the socio-cultural context, the teacher creates conditions of communication and a classroom and school environment that allow a holistic approach to human creation. The development of teaching activities in the classroom is planned and carried out based on the set of cognitive, imaginative, emotional, physical and social data that can be processed and interacted with. This is why the use of a variety of media such as painting, physical and rhythmic expression, music, symbolic and real play create a space of emotions and mental motivation that inevitably affect learning and cognitive development. Children develop initiatives, interact and communicate with both their peers and teachers, use materials in many ways, draw, and engage in various symbolic roles. Consequently, they approach the natural world through different ways that fit into social, cultural and historical elements that constitute their daily reality (Fleer & Robbins, 2003; Hadzigeorgiou, 2001; Pantidos, Herakleioti & Chachlioutaki, 2017; Plakitsi, 2013). In Table 1 a brief overview of the key features of the four frameworks regarding both learning theory and the role of the teacher as well as expectations of learners, is presented.

Table 1 SECPA* framework highlighting key features of the four pedagogical approaches for teaching physical science in the context of early childhood education

Empiricist framework	Piagetian framework	Socio-cognitive framework	Socio-cultural/cultural-historical framework
		Learning theory	
Behaviourism, empiricism	Piagetian genetic epistemology	Post-Piagetian socio-constructivism and Vygotskian framework of cognitive development	Vygotskian holistic theory
		Role of the teacher	
Stands in the centre of the educational process Possess the empirically simplified knowledge and tries to transmit it Implements activities by presenting scientific knowledge, information, teaching materials and demonstration experiments Possess a strong guiding role (defines learner action, formulates questions, provides explanations, draws conclusions and provides "correct" answers)	Facilitates and supports – Intervenes in children's activities for particular reasons Opt for appropriate developmental activities, prepares the educational environment, choose teaching materials Provides instructional materials to learners to manipulate and experiment freely Intervenes in the free experimentation of children only for changing the handling of the teaching material and setting more complex goals	Develops teaching situations based on children's difficulties, guides, supports and facilitates Records and takes advantage of children's mental representations Develops conditions for exploration, discovery and experimentation with the aim of transforming learner representations (barriers to learning) in others compatible with the scientific ones Enhances the interaction between learners as well as between learners and the teacher with the aim being the construction of knowledge	Participates in activities in an active manner and mediates in children's thinking as a cultural tool Actively participates in activities and mediates in children's thinking as a cultural tool Identifies the factors that are incorporated in children's thinking on three levels: a) personal (individual elements of children's thinking and actions, e.g. children express their ideas through sketches), b) interpersonal (children's interactions with others, e.g. the language they use in exchanges), c) wider socio-cultural (social, cultural, and historical elements related to objects, natural phenomena/concepts) Enhances communication, collective action and interaction between learners and between learners and teacher with the aim of conceptual development Approaches scientific concepts by linking them with everyday concepts related to the cultural, historical and social elements that constitute children's everyday reality Emphasises imagination, creativity, role-play and imaginary play
		What is expected of learners	
Passive monitoring of activities and experiments Follow instructions for acting – answer questions Memorise and retrieve knowledge Work individually or attend in groups	Active participation Handle materials autonomously, try, test and plans, set goals and try to achieve them Discover knowledge on their own as they manipulate and experiment with teaching materials Work individually in the first instance and secondly in groups	Active participation Express mental representations, make assumptions and predictions Test their mental representations through investigations and experimental situations Transform their mental representations into others compatible with the scientific ones Work in groups to construct knowledge together	Active participation Express their ideas through different means (speech, drawing, writing, gestures, songs) Participate in role-play/imaginary play Correlate everyday concepts with scientific concepts Work in groups and via interactions are led to the development of concepts

Note. *Science Early Childhood Pedagogical Approaches.

However, most of the relevant research that study practices adopted by pre-school teachers when teaching science is not aimed at finding broader teaching approaches but confined in the illustration of some distinct features in the teaching process. Undoubtedly, these characteristics can be encompassed in one or more frameworks. These options have a clear empiricist orientation. For example, pre-school teachers simply refer to demonstrating experiments and teaching processes that lack considering children's assumptions, drawing conclusions and systematic observation. Still, they often seem to rather prefer the preparation that will allow them to provide correct answers to children's questions than making an effort to understand and promote their scientific thinking (Bagakis, Balaska, Komis & Ravanis, 2006; Draganoudi, Kaliampos & Lavidas, 2021; Kallery, 2004; Kambouri, 2016; Kavalari, Kakana & Christidou, 2014).

Moreover, pre-school teachers seem not to experience feelings of satisfaction when dealing with science activities as they consider natural sciences to be a difficult learning and teaching area for which they are not adequately trained at various levels; that of adequate knowledge from natural sciences, that of teaching strategies and that of selection and usage of necessary materials and instruments (Hedges & Cullen, 2005; Howitt, 2007; Kavalari et al., 2012; Nayfeld, Brenneman & Gelman, 2011; Oppermann, Hummel & Anders, 2021; Pendergast, Lieberman-Betz & Vail, 2017; Vellopoulou & Papandreou, 2019). The current data clearly does not relate in a direct way to pre-school teachers' practices. However, it emphasises the lack of familiarity with a wide range of tools that exist in all three frameworks apart from empiricist, which clarifies to some extent why issues such as knowledge, materials and instruments remain attached.

Research Objectives

The four distinct pedagogical approaches for developing activities in the field of physical sciences discussed above, were developed into a framework which focused on the three criteria given in Table 1. Thus, regarding young children's activity, teachers' roles, and generally the whole pedagogical and teaching context, distinct and divergent choices can be identified. On the one hand, identifying these options facilitates the exploration of the effectiveness of the activities being implemented in practice, and on the other hand, this enables pre-school teachers to use systematic and documented choices.

The distinct importance that is often attributed to the way in which pre-school teachers plan and carry out activities for natural sciences, as well as the researchers' effort to capture them as distinct practices (Kallery, 2004; Kavalari et al., 2012; Merino et al., 2014), led to the development of an instrument, based on the four theoretical frameworks, that enables the recording of pre-school teachers' beliefs expressed about their practices. Therefore, the aim with our research was to

- investigate pre-school teachers' beliefs based on the four approaches of the framework developed
- investigate the factorial structure of the questionnaire administered for the investigation of pre-school teachers' beliefs regarding the four approaches.

Methods

Research Procedure and Sample

The research was carried out in the first 2 months of 2019 with a total of 94 pre-school teachers who worked in schools across two prefectures in Greece. These pre-school teachers had studied in Greece, where nine early childhood education university departments are run, all of which offer 4-year study programmes. Along these programmes, students attend two to three compulsory modules on science education and three to five optional modules in the same field. The systematic analysis of the curricula of the nine departments show that all these modules mainly support the socio-cognitive approach in teaching and learning of science (cf. Appendix A).

All the pre-school teachers participated voluntarily, and they were informed about the completion of a questionnaire. They were also informed that they would remain anonymous, and that the collected data would be solely used for research purposes. Pre-school teachers' responses to the web questionnaire were collected via Google Forms and the completion of the questionnaire took approximately 10 minutes. The distribution of the participants' gender, age, educational level and teaching experience is presented in Table 2.

Table 2 Demographic information (*N* = 94)

		Frequency	Percentage
Gender	Male	2	2.1
	Female	92	97.9
Age (years)	22–29	3	3.2
	30–39	26	27.7
	40–49	40	42.6
	at least 50	25	26.6
Education level	Graduate	68	72.3
	Post-graduate	26	27.7
Experience (years)	1–5	4	4.3
	6–10	19	20.2
	11–15	26	27.7
	16–20	25	26.6
	21–25	11	11.7
	at least 26	9	9.6

The Research Instrument

Following a descriptive account of the literature on the four distinct pedagogical approaches and development of the SECPA framework, a research instrument consisting of 30 items was developed. The research instrument was reviewed by five experts who indicated the exclusion of seven items which were evaluated as either “not relevant” or “somewhat relevant” to any of the four pedagogical theoretical schemes mentioned above. Consequently, the final version of the questionnaire consisted of 23 items, distributed as follows: five items for the empiricist approach, five items for the Piagetian approach, six items for the socio-cognitive approach and seven items for the S-C/C-H approach (cf. Table 3). A five-point Likert-type scale was used for each item: 1) Not at all to 5) Extremely. All items were randomly distributed, in order to avoid bias in answering. Moreover, the titles of the four categories shown in Table 3, namely empiricist, Piagetian, socio-cognitive and S-C/C-H, were not observable to the subjects of the research. The questionnaire, enriched with questions on the gender, age, education level, and years of teaching experience was administrated in a sample of in-service pre-school teachers. Finally, the questionnaire was administered in Greek, the mother tongue of all the subjects. Nevertheless, for the purpose of publication, the research instrument was forward-backward translated into English (Lavidas & Gialamas, 2019).

Table 3 Administrated instrument: Distribution of participants' responses

Teachers' items	1 Not at all	2	3	4	5 Extremely
Empiricist framework (five items)					
1) During the activities I present information about objects, natural phenomena and concepts of the natural world	1.1%	2.1%	33.0%	48.9%	14.9%
2) I conduct demonstration experiments to confirm the concepts or physical phenomena that I previously presented to my students	2.1%	7.4%	30.9%	41.5%	18.1%
3) I formulate with clarity the conclusions drawn from the experimental activities	1.1%	3.2%	33.0%	42.5%	20.2%
4) I coordinate the work done in the classroom by asking questions, formulating problems and providing explanations	1.1%	5.3%	33.0%	40.4%	20.2%
5) My main goal in teaching science is to transfer knowledge to my students about the natural world	1.1%	12.7%	31.9%	38.3%	16.0%
Piagetian framework (five items)					
6) I choose activities that maximise the child's initiative	0.0%	4.3%	34.0%	44.7%	17.0%
7) I interfere on children's experimentation with object and materials in order to help them set more complex goals	0.0%	27.6%	38.3%	30.9%	3.2%
8) I intervene in children's experimentation with object materials in order to encourage them to handle the materials in a different manner	1.1%	18.1%	48.8%	27.7%	4.3%
9) I choose activities that take the general mental development of my students into account	1.1%	2.1%	31.9%	54.3%	10.6%
10) I offer object materials to my students without suggestions and encourage them to experiment with the materials freely	2.1%	28.7%	37.2%	20.3%	11.7%
Socio-cognitive framework (six items)					
11) I explore children's alternative representations (learning barriers) on concepts, physical phenomena and materials	0.0%	3.2%	26.6%	48.9%	21.3%
12) I am trying to group children's alternative representations (learning barriers) on concepts, physical phenomena and materials	1.1%	7.4%	41.5%	35.1%	14.9%
13) I set up activities and try to fulfil my teaching goals by taking into account the children's alternative representations (learning barriers)	0.0%	4.3%	31.9%	44.7%	19.1%
14) The course of activities development is flexible and I make revisions whenever needed	0.0%	3.2%	29.8%	43.6%	23.4%
15) My teaching activities foster the transition from children's alternative representations to other new ideas that are close to the scientifically accepted ideas	0.0%	2.1%	42.6%	40.4%	14.9%
16) I am aware of children's alternative representations (learning barriers) on the subject I am going to teach	0.0%	9.6%	41.5%	39.3%	9.6%
Socio-cultural and/or cultural-historical framework (seven items)					
17) I explore each child's alternative representations on concepts, physical phenomena and materials object properties as I interact with them	0.0%	2.1%	33.0%	44.7%	20.2%
18) I explore each child's alternative representations on concepts, physical phenomena and material object properties through his/her paintings which he/she explains to me	0.0%	5.3%	30.8%	42.6%	21.3%
19) I observe and record the language that my students use as they interact, exchange views, agree and disagree with each other	3.2%	17.0%	36.2%	29.8%	13.8%
20) I take the socio-cultural background of my students into account, which is likely to influence the way children conceptualise their ideas about objects, physical phenomena and the natural world itself	5.3%	22.3%	42.6%	20.2%	9.6%
21) I associate children's alternative representations on physical phenomena with their social, cultural, and historical elements that are part of their every-day lives	2.1%	7.4%	43.7%	33.0%	13.8%
22) I take the children's diverse ideas into account as they change and shape according to the socio-cultural environment in which they are developed	1.1%	7.4%	29.8%	41.5%	20.2%
23) I encourage communication between children during teaching activities	0.0%	4.3%	31.9%	42.5%	21.3%

Research Procedure for Instrument Development

Instrument development and content validity

The method that we used consisted of two stages. In the first stage, our aim was to develop items that demonstrated content validity according to the theoretical domain of interest. To fulfil this goal, we created a pool of suitable items for each of the four theoretical approaches. At the same time, in order to enhance the content validity of the research instrument, five researchers working in the field of early childhood science education evaluated whether the above items fit each of the above theoretical schemes. For the assessment procedure, a four-point scale was used (Not relevant, Somewhat relevant, Quite relevant, Very relevant).

Factorial structure – Reliability and validity of instrument

In the second stage, we administrated the questionnaire, after amendment, based on the expert's intervention, to the sample of in-service pre-school education teachers. Before the administration of the final questionnaire a pilot study carried out with five pre-school teachers who were not included in the final sample. The discussion with them did not reveal significant issues about the wording of the different questionnaire items. The analysis of the responses supported the final factorial structure of the research instrument. We determined the factorial structure as the number of components (cf. Table 3) and the items that load in each component (cf. Table 4). We established the construct validity and reliability (cf. Table 5) as well. Initially, a parallel analysis was conducted to determine the factorial structure of teachers' responses, and particularly the number of components (Horn, 1965). According to this analysis, the components with eigen values greater than corresponding eigen values of simulated data were retained. Subsequently, we applied variance-based structural equation modelling (VB-SEM) and, in particular, partial least squares-structure equation modelling (PLS-SEM) or PLS path analysis (Hair, Hult, Ringle & Sarstedt, 2017; Lowry & Gaskin, 2014). The PLS-SEM is considered suitable for exploratory research purposes since it can account for the total variance in the observed variables rather than only to explain the correlations between the variables. Moreover, PLS-SEM was considered suitable for this research since this analysis was flexible regarding normality distribution and sample size (Hair et al., 2017; Lowry & Gaskin, 2014). This was a contemporary multivariate method of analysis, which we find in social sciences as well (Meli, Lavidas & Koliopoulos, 2020). With PLS-SEM the factorial structure is determined according to the number of components revealed by parallel analysis. Simultaneously, we established the structural validity (convergent and discriminant validity) and reliability of the final factorial structure (Gaskin, 2016). The factorial structure of the responses consisted of the measurement model and the structural model and this analysis was an iterative process. We established the measurement model or outer model, that is the part of the model that has to do with the relationships between each latent variable (component) and its block of indicators (items), and subsequently the structural model or inner model that is the part of the model that has to do with the relationships between latent variables.

During the evaluation of the measuring model (Gaskin, 2016; Hair et al., 2017), we tried to fulfil the following criteria: a) unidimensionality of each component of the indicators (items), that is the reflective indicators to be in a geometrical space of one dimension, b) loadings for each indicator to be close to the recommended threshold of 0.7 without cross-loadings. So, each item loads more highly on their own construct than on other constructs. According to Gaskin (2016), cross-loadings are not revealed when primary loading is at least 0.2 greater than secondary loading and c) satisfactory construct validity and reliability for each component. To verify the construct validity of the research instrument, we had to establish the convergent and discriminant validity. Convergent validity for each component was assessed by the magnitude of loadings extracted by PLS-SEM (cf. Table 4). Moreover, AVE over 0.5 indicates a satisfactory convergent validity (cf. Table 5) (Fornell & Larcker, 1981; Hair et al., 2017). To assess discriminant validity, we used the Fornell-Larcker criterion (Fornell & Larcker, 1981) and the Heterotrait-Monotrait ratio (HTMT) (Henseler, Ringle & Sarstedt, 2015). The first method demanded that the square root of each factor AVE should be greater than the correlations with other latent components. With the second method the HTMT ratio must not exceed the criterion of 0.85 (cf. Table 5). Reliability was assessed by the estimates of Cronbach's alpha (Cronbach, 1951) and composite reliability values (Raykov, 1997). These coefficients should be greater than 0.7 (cf. Table 5). Regarding the evaluation of the structural model (Hair et al., 2017), we examined the bivariate correlation among the latent variables (Gaskin, 2016). Finally, we performed bootstrap resampling with 5,000 samples to get confidence intervals for evaluating the precision of the PLS parameter estimates (Sanchez, Trinchera & Russolillo, 2017).

The parallel and PLS-SEM analysis was conducted in R environment (R Core Team, 2018) with the psych (Revelle, 2018) and plspm (Sanchez et al., 2017) packages respectively.

Results

Data analysis is presented in two distinct level forms. On the first level, based on frequency of responses, an attempt is made to identify the approaches that in-service pre-school teachers identify with when they refer to their beliefs on teaching practices for physical sciences activities in pre-schools. On the second level, the structure validity and reliability of the instrument is examined.

In Table 3, the frequency of pre-school teachers' responses to each one of the 23 items of the web-questionnaire instrument is presented. Subsequently, pre-school teachers' beliefs are discussed and the main tendencies in the four distinct pedagogical approaches are highlighted.

The most prevalent approach that seems to emerge when pre-school teachers referred to their beliefs on implementing activities from physical sciences was that these activities were strongly characterised as teacher-centred approaches in which teachers take a strong, guiding, and dominant role in the educational process. In this approach the teacher presents information on objects, physical phenomena, and concepts of the physical world, conducts demonstration experiments, coordinates classroom work by asking questions, provides explanations and seeks for conclusions, with the main aim being the transfer of knowledge to learners. Such practices hold a key role in the empirical approach.

The second most prevalent approach that emerged from the pre-school teachers' responses referred to a Piagetian framework, as it incorporated practices dominated by both children's free experimentation with teaching materials and the limited involvement of their teachers. Nevertheless, these choices seemed to be rarely adopted by pre-school teachers. Instead, other choices from the Piagetian approach, such as activity plans that take into account the general cognitive development of children and/or maximise their own initiative, seemed to be preferentially chosen by them.

Another recorded approach constituted practices related with children's mental representations and the enhancement of flexible teaching activities that favour the transition of children's thinking from initial representations to the formation of others that are compatible with the scientifically accepted ideas. These practices, such as exploring children's representations and setting up appropriate activities, seemed to be adopted very often by pre-school teachers and they were typical of the socio-cognitive framework.

Finally, the approach that was least presented in pre-school teachers' beliefs involved practices that were mainly related to the analysis of child involvement at three levels: individual, interpersonal and wider socio-cultural. At the individual level, the practices that seemed to be adopted were those that probed children's mental representations of the concepts and phenomena of natural sciences by emphasising communication with children and looking through their learning trajectories. At the interpersonal level, most of their practices mainly focussed on observing language communication among children. Finally, practices that were based on the socio-cultural elements of the learners' environment as an aiding tool for dealing with their distinct concepts and representations about a number of physical phenomena, were also recorded. These kinds of practices appear in the socio-cultural approach.

Structure Validity and Reliability of Instrument

Initially, a parallel analysis (Horn, 1965) of the data, conducted in R (in package psych), suggested that four factors or components should be extracted, consistent with the number of themes targeted. Specifically, the eigen values of original components (8.81, 2.25, 1.69 and 1.56) were greater than the eigen values of simulated components (2.02, 1.84, 1.63 and 1.55). For exploratory factor analysis using PLS-SEM (Gaskin, 2016), based on the theoretical structure of four-components with 23 items, we created a baseline model. Each component was linked with the indicators (items) according to the theoretical structure. In particular, we linked five items to the first component of empirical practice, five items to the second component of Piagetian practice, six items to the third component of socio-cognitive practice and finally seven items to the fourth component of S-C/C-H practice.

The estimation of measurement model revealed two items (5 and 10) with loadings lower than 0.4. These items of empirical and Piagetian components of practice respectively seemed to be covered by others in their group without causing content validity. Therefore, we decided to exclude them from their respective components. Re-evaluation of the model with the remaining 21 items showed satisfactory results in all control criteria of the measurement model. Specifically, for each component, the investigation of eigen values revealed that only the first eigen value was greater than 1, which was taken as evidence that the variables in each block were in a unidimensional space. With some exceptions (items 1, 9 and 23), loadings (close to 0.6) exceeded the criterion value of 0.7 (cf. Table 4). Moreover, cross loadings were not observed (Gaskin, 2016) since all the items showed $|\text{primary loading} - \text{secondary loading}| < 0.2$. Our decision was to retain the three items with $|\text{loading}| < 0.7$ in the model because these items were considered important for both the formation of the specific theoretical schemes as well as for their validity and reliability (Hair et al., 2017).

Table 4 Measurement model: Loadings and 95% confidence intervals

Items	Loadings	Mean bootstrap	*SE*	95% CI
1	.648	.647	.073	.488 - .775
2	.785	.785	.046	.682 - .864
3	.890	.889	.023	.833 - .928
4	.859	.857	.032	.784 - .910
6	.711	.713	.053	.594 - .810
7	.770	.760	.075	.574 - .867
8	.776	.769	.069	.606 - .871
9	.595	.594	.094	.370 - .751
11	.706	.702	.065	.552 - .808
12	.773	.769	.052	.651 - .857
13	.836	.836	.039	.752 - .901
14	.764	.762	.054	.642 - .852
15	.779	.779	.043	.687 - .853
16	.717	.713	.062	.573 - .815
17	.837	.838	.029	.774 - .889
18	.813	.814	.033	.740 - .873
19	.791	.787	.047	.680 - .866
20	.737	.729	.057	.604 - .823
21	.765	.761	.053	.643 - .851
22	.868	.866	.030	.797 - .915
23	.656	.658	.075	.492 - .791

Note. These items form the final suggested instrument with the corresponding formulation (cf. Table 2).

Subsequently, we investigated the convergent and discriminant validity (cf. Table 4). Average variance extracted (AVE) over 0.5 for each component indicates a satisfactory convergent validity (Fornell & Larcker, 1981; Hair et al., 2017). For the discriminant validity, the Fornell-Larcker criterion (Fornell & Larcker, 1981) and Heterotrait-Monotrait ratio (HTMT) (Henseler et al., 2015) revealed satisfactory discriminant validity. In particularly, the square root of each factor AVE was greater than the correlations with other latent components (cf. Table 5). Also, the HTMT did not exceed the threshold 0.85. As far as reliability is concerned, (cf. Table 5), Cronbach's alpha (Cronbach, 1951) and composite reliability (Raykov, 1997) revealed coefficients over or close to 0.7.

Table 5 Reliability and construct validity of four-component model

				Heterotrait-Monotrait ratio (HTMT)			
Components	Cronbach's alpha	CR	AVE	Empiricist (Empir.)	Piagetian (Piaget.)	Socio-cognitive (Sociocogn.)	Socio-cultural (Sociocult.)
Empir.	.807	.875	.642	-			
Piaget.	.681	.806	.514	.660	-		
Sociocogn.	.857	.893	.583	.731	.703	-	
Sociocult.	.894	.917	.614	.592	.728	.719	-

Regarding the evaluation of the structural model (Hair et al., 2017), statistically significant moderate bivariate correlations among the latent variables were observed (cf. Table 6) (Gaskin, 2016). Drawing from the average value of each approach/factor we conclude that pre-school teachers tended to state that they adopted practices that fit the empirical approaches to a greater extent, followed by practices that fit the socio-cognitive approach, while to a lesser extent they follow practices that fit the socio-cultural and Piagetian approaches.

The ANOVA repeated measures test showed that the above classification was statistically significant, F (3, 279) = 9.613, p = .001, partial eta square = .094. Additionally, using the Bonferroni correction, the above scores of both empiricist (95% CI: 3.59–3.87) and social-cognitive (95% CI: 3.59–3.84) approaches significantly differed (p < .001) from the scores of the Piagetian approach (95% CI: 3.31–3.54). A Kruskal-Wallis test revealed statistically significant differences only in the socio-cognitive (x2(2) = 6.364, p = 0.042) and the socio-cultural (x2(2) = 7.092, p = 0.029) approach regarding scores among the various age groups (22–39 years, 40–49 years). The pre-school teachers up to 39 years old presented higher scores in these two approaches than the other pre-school teachers (40–49 years). Similarly, Kruskal-Wallis test revealed statistically significant difference only in the socio-cultural (x2(2) = 8.617, p = 0.035) approach regarding scores among the various teaching experience groups (up to 10 years, 11–15 years, 16–20 years and at least 21 years). The pre-school teachers with teaching experience up to 10 years presented higher scores in this approach than the other pre-school teachers. Finally, we did not observe statistically significant differences between pre-school teachers who held postgraduate diplomas or not in the scores on the four approaches.

Table 6 Descriptive statistics and Correlation matrix

	*M**	*SD*	Emp.	Piaget.	Sociocogn.	Sociocult.
Emp.	3.728	.686	(.801)			
Piaget.	3.428	.569	.489	(.717)		
Sociocogn.	3.711	.612	.616	.559	(.764)	
Sociocult.	3.579	.702	.517	.592	.661	(.784)

Note. The average score for all of the items included in the component on the diagonal are the square root of AVE. Off-diagonal elements arc correlations among components. For all correlation $p < .001$.

Discussion

With this research we investigated the factorial structure of a questionnaire administered for the investigation of pre-school teachers' beliefs regarding the four frameworks, namely the empiricist, the Piagetian, the socio-cognitive and the S-C/C-H approach. The exploratory factorial analysis of the 94 pre-school teachers' responses clearly suggest that this 21-item instrument is a valid and reliable research instrument that can be used by researchers in the field of early childhood science education to capture pre-school teachers' beliefs about their practices when developing activities for natural sciences. The development of a valid and reliable instrument which classifies the beliefs of pre-school teachers into four organised pedagogical approaches, filled a gap in the academic literature (Kallery, 2004; Kavalari et al., 2012; Merino et al., 2014), as there seems to be a lack of such an instrument in the area of natural sciences. The instrument incorporates a new approach in its classification, namely the socio-cultural approach, which seems to be given special emphasis in recent years among the scientific and educational community.

The results of the data analysis illustrate a clear tendency of pre-school teachers' choices toward the empiricists and socio-cognitive approached. These two orientations were to some extent expected. Undoubtedly, the world of early childhood education seems to have been strongly influenced by the empiricist approach. Indeed, the heavy tradition of pedagogical currents that dominated every educational process until the end of the 20th century, as well as the ordinary school curricula and the activity-centred books were usually based on empiricist elements: at the centre of every learning mechanism lies the "transfer" of knowledge which is facilitated from teachers to children as they share roles which are pre-designed uneven. On the other hand, studies at university departments of early childhood education have a clear orientation towards the socio-cognitive approaches that lie at the heart of constructivism, which constitutes the paradigm of science education (Ravanis, 2021).

In the official curriculum of all these departments where the potential pre-school teachers complete their studies, are included two to three compulsory and three to five optional modules in modern science education at the centre of which lie the basic assumptions of the socio-cognitive framework. All the pre-school teachers of the sample have studied in these departments. In line with this, workshops organised by academics as well as initial and in-service training coordinated by consultants in the education field promote the socio-cognitive approach. This is partly confirmed by our findings as pre-school teachers with less experience seemed to follow this framework to a greater extent. Indeed, these modern studies place at the centre of learning processes the active construction of knowledge and the importance of organised interactions between teachers and learners. Consequently, this dual influence could justify the above-mentioned preferences of pre-school teachers. In spite of the fact that pre-school teachers often recognise the importance of representations of young children for concepts and phenomena of physical sciences, they rarely rely on them in order to work with children. This happens either for practical reasons such as a lack of time or due to the fact that they often do not know how to use representations to create appropriate activities (Kallery, 2004; Kambouri, 2016; Papandreou & Kalaitzidou, 2019; Puig Gutiérrez, Cruz-Guzmán & Rodríguez-Marín, 2019). This finding features pre-school teachers' preferences for a socio-cognitive approach, although limited by the material conditions of their work.

It should certainly not go unnoticed that a number of pre-school teachers also approached practices from Piagetian and socio-cultural approaches. These findings are compatible with those in the literature, where two major frameworks are emerging. With regard to the empiricist framework it is often labelled as the empirical or traditional framework while the socio-cognitive framework is referred to as the contemporary framework (Kavalari et al., 2012; Merino et al., 2014). Nevertheless, in doing so, they seem to make contradictory choices as they approach these two frameworks fragmentally and opportunistically, without being aware of the consequences of their choices.

Implications

The results of our research suggest that the instrument with the 21 items can measure, with validity, pre-school teachers' beliefs about their practices when developing activities for pre-school physical sciences. This short scale could be used in studies where survey time is limited since these instruments usually have higher response rates (Creswell, 2002). In addition, this scale may well be used with researchers in other countries to identify similarities or contrasts. Nevertheless, further investigation could be carried out with representative samples through Greece to affirm this factorial structure.

The classification of pre-school teachers' beliefs in the four pedagogical approaches through the tool and consequently the classification of their teaching choices is considered particularly useful for both teachers and the scientific community. With regard to in-service pre-school teachers, it provides them with a complete picture of what their preferred pedagogical approaches are and could lead to reflection or considerations of other more suitable pre-school science teaching activities. Moreover, it enables them to move towards systematic and documented choices in order to enrich and structure their natural sciences teaching strategies.

Regarding the early childhood education research community, the framework given in Table 1 provides characteristics and teaching practices of each of the four pedagogical approaches for teaching physical science in pre-schools. At a functional level, the findings can lead to the development of specific educational materials and activity guides for teachers. In this frame, SECPA could capture the pre-school teachers' beliefs and, therefore, feed future training programmes and simultaneously feed school curricula with teaching suggestions to improve their practices.

Limitations

Both the limited research sample and the lack of relevant research instruments that could serve as a criterion of validity, undoubtedly constitute two systematic limitations of our research. Nevertheless, the recorded approaches make it interesting to approach the factor structure in a survey of pre-school teachers, as well as teachers with different cultural and educational profiles. It would be particularly interesting to consider the use of a larger and more representative sample in which confirmatory factor analysis techniques could confirm the recorded factor structure.

Finally, it should be noted that the voluntary participation of pre-school teachers in research often leads to response biases (Lavidas & Gialamas, 2019). Certainly, future research combining quantitative data with qualitative records of pre-school teachers' beliefs on implementing activities from natural sciences would help validate the proposed version and structure of the research instrument.

Authors' Contributions

All authors contributed to the writing of the article; AD and KR designed the survey tool; AD and GK conducted the investigation; AD and KL carried out the statistical analysis; all authors reviewed the final manuscript.

Notes

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Appendix A

The curricula of the nine Greek early childhood education departments

1) Department of Early Childhood Education, National and Kapodistrian University of Athens (https://www.ecd.uoa.gr/?page_id=1349)
2) Department of Early Childhood Education, Aristotle University of Thessaloniki (https://www.nured.auth.gr/dp7nured/?q=en/node/35)
3) Department of Educational Sciences and Early Childhood Education, University of Patras (http://150.140.160.61:8000/el/coursespms/)
4) Department of Early Childhood Education, University of Thessaly (http://www.ece.uth.gr/main/el/content/39-odigos-spoydon-proptyxiakoy)
5) Department of Preschool Education, University of Crete (https://ptpe.edc.uoc.gr/en/page/6/74/odigos-proptyxiakwn-spoydwn)
6) Department of Early Childhood Education, University of Ioannina (https://ecedu.uoi.gr/course-outlines-2020-2021/?lang=en)
7) Department of Preschool Education Sciences and Education Design, University of Aegean, (http://www.pse.aegean.gr/en/?page_id=5421)
8) Department of Early Childhood Education, University of Western Makedonia (https://nured.uowm.gr/en/)
9) Department of Education Sciences in Early Childhood, Democritus University of Thrace (https://www.psed.duth.gr/en/students-guide/)