ACTA SCIENTIAE
ISSN: 2178-7727
DOI: 10.17648/acta.scientiae.6814

Review of Educational Research in Astronomy in Early Childhood and Primary Education from 2009 to 2019

María Sonia Blanco-Chamborro[a]
Mercedes Varela-Losada[b]
María Lorenzo-Rial[b]
Uxío Pérez-Rodríguez[b]

[a] Consellería de Cultura, Educación e Universidade, Xunta de Galicia (Pontevedra, España)
[b] Universidad de Vigo (Pontevedra, España)

Received for publication 29 Ago. 2021. Accepted after review 22 Jul. 2022
Designated editor: Renato P. dos Santos

ABSTRACT

Background: In recent decades, a wide variety of aspects related to astronomical phenomena have been investigated. However, astronomy research in school has not been a very active field compared to other topics. In addition, a great part of that research involves high school or university students. Few studies address the early schooling stages. **Objective**: Our goal is to make a narrative and bibliometric review of the articles published in relevant scientific journals from 2009 to 2019 on astronomy teaching in early childhood (0–6 years) and primary education (6–12 years), using the Big Ideas in astronomy as a conceptual framework (Lelliott & Rollnick, 2010). The purposes are to characterise these studies, investigate how research on astronomy education has fostered our understanding of its learning, and analyse which methodologies and theoretical frameworks are the most frequent in them. **Design**: A systematic narrative and bibliometric literature review is carried out with the help of specific software (Bibliometrix and VOSwiever). **Setting and participants**: To locate the articles to be analysed, we used the ERIC - Education Resources Information Center resource database. We also selected research works in English centred on the educational stages of early childhood and/or primary education whose focus is one or more of the Big Ideas. They must have been published between 2009 and 2019 in journals dedicated to the didactics of experimental sciences and indexed in JCR (2019). **Data collection and analysis**: The data is collected systematically using a descriptive coding instrument. A bibliometric analysis is carried out, providing basic information on the analysed articles, relevant journals, trend by year of publications on the subject, publications by country and international collaboration, number of citations of the articles, and coauthorship networks, publications by year and genre, identification of the most addressed concepts through

Corresponding author: Uxío Pérez-Rodríguez. E-mail: uxio.perez@uvigo.es

word clouds and networks of key concepts combined with cluster analysis. Likewise, we analyse issues such as the most frequent conceptual frameworks, the educational levels corresponding to the articles, and the most studied Big Ideas. **Results**: There is little research in international journals on astronomy teaching in the educational stages analysed, and there are practically no articles focused on early childhood education. The journal that has published the most on the subject is by far the International Journal of Science Education, and most of the studies are from the USA and published by women. The author with the most significant impact worldwide is Julia D. Plummer. The most frequent conceptual frameworks are those of conceptions and mental models. The cluster analysis of the keywords has made it possible to identify four thematic fields: mental models and conceptual change, teachers' and students' conceptions of astronomy, science and school, and other relevant aspects of astronomy teaching. The Big Ideas studied the most are the Earth–Sun–Moon system (combined or not with the stars) and day and night. **Conclusions**: The research with the highest global impact in recent years on the teaching of astronomy in early childhood and primary education has been analysed, describing its characteristics and centres of interest, demonstrating that this issue does not receive much attention in the literature.

Keywords: Revision; Astronomy teaching; Bibliometric study; Big Ideas; Early childhood and primary education.

Revisão da investigação educacional em astronomia na primeira infância e ensino primário de 2009 a 2019

RESUMO

Contexto: Uma grande variedade de aspectos relacionados com fenómenos astronómicos tem sido investigada nas últimas décadas, embora em comparação com outros tópicos de investigação, este não seja um campo muito activo. Além disso, grande parte desta investigação tem sido realizada com estudantes do ensino secundário ou universitário, e há falta de trabalho a tratar das fases mais precoces. **Objectivo:** O objectivo deste trabalho é realizar uma revisão narrativa e bibliométrica de artigos em revistas científicas de impacto na Educação Astronómica de 2009 a 2019 nas fases de Educação Infantil (0-6 anos) e Ensino Primário (6-12 anos), utilizando as *Grandes Ideias* em Astronomia (Lelliott & Rollnick, 2010) como quadro conceptual. Os objectivos são caracterizar estes estudos, investigar como a investigação sobre a educação em astronomia tem contribuído para a nossa compreensão da aprendizagem da astronomia, e analisar que metodologias e quadros teóricos são mais prevalecentes nestes estudos. **Desenho:** Uma revisão narrativa sistemática e bibliométrica sistemática da literatura é realizada com a ajuda de software específico para este fim (Bibliometrix e VOSwiever). **Definição e participantes:** A base de dados de recursos ERIC - Education Resources Information Center é utilizada para localizar os artigos a serem analisados. Os trabalhos de investigação são seleccionados em língua inglesa, centrando-se nas fases educacionais da Primeira Infância e/ou do Ensino Primário, cujo foco de estudo é uma ou mais das *Grandes Ideias*. Devem ser publicadas entre 2009 e 2019 em revistas dedicadas ao ensino das ciências experimentais e indexadas em JCR (2019). **Recolha e análise de dados:** Os dados são recolhidos sistematicamente utilizando um instrumento de codificação descritivo. É realizada uma análise bibliométrica, fornecendo informação básica sobre os artigos analisados, revistas de origem, tendências por ano de publicações sobre o assunto, publicações por país e colaboração internacional, número de citações dos artigos e redes de co-autoria, publicações por ano e género, identificação dos conceitos mais tratados através de nuvens de palavras e redes de conceitos-chave combinados com a análise de agrupamento. São também analisadas questões como os quadros conceptuais mais frequentes, os níveis educacionais correspondentes aos artigos e as Grandes Ideias mais estudadas. **Resultados:** há pouca investigação em revistas internacionais sobre Educação Astronómica nas fases educacionais analisadas, e praticamente não há artigos centrados na Educação da Primeira Infância. A revista que mais publicou sobre o assunto é de longe o International Journal of Science Education, e a maioria dos estudos são dos EUA e publicados por mulheres. A autora com o maior impacto a nível mundial é Julia D. Plummer. Os quadros conceptuais mais frequentes são concepções e modelos mentais. A análise de agrupamento das palavras-chave identificou quatro campos temáticos: modelos mentais e mudança conceptual, concepções astronómicas de professores e estudantes, ciência e escola, e outros aspectos relevantes da educação astronómica. As *Grandes Ideias* mais estudadas são o sistema Terra-Sol-Lua (combinado ou não com estrelas) e o dia e a noite. **Conclusões:** Analisámos a investigação com maior impacto internacional nos últimos anos sobre a Educação Astronómica no Ensino Infantil e Primário, descrevendo as suas características e analisando os seus centros de interesse, e mostrando que esta questão não recebe muita atenção na literatura.

Palavras-chave: revisão; educação astronómica; estudo bibliométrico; Grandes Ideias; primeira infância e educação primária.

Revisión de investigación educativa en astronomía en educación infantil y primaria desde 2009 hasta 2019

RESUMEN

Contexto: En las últimas décadas se ha investigado una amplia variedad de aspectos relacionados con los fenómenos astronómicos, aunque en comparación con otros temas de investigación este no es un campo muy activo. A ello se suma que gran parte de dicha investigación es con alumnado de educación secundaria o universitario, no abundando los trabajos que aborden las etapas más tempranas. **Objetivo**: El objeto de este trabajo es hacer una revisión narrativa y bibliométrica de los artículos en revistas científicas de impacto sobre trabajos de Enseñanza de la Astronomía desde el año 2009 hasta 2019 en las etapas de Educación Infantil (0-6 años) y Educación Primaria (6-12 años), usando como marco conceptual las *Big Ideas* en Astronomía

(Lelliott & Rollnick, 2010). Las finalidades son caracterizar dichos estudios, indagar sobre cómo la investigación sobre la educación en Astronomía ha fomentado nuestra comprensión de su aprendizaje y analizar qué metodologías y marcos teóricos son los más frecuentes en estos estudios. **Diseño**: Se lleva a cabo una revisión sistemática narrativa y bibliométrica de la literatura con ayuda de software específico para tal fin (bibliometrix y VOSwiever). **Entorno y participantes**: Para localizar los artículos a analizar se utiliza la base de datos de recursos ERIC - Education Resources Information Center. Se seleccionan trabajos de investigación en lengua inglesa centrados en las etapas educativas de Educación Infantil y/o Primaria cuyo foco de estudio sea una o varias de las Big Ideas. Deben estar publicados entre los años 2009 y 2019 en revistas dedicadas a la didáctica de las ciencias experimentales e indexadas en JCR (2019). **Recogida y análisis de datos**: Los datos se recogen de forma sistemática empleando un instrumento descriptivo de codificación. Se lleva a cabo un análisis bibliométrico, proporcionando información básica sobre los artículos analizados, revistas de procedencia, tendencia por años de las publicaciones sobre la temática, publicaciones por países y colaboración internacional, número de citas de los artículos y redes de coautoría, publicaciones por año y género, identificación de los conceptos más tratados a través de nubes de palabra y redes de conceptos clave combinados con análisis cluster. Asimismo, se analizan cuestiones como los marcos conceptuales más frecuentes, los niveles educativos correspondientes a los artículos y las *Big Ideas* más estudiadas. **Resultados**: hay poca investigación en revistas internacionales sobre la Enseñanza de la Astronomía en las etapas educativas analizadas, y prácticamente no hay artículos que se centren en Educación Infantil. La revista que más ha publicado sobre la temática es con diferencia International Journal of Science Education, y la mayoría de los estudios son de USA y publicados por mujeres. La autora con mayor impacto a nivel mundial es Julia D. Plummer. Los marcos conceptuales más frecuentes son los de concepciones y modelos mentales. El análisis cluster de las palabras clave ha permitido identificar cuatro campos temáticos: modelos mentales y cambio conceptual, concepciones astronómicas de profesorado y estudiantado, ciencia y escuela y otros aspectos relevantes en la enseñanza de la Astronomía. Las *Big Ideas* más estudiadas son el sistema Tierra-Sol-Luna (combinado o no con las estrellas) y el día y la noche. **Conclusiones**: Se ha analizado la investigación de mayor impacto internacional de los últimos años sobre Enseñanza de la Astronomía en Educación Infantil y Primaria, describiendo sus características y analizando sus centros de interés, y mostrando que esta cuestión no recibe una gran atención en la literatura.

Palabras clave: revisión; enseñanza de la astronomía; estudio bibliométrico; Grandes Ideas; educación infantil y primaria.

INTRODUCTION

Astronomy and its different aspects have always been topics that arouse the interest of students in their initial education. In 1920 Piaget carried out the first studies related to astronomy, investigating how girls and boys conceive astronomical phenomena. In two of his books (Piaget, 1929, 1972), he collects the toddlers' ideas about the Earth and the cause of the day-night phenomenon. His work provides insight into how the non-intuitive phenomena around us can be explained, also drawing on psychologists' work.

However, not only young children (Solbes & Palomar, 2013) but also adults (Comins, 2003) find it challenging to learn astronomy. This is because students have deeply ingrained conceptions and ideas that get in the way of learning science (Duit & Treagust, 2003).

The publications in the different scientific and research journals represent the interests and the different approaches of the researchers. In recent decades, a wide variety of aspects related to astronomical phenomena have been investigated, although, compared to other research topics, this is not a well-studied field (Adams & Slater, 2000; Stahly, Krockover & Shepardson, 1999). Issues such as historical-astronomical aspects, essential for the students' formation, are treated without the slightest historical rigour (Author 4). It is also not usual, in this field, to carry out, as would be advisable, "significant activities of application in the classroom that develop the ability to mathematise real situations, proposing activities articulated with other areas of knowledge, establishing relationships between the problems of the middle in which the student lives" (C.K. da Silva & Groenwald, 2015).

Moreover, most research on these topics involves high school or university students. Few works address the earliest stages, despite the existence of interesting examples (Azevedo et al., 2013; Santos & Mackedanz, 2019) that show possibilities of innovations in research in astronomy teaching in the initial years (J.A. da Silva & Bartelmebs, 2013), such as the Communities of Practice (CoP). That is why we intend to focus this review on the studies that address the initial stages, early childhood education (0–6) and primary education (6–12).

The fundamental framework with which we work is the Big Ideas. This concept comes from Project 2061, established in 1985 by the American Association for the Advancement of Science (AAAS), to help all USA students achieve an appropriate education in science, mathematics, and technology.

The Big Ideas, which refer to key concepts in astronomy, are the following:

- Earth

- Day-night cycle
- Earth–Sun–Moon system
- Solar System
- Stars
- Seasons
- Gravity
- Concepts of size and distance

The Big Ideas have broad explanatory power in this field; they establish connections between isolated concepts and have the potential to develop over time as students understand them in increasingly sophisticated ways (Anderson et al., 2008). Some represent topics that are taught in educational centres since they are included in the curricula of the different educational stages or arouse great interest, such as the day-night cycle, the seasons, etc.

Not all of these ideas are explored in this study. Specifically, we disregard gravity because it is not included as content to be addressed in early childhood and primary education in Spain, as seen in the curriculum decrees analysed: Decree 330/2009, of June 4, which establishes the curriculum for early childhood education in the Autonomous Community of Galicia, 2009 and Decree 105/2014, of September 4, which establishes the curriculum for primary education in the Autonomous Community of Galicia, 2014.

This work consists of a review of the literature published in the field of astronomy, having as a starting point and fundamental reference the last similar existing review, which analysed publications from 1974 to 2008 (Lelliott & Rollnick, 2010). The following eleven years (2009-2019) are covered here.

The key questions we ask to guide us are:

- How has research on astronomy education furthered our understanding of learning aspects of astronomy?
- What methodologies and theoretical frameworks have researchers used to understand astronomy learning?

METHODOLOGY AND DATA SOURCES

The present study is a systematic narrative and bibliometric literature review. As indicated, the most relevant similar work done before on the subject is Lelliot and Rollinck's (2010), who analysed articles up to 2008. The objective of this article is to update that work to date.

The ERIC (Educational Resources Information Center) search engine was used to locate the articles to be analysed. The criteria for the selection of works were the following:

- Research papers in which one or more of the Big Ideas are the focus of the study
- Studies dedicated to the educational stages of early childhood and/or primary education (they may also include other stages)
- Articles published between the years 2009-2019
- Only research journals dedicated explicitly to the didactics of experimental sciences indexed in JCR (2019)
- English language articles

We used the keywords "education", "learning", and "teaching". A total of 249 results appeared in ERIC, where "Astronomy" was the descriptor. We selected 19 articles that met the requirements after we applied the criteria established in Table 1. Those publications were reviewed through the descriptive coding instrument for data collection that can be consulted in Appendix I.

The bibliometric analysis was carried out through the Bibliometrix 3.0.3 package (Aria & Cuccurullo, 2017) for R version 4.0.3 and the VOSviever 1.6.16 software (van Eck & Waltman, 2010), both for Microsoft Windows. For giving basic information on the analysed articles, we used relevant journals, trend by year of publications on the subject, publications by country and international collaboration, number of citations of the articles, and coauthorship networks, publications by year and genre, identification of the most discussed concepts through word clouds and networks of key concepts combined with cluster analysis.

Likewise, we analysed issues such as the most frequent conceptual frameworks, the educational levels corresponding to the articles, and the most studied Big Ideas.

RESULTS

Bibliometric information on the studies

Next, we present bibliometric information on the analysed studies. Table 1 shows a summary of the basic information of all these works.

Table 1

Summary of basic search results

Descriptor	Result
Total documents	19
Total journals	6
Keywords Plus (ID)	62
Author´s Keywords (DE)	56
Number of publications per year	1.73
Average number of citations per document	15.47
Authors	35
Documents by author	0.54
Authors per document	1.84
Coauthors per document	2.32
Collaboration Index	2.29

Revelant journals

Table 2 shows the journals from which the articles were extracted. The one that has published the most on the subject is by far *International Journal of Science Education*, from which almost two-thirds of the articles analysed come and would be the core source, according to Bradford’s Law (Figure 1).

Table 2

Articles per journal

Journal	Number of articles found
International Journal of Science Education	12
Journal of Research in Science Teaching	2
Science Education	2

International Journal of Science and Mathematics Education	1
Research in Science Education	1
Studies in Science Education	1

Figure 1

Core sources according to Bradford's Law

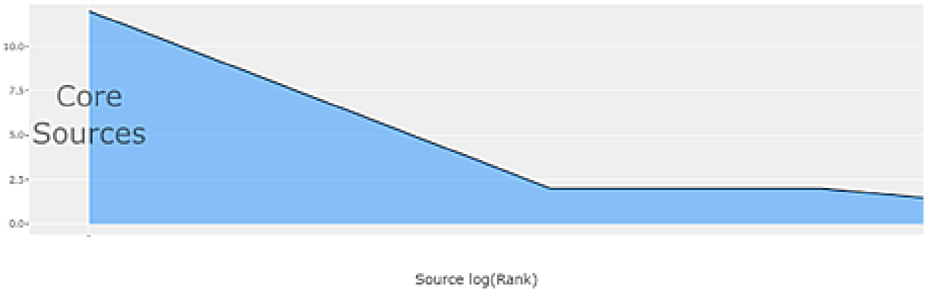
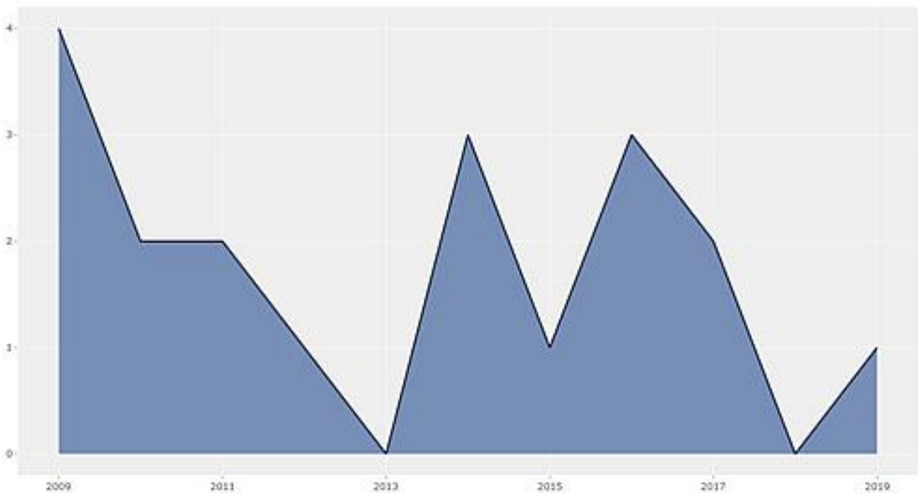


Figure 2

Number of publications per year



Trend by year of publications on the subject

Figure 2 shows how few articles are published per year on the subject analysed. The year in which the largest number is produced was 2009, the International Year of Astronomy, with four articles, and after that there is a gap of two years.

Publications by countries

As can be seen in Figure 3, most research on astronomy in done in the USA. Figure 4 shows the collaborations between countries.

Figure 3

Publications by countries

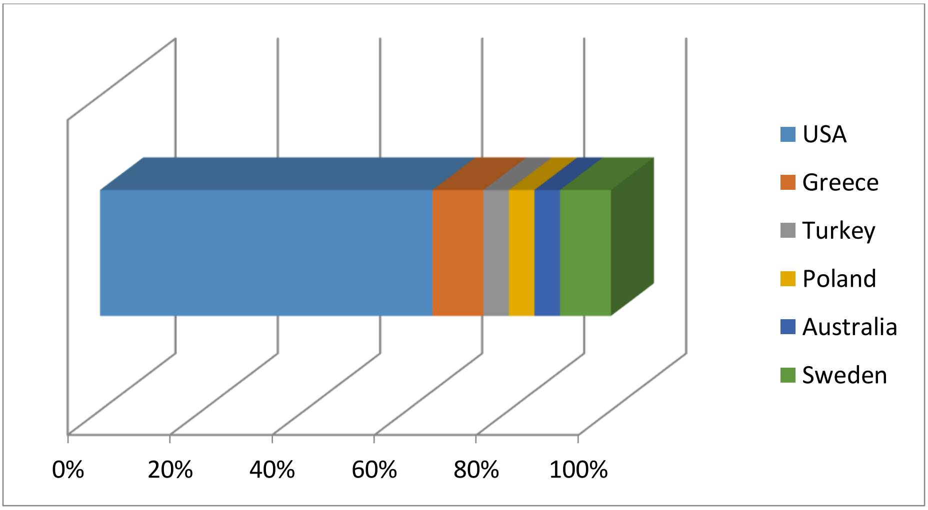


Figure 4

Collaborations between countries

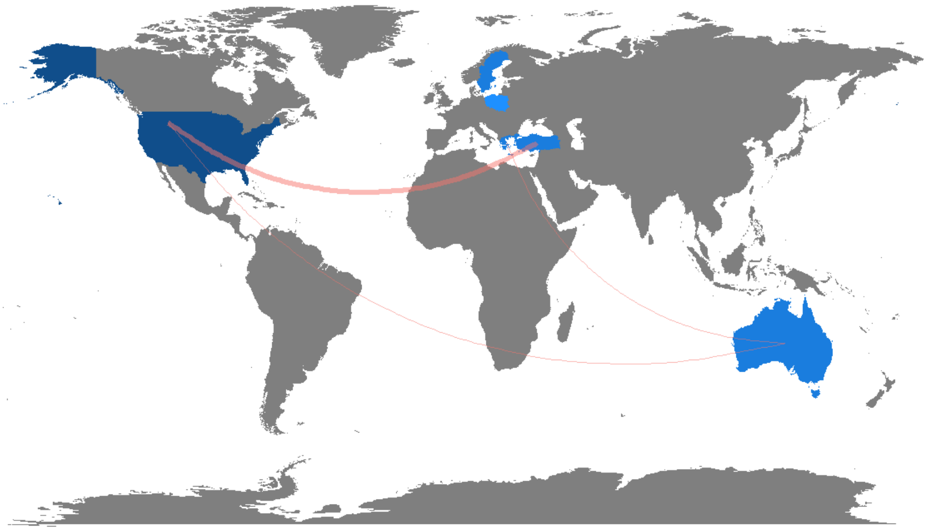
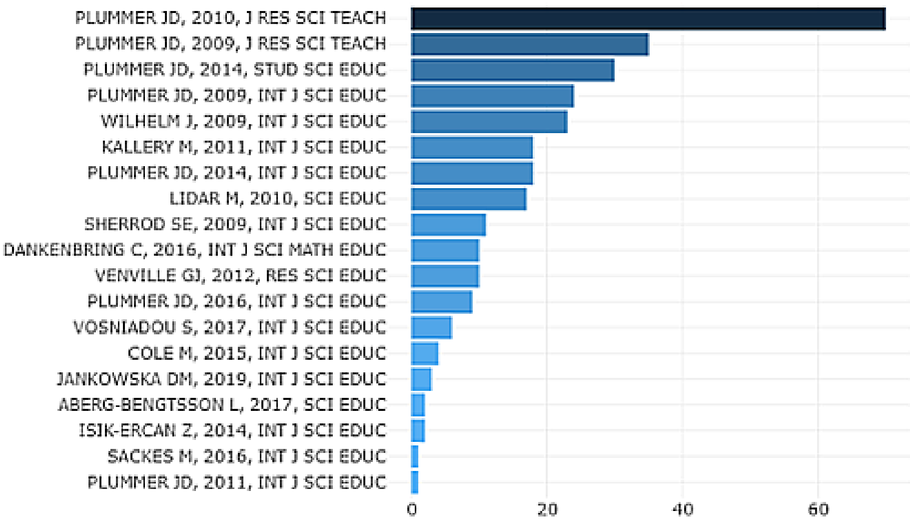


Figure 5

Citations received by the articles



Number of citations of the articles

Figure 5 brings Julia Diane Plummer, associate professor at Pennsylvania State University, as the most cited first author. Figure 6 shows her coauthorship network in the selected articles.

Figure 6

Julia D. Plummer's coauthorship network

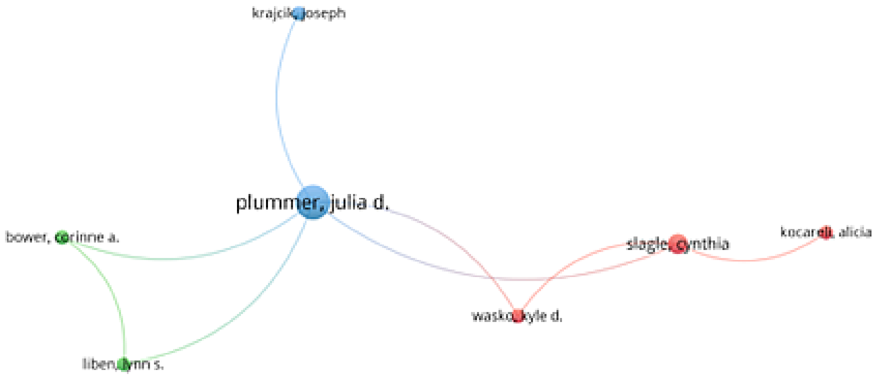
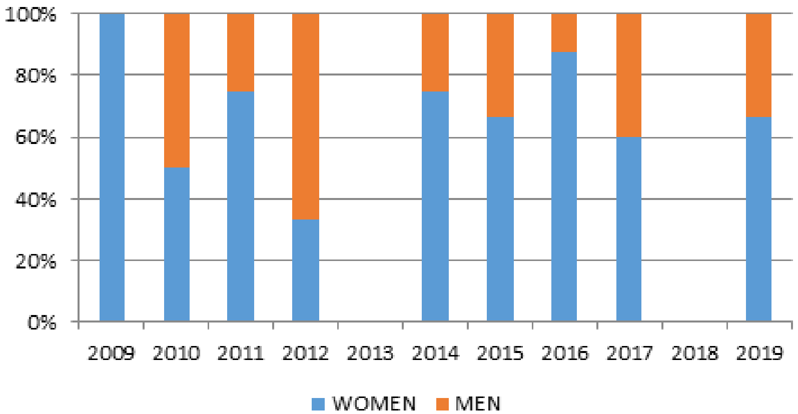


Figure 7

Publications and genre



Publications by year and authors' gender

Looking at Figure 7, we can see that most of the studies and publications in research journals during the years covered by this study are signed by women.

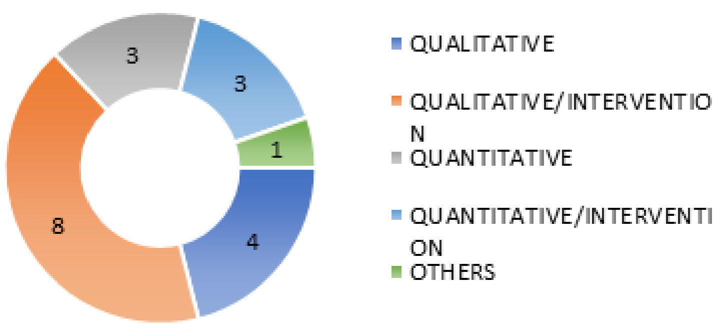
Methodologies of the articles

The classification of the methodologies used by the researchers in quantitative and qualitative research designs turned out to be somewhat difficult, since some of the studies used mixed methods and others that were difficult to classify.

The analysis of the results (Figure 8) reveals that most of the methodologies used are qualitative with intervention, followed by qualitative studies and, to a lesser extent, quantitative studies. Qualitative intervention studies are mainly learning sequences or planetarium interventions (Plummer, 2009b; Plummer & Krajcik, 2010), while quantitative studies determine the importance of the dialogue or the effect of gender on learning astronomical concepts.

Figure 8

Methodologies of the studies



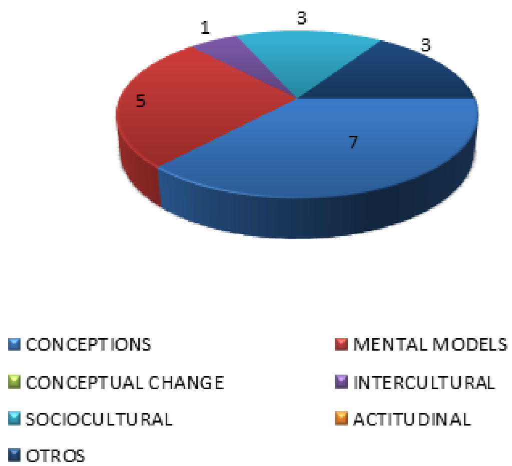
What is clear is that the tendency to carry out intervention studies, some of which last only one week, such as the study carried out in a camp by Plummer et al. (2016) and others, is longitudinal, although most refer to a period of months.

Classification by conceptual framework

Like the methodologies, the researchers' theoretical frameworks were difficult to classify because most authors did not make this issue explicit in their research. Figure 9 shows that the studies are classified into two main categories: conceptions and mental models. A mental model is an individual's internal and unique representation of an event, thing, or phenomenon (Pirnay-Dummer, Ifenthaler & Seel, 2012). Another theoretical framework is sociocultural theories. There is only one comparative study of the intercultural type by Turkish and American students. The remainder was grouped into a category called Others.

Figure 9

Conceptual frameworks

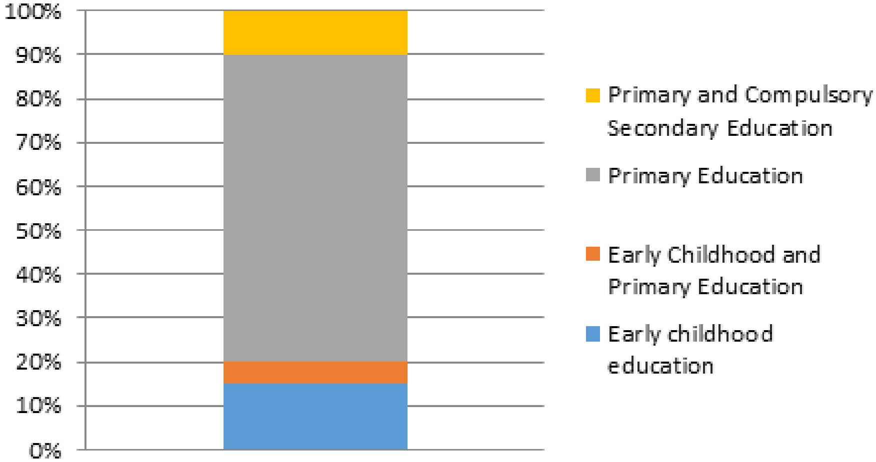


Educational stages of the articles

Most of the studies found are carried out in primary education (6–12 years), much more than in early childhood education (0–6 years) (Figure 10). This study does not aim to analyse works corresponding to compulsory secondary education (12–16 years). However, if those studies use data from primary education, they are included in the graph.

Figure 10

Educational stages investigated in the articles



Keywords (Keywords Plus) of articles

Figure 11 shows a word cloud using the Keywords Plus that Web of Science assigns to articles. It contains words corresponding to the Big Ideas (Earth, Moon, phases, night cycle) and some of the main topics covered in these articles, as will be discussed later (mental models, conceptual change, etc.).

Figure 11

Word cloud of the Keywords Plus of the selected articles

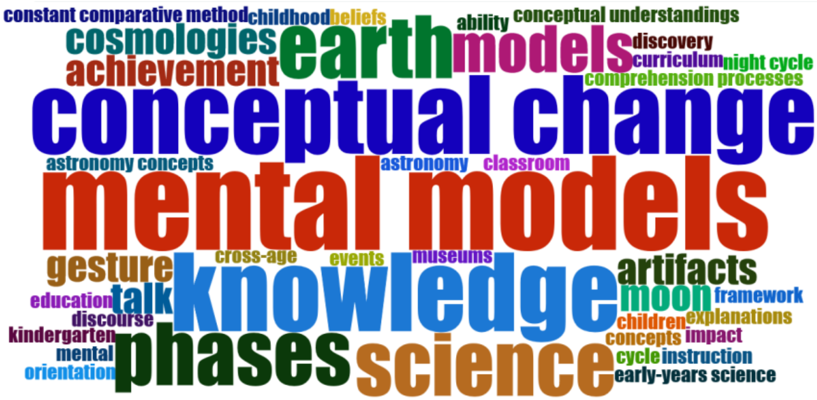


Figure 12

Conceptual network of the most frequent KeywordsPlus of the selected articles

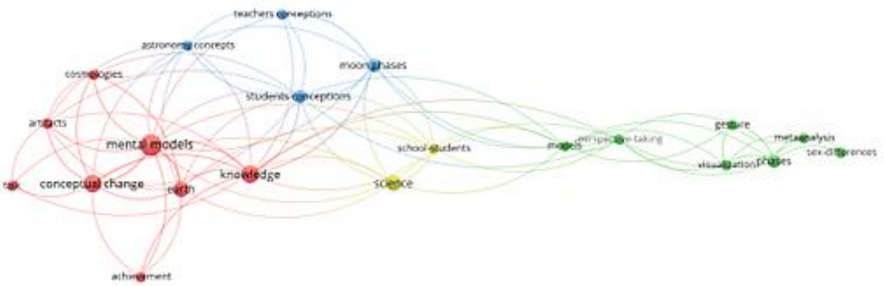


Figure 12 presents a conceptual network of the most frequent KeywordsPlus. Four main clusters can be seen (shown in different colours):

- Red: aspects related to mental models, conceptual change, and knowledge, etc.
- Blue: teachers' and students' astronomical conceptions.
- Yellow: science and school.

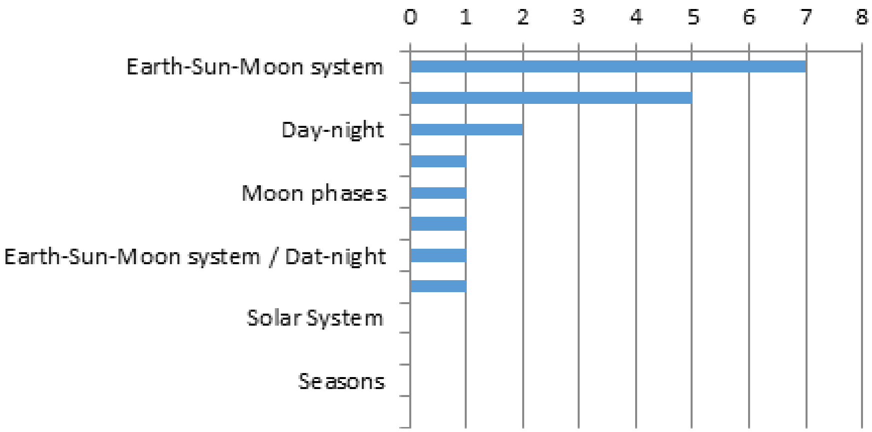
- Green: various relevant aspects in the teaching of astronomy such as perspective-taking, visualisation, and phases, etc.

Classification of articles by Big Ideas

Most studies examined more than one big idea within astronomy rather than investigating a single topic in depth (Figure 13).

Figure 13

Big Ideas



Taking into account the results obtained, we can highlight that the Earth–Sun–Moon system is the most studied in published articles, followed by those that combine this system with the study of the stars. The third place is for day and night.

Tables 3a to 8b show the information on the articles classified per journal, with the summary of those selected organised per first author's name and year. This results from data collection using the instrument listed in Appendix I.

Table 3a

Articles of the International Journal of Science Education. Classification of the studies.

Authorship	Year	Country	Type of study	Stage	Instrument
Plummer	2009a	USA	Qualitative/ intervention	EP/ ESO	Interviews
Sherrod & Wilhelm	2009	USA	Quantitative	EP/ ESO	LPCI
Wilhelm	2009	USA	Quantitative	EP	LPCI GSA
Kallery	2011	Greece	Qualitative/ intervention	EI	Eight ativities Three units
Plummer, Wasko & Slagle	2011	USA	Qualitative/ intervention	EP	Interviews
Isik-Ercan, Zeynep Inan, Nowak & Kim	2014	USA	Qualitative	EP	3D software
Plummer, Kocareli & Slagle	2014	USA	Qualitative/ intervention	EP	Interviews DBR
Cole, Wilhelm & Yang	2015	USA	Qualitative/ quantitative	EP	LPCI questionnaires
Saçkes, Smith & Trundle	2016	USA Turkey	Qualitative/ quantitative	EI	Interviews
Plummer et al.	2016	USA	Qualitative	EP	Interviews
Vosniadou & Skopeliti	2017	Greece	Qualitative/ intervention	EP	Text interviews
Jankowska, Gajda & Karwowski	2019	Poland	Qualitative/ quantitative	EI	TCIA TCT-DP

Table 3b

Articles of the International Journal of Science Education. Contents of the study

Authorship	Year	Theoretical framework	Objective	Results	Conclusions/ Implications
Plummer	2009a	Conceptions	Investigate the development of concepts	There are no differences in the results of primary and	Need to investigate instructional strategies to

			beginning in primary and secondary education without specific instruction	secondary education	improve understanding of celestial motion
Sherrod & Wilhelm	2009	Conceptions	Determine to what extent the dialogue in the classroom helps to understand the lunar phases	Dialogue is the optimal framework for rebuilding understanding	Research indicates that understanding is confirmed or reformed by knowledge sharing
Wilhelm	2009	Conceptions	Reporting the effect of gender on measurable learning using a moon research lesson unit	Both genders present equal gain in pre-test and post-test	There is no significant increase in the understanding of any group in the conceptual domains
Kallery	2011	Conceptions	Familiarise the EI students with astronomical concepts: Earth/day-night/Sun/Moon sphericity	Fruitful study approach, successful intervention	Recommendation for inclusion of the intervention in the EI study plan
Plummer, Wasko & Slagle	2011	Mental models	Explain astronomy through reference frameworks	More post-instruction capacity	Additional research is needed
Isik-Ercan, Zeynep Inan, Nowak & Kim	2014	Conceptions	Investigate whether 3D visualisation supports astronomy learning and perceptions	Understanding concepts better after the didactic unit	It is a pilot study on potential 3D visualisation
Plummer, Kocareli & Slagle	2014	Other	Investigate the importance of instruction to the connections	Supports the hypothesis that instruction enhances comprehensio	Need for additional scaffolding

			between Earth-space observations	n	
Cole, Wilhelm & Yang	2015	Mental models	Examine link between student performance in lunar diaries and LPCI	Students with more lunar diary entries get more LPCI score	Teachers and students benefit from the use of lunar diaries
Saçkes, Smith & Trundle	2016	intercultural	Describing/comparing knowledge of day/night observation among US-Turkish children	Similarities in the observational knowledge of the two cultures	Scientific concepts and skills best represented in EE programs. UU. of Turkish program, results suggest that this advantage did not translate into performance differences between Americans and Turks.
Plummer et al.	2016	Other	Study link between taking perspective-astronomical explanation	Earth-based perspective can be explained spatial reference frame	Study provides new insights into spatial reasoning
Vosniadou & Skopeliti	2017	Conceptions	Investigate conceptions with understanding of non-intuitive expository texts	Participants provide day/night cycle explanations in pre-test inconsistent with scientific explanation, recalled -information and generated +invalid inferences. Analysis of subsequent	Research should replicate the results with older students

				test explanations indicated that participants formed new misconceptions fragmented and synthetic conceptions obtained research development.	
Jankowska, Gajda & Karwowski	2019	Mental models	Explore the role of creative abilities in building mental models	Creative visual imagination predicts spatial knowledge/comprehension	First study to address the role of creativity

Table 4a

Articles of the Journal of Research in Science Teaching. Classification of the studies.

Authorship	Year	Country	Type of study	Stage	Instrument
Plummer	2009b	USA	Qualitative/ intervention	EP	Planetary
Plummer & Krajcik	2010	USA	Qualitative/ intervention	EP	Interviews

Table 4b

Articles of the Journal of Research in Science Teaching. Contents of the study

Authorship	Year	Theoretical framework	Objective	Results	Conclusions/ Implications
Plummer	2009b	Conceptions	Investigate how instruction improves understanding of apparent celestial motion	Successful method to improve students' description of apparent celestial motion	Planetary instruction leads to more sophisticated descriptions
Plummer & Krajcik	2010	Other	Develop a learning progression for big ideas	Shows that focused instruction develops more advanced	This work is an advance in the literature on the set of trajectories

			understanding	of the apparent celestial motion	

Table 5a

Articles from Research in Science Education. Classification of the studies.

Authorship	Year	Country	Type of study	Stage	Instrument
Venville, Louisell & Wilhelm	2012	Australia	Qualitative	EI/EP	Interviews

Table 5b

Articles from Research in Science Education. Contents of the study

Authorship	Year	Big Ideas	Theoretical framework	Objective	Results	Conclusions/ Implications
Venville, Louisell & Wilhelm	2012	Moon	Sociocultural	Examine knowledge about the Moon with a multidimensional theoretical framework	Strong relationship between children, environment and construction of ideas about the Moon	Ideas are conditioned by environment, social interaction, cultural activities

Table 6a

Articles from Science Education. Classification of the studies.

Authorship	Year	Country	Type of study	Stage	Instrument
Lidar, Almqvist & Östman	2010	Sweden	Other	EP	Questionnaire
Åberg-Bengtsson, Karlsson & Ottosson	2017	Sweden	Qualitative/ intervention	EP	Illustrations

Table 6b

Articles from Science Education. Contents of the study

Authorship	Year	Big Ideas	Theoretical framework	Objective	Results	Conclusions/ Implications

Lidar, Almqvist & Östman	2010	Earth	Sociocultural	Illustrate how a pragmatic approach allows taking into account role situation/experiences	Sociocultural perspective. It is possible to take into account the role experiences of people as well as situations with regard to meaning-making, making problems and questions intelligible, and the use of artefacts.	The way questions are made intelligible will drive the creation of meaning and when an artefact is used to answer questions, it is not the artefact itself, but the specific use of the artefact that mediates the action
Åberg-Bengtsson, Karlsson & Ottosson	2017	Phases of the moon	Sociocultural	Interpret/analyse use of moon phase illustrations	Most students can make sense of the most important features of illustrations	The lunar phases are difficult to understand at this educational stage. The study indicates that the type of image used to illustrate this phenomenon may contribute to that difficulty. The teacher must be aware of alternative ideas and be clear about how difficult it can be to switch between an Earth-based and a space-based perspective. Relating to children's

					experiences of seeing the full Moon at night can be a fruitful starting point.

Table 7a

Articles from Studies in Science Education. Classification of the studies.

Authorship	Year	Country	Type of study	Stage	Instrument
Plummer et al.	2014	USA	Qualitative/ intervention	EP	Interviews

Table 7b

Articles from Studies in Science Education. Contents of the study

Authorship	Year	Big Ideas	Theoretical framework	Objective	Results	Conclusions/ Implications
Plummer et al.	2014	Earth-Sun-Moon/Star System	Mental models	Develop a learning progression framework that integrates: cognition, instruction, assessment	Spatial thinking helps define progress on two construction maps, DCM and Moon Phases, within the larger LP. The two construction maps illustrated the role of spatial thinking in the elements that define a LP: cognition, instruction, and assessment.	Additional work is needed to facilitate teachers' use of construction maps to make connections between curriculum and supporting student learning.

Table 8a

Articles of the International Journal of Science and Mathematics Education. Classification of the studies.

Authorship	Year	Country	Type of study	Stage	Instrument
Dankenbring & Capobianco	2016	USA	Qualitative	EP	Interviews drawings

Table 8b

Articles of the International Journal of Science and Mathematics Education. Contents of the study

Authorship	Year	Big Ideas	Theoretical framework	Objective	Results	Conclusions/ Implications
Dankenbring & Capobianco	2016	Sun-Earth	Mental models	Elucidate/examine student mental models of Sun-Earth relationship	They show the fragmented conceptions of the students	Draw+explanation is an effective approach to determining conceptual understanding in science

The *Big Ideas* on selected items

The conceptions of the Earth

Only one of the 19 articles selected works on this topic (Lidar et al., 2010), starting from a study by Nussbaum and Novak (1976). This paper addresses how it is possible to consider the role of situations and experiences within a sociocultural perspective on learning when analysing children’s meaning-making. The objective is to illustrate how an approach based on pragmatism and the works of Wittgenstein allow considering the role of the situation and that of the experiences within a sociocultural perspective on learning. In the video recordings of second and fourth to fifth-grade students working in pairs, the creation of meaning is studied using a practical epistemological analysis, i.e., what the children talk about as something relevant and what experiences they relate when answering the questions.

Earth-Sun-Moon system

This is the Big Idea that is repeated the most in the different articles. Seven papers address this system (Cole et al., 2015; Isik-Ercan et al., 2014; Jankowska et al., 2019; Plummer, 2009a; Plummer et al., 2014; Sherrod & Wilhelm, 2009; Wilhelm, 2009) since they are topics that are included in the curricula of the different educational stages.

Plummer's study (2009a) on students' understanding of apparent celestial movement patterns from an Earth-based perspective relates to her former research (Plummer, 2014) on the importance of providing instructional support for the connections between Earth-based observations and space-based explanations in learning to explain daily celestial motion (DCM). She explains Earth-based descriptions of the apparent motion of the Sun, Moon, and stars using the Earth's daily rotation. The results, which provide insight into how children learn, support that instruction should have students learn both Earth-based observations and space-based explanations, since focusing on a single reference frame gives rise to less sophisticated explanations.

As Sherrod and Wilhem (2009) state, classroom discourse provides the optimal framework for students to deeply reflect on their old misconceptions and reconstruct their understanding of the causes of the lunar phases. Chin and Brown (2000, p. 109) proposed that if teachers "provide contextualised prompts and scaffolding, and students are encouraged to ask questions, predict, and explain during activities," learning is more likely to occur faster and at a deeper level.

Isik-Ercan et al. (2014) highlight the importance of 3D visualisation since it stimulates interest in space and supports astronomy learning and children's and teachers' perceptions.

In turn, Jankowska et al. (2019) explore the role of creative abilities in constructing mental models of space. Mental models allow students to understand what causes the phenomena, the factors that influence them, and how to control them (Greca & Moreira, 2002). They derive from personal experiences and the meanings generated by those experiences. They are unique to an individual.

Cole et al. (2015) examine the use of lunar diaries and the lunar phase conceptual inventory (LPCI) (Lindell & Olsen, 2002). Because they create a link between classroom experiences and the natural world that students experience daily, they improve moon phase awareness and spatial ability.

Earth-Sun-Moon/Star System

The selected articles that cover these aspects are five, all by Plummer as the first author (Plummer, 2009a, 2014; Plummer et al., 2011, 2016; Plummer & Krajcik, 2010). It aims to explain astronomy through reference frameworks. The three most used astronomical coordinate systems are: Topocentric, Geocentric, and Heliocentric, each of which has its origin at a different point in space.

Plummer uses a body recognition framework to investigate how children understand and express the connections between terrestrial experiences of astronomical phenomena and spatial descriptions of those phenomena (i.e., referring to the motions of celestial objects to explain the astronomic phenomena as experienced by someone on Earth).

Earth-Sun-Moon and day-night system

Astronomic concepts and phenomena such as the sphericity of the Earth and the alternation of day and night, considered difficult for very young children, can be more accessible if they are introduced to resources, strategies, and teaching styles that motivate them. Such action may raise children's interest, and reduce their learning difficulties (Sharp, 1995, 1999). Kallery (2011) develops an action research to familiarise children aged 4–6 with the concept of sphericity of the Earth and to help them realise that the alternation day-night is caused by the rotation of the spherical Earth on its axis.

Day and night time cycle

There are two major competing explanations in the literature for how children interpret and represent their observational knowledge: the framework theory (Vosniadou & Brewer, 1992) and the theory of knowledge in pieces (DiSessa, 1993). The first explanation suggests that assumptions (for example, physical objects are solid, stable, and fall over if not placed) influence children's interpretations of their everyday observations of the day and night skies (Vosniadou & Brewer, 1994; Vosniadou, Vamvakoussi & Skopeliti, 2008).

Two articles focus on the day-night cycle. Saçkes et al. (2016) do a comparative, cross-cultural study to describe and compare Turkish and American children's observational knowledge of the day and night cycle.

Vosniadou and Skopeliti (2017) test the hypothesis that new fragmented and/or synthetic conceptions can emerge when readers with initial conceptions are exposed to a counterintuitive scientific explanation.

Solar System-Earth

Only the article by Dankenbring and Capobianco (2016) examines elementary school students' conceptions of the relationships between the Sun and the Earth as a result of participating in a scientific task based on engineering design. To elucidate and examine students' mental models of the relationship between the Sun and the Earth, the results of this study demonstrate a range of synthetic mental models that students have for the cause of the different amounts of daylight in the summer and winter.

Phases of the Moon

One of the selected articles focuses on the lunar phases. From a sociocultural perspective, Åberg-Bengtsson et al. (2017) investigate how illustrations are used (moon phases), how photos and the models they represent are handled, and what difficulties can be faced. Wells (2008) underlines that all concepts are abstract, but scientific concepts are of an even more abstract kind and learning them requires some kind of instruction.

Moon

Venville et al. (2012) carry out a qualitative investigation of children's conceptions of the Moon and how social/cultural factors influence them. They examine the knowledge of children's students about the Moon through a multidimensional theoretical framework. The findings reflected the strong and complex relationship between individual children, their social and cultural backgrounds, and how they construct ideas about the Moon and astronomy.

Seasons and size and distance

None of the articles in this review deals with seasons or the concepts of size and distance.

DISCUSSION AND CONCLUSIONS

As previously stated, there is little research in international journals on astronomy teaching in the educational stages analysed (19 studies in 11 years), and there are almost no articles focusing on early childhood education. The journal that has published the most on the subject is by far the International Journal of Science Education, and most of the studies are from the USA and published by women. The author with the greatest impact worldwide is Julia D. Plummer. The most frequent conceptual frameworks are conceptions and mental models.

The cluster analysis of the keywords has made it possible to identify four thematic fields: mental models and conceptual change, teachers' and students' conceptions of astronomy, science and school, and other relevant aspects of astronomy teaching. The most studied Big Ideas are the Earth-Sun-Moon system (combined or not with the stars) and day and night.

Next, we try to answer the research questions formulated at the beginning.

Learning comprehension

To answer the first of the two research questions about how recent studies have advanced our understanding of learning aspects of astronomy, this paper categorises the research found on Big Ideas and notes that most studies examined aspects of the conceptions held by the participants in these studies. Some of the articles that study conceptions do so from a line of study with intervention, obtaining fascinating results.

In the article by Lelliot and Rollnick (2010), the most studied Big Idea is the Earth concept, followed by the Earth-Sun-Moon system and, in third place, the Day-Night cycle. The seasons, gravity, the concepts of size and distance and the solar system are studied to a lesser extent. Comparing the results with those obtained in this study, the Big Ideas that most appear in the selected articles are the Earth-Sun-Moon system and the Earth concept. Schneps and Saler (1989) reported that misconceptions related to Earth and space are extremely difficult to change, even after extensive instruction and as time progresses.

The repeatedly cited earlier review by Lelliot and Rollnick (2010) highlights the lack of student understanding. The students' answers about everyday natural phenomena suggest poorly learned content, possibly due to having been poorly taught. Early-childhood boys and girls develop their own implicit (naive) theories about astronomical phenomena. Until they reach the stage where they can acquire more structured scientific knowledge, their understanding of the Earth, space, and the various astronomical phenomena is inconsistent and fragmented. In primary education, some works reveal students' serious cognitive difficulties, for which they finally fail to acquire an understanding of the location of the Earth in space (López et al., 1995).

Considering the results obtained from the different articles of this study, we can see that the learning of contents related to the Earth and the Earth-Sun-Moon system can be improved in a research environment.

Methodologies and theoretical frameworks

The second of the research questions raised in this study refers to the theoretical frameworks and the methodologies used by researchers to understand astronomy learning.

Usually, the methodology used in the classroom is expository, decontextualised, and non-significant, and little attention is paid to observational and descriptive content despite working with students with whom the use of specific analogues is required, as reflected in Trumper (Trumper, 2006).

In different articles in this review, there are proposals for carefully planned teaching-learning activities: activities using 3D software, the planetarium, etc. The use of 3D visualisation in combination with other teaching methods such as literacy experiences, videos, photos, simulations, discussions, and presentations supports student learning.

There is considerable support in the literature for both virtual (Barnett et al., 2000) and physical (Shen & Confrey, 2007) modelling activities to enable students to more clearly understand the three-dimensional nature of astronomical concepts

The most commonly identified theoretical framework used by researchers is that of "conceptions". Children's understanding of astronomy is not rooted in direct experiences, and revealing the secrets of nature begins with careful observation of the phenomenon.

Implications for teaching and learning

Astronomy in the school context continues to be a discipline that receives little attention, but that can be pedagogically reoriented so that it is understood as something that is part of our daily lives. That is why it is worth reflecting on opening new investigative and pedagogical possibilities, and through the understanding that astronomy is a science that encompasses natural and universal phenomena, which explains why it is not more included in the teaching of boys and girls as a curricular component.

We recommend that future research in the astronomy field consider teacher education. We also believe that the teaching of the discipline should exceed the physical limits of educational centres. Science is typically taught as an overwhelming number of disconnected facts, conveyed from teacher to student in a context-free learning environment through lectures and books (Banilower et al., 2006). For this, it is necessary to promote actions aimed at the continuous education of teachers in the search for significant changes in the school environment (Kurz et al., 2021).

Limitations of the study

Although the results of this study are satisfactory, it is also convenient to talk about its limitations. First, not all possible journals have been analysed, but only those with the highest impact and published in English have been selected. It would be of great interest to expand the number of journals analysed. On the other hand, extending the study to secondary education would also be interesting.

ACKNOWLEDGEMENTS

Research projects financed by the Ministry of Science, Innovation and Universities EDU2017-82915-R and by FEDER/Ministry of Science, Innovation and Universities – State Research Agency/ ESPIGA Project ("Promoting the Development of Critical Thinking and the Dimensions of Cognitive and Emotional Implication of Epistemic Performances in Science Classes in the Post-Truth Era"), reference PGC2018-096581-B-C22.

AUTHORSHIP CONTRIBUTION STATEMENT

MSBC and UPR conceptualisation. Data analysis: MSBC, MVL, MLR and UPR. Obtaining funds: MVL, UPR. Research: MSBC and UPR. Methodology: MSBC, MVL, MLR and UPR. Supervision: UPR. Visualisation: MSBC, MVL, MLR and UPR. Writing – original manuscript and proofreading and editing: MSBC, MVL, MLR and UPR. All authors reviewed and approved the final version of the work.

DATA AVAILABILITY STATEMENT

Data supporting the results of this study will be made available for correspondence upon reasonable request.

REFERENCES

Åberg-Bengtsson, L., Karlsson, K. G., & Ottosson, T. (2017). "Can There be a Full Moon at Daytime?" Young Students Making Sense of Illustrations of the Lunar Phases. *Science Education*, *101*(4), 616-638. https://doi.org/10.1002/sce.21279

Adams, J. P., & Slater, T. F. (2000). Astronomy in the national science education standards. *Journal of Geoscience Education*, *48*(1), 39-45. https://doi.org/10.5408/1089-9995-48.1.39

Anderson, C. W., Krajcik, J., Duschl, R., Gunckel, K., Tsurusaki, B., & Draney, K. (2008). Learning progressions for environmental science literacy. In *Meeting of the National Association for Research in Science Teaching, Baltimore, MD.*

Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, *11*(4), 959-975. https://doi.org/10.1016/j.joi.2017.08.007

Azevedo, S. da S. M., Pessanha, M. C. R., da Silva Schramm, D. U., & de Oliveira Souza, M. (2013). Relógio de sol com interação humana: Uma poderosa ferramenta educacional. *Revista Brasileira de Ensino de Física, São Paulo*, *35*(2), 2403. https://doi.org/10.1590/s1806-11172013000200018

Banilower, E. R., Smith, P. S., Weiss, I. R., & Pasley, J. D. (2006). The status of K-12 science teaching in the United States. *The impact of state and national standards on K-12 science teaching*. (p. 83-122).

Barnett, M., Keating, T., Barab, S. A., & Hay, K. E. (2000). Conceptual change through building three-dimensional virtual models. *International Conference of the Learning Sciences: Facing the Challenges of Complex Real World Settings*.

Chin, C., & Brown, D. E. (2000). Learning in science: A comparison of deep and surface approaches. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *37*(2), 109-138.

Cole, M., Wilhelm, J., & Yang, H. (2015). Student moon observations and spatial-scientific reasoning. *International Journal of Science Education*, *37*(11), 1815-1833. https://doi.org/10.1080/09500693.2015.1052861

Comins, N. (2003). *Heavenly errors*. Columbia University Press.

Decreto 330/2009, de 4 de junio, por el que se establece el currículo de la Educación Infantil en la Comunidad Autónoma de Galicia (2009) Consellería de Cultura, Educación e Ordenación Universitaria. Xunta de Galicia.

Decreto 105/2014, de 4 de septiembre, por el que se establece el currículo de la educación primaria en la Comunidad Autónoma de Galicia, (2014) Consellería de Cultura, Educación e Ordenación Universitaria. Xunta de Galicia.

da Silva, C. K., & Groenwald, C. L. O. (2015). Integrando a matemática ao tema educação ambiental. *Paradigma*, *22*(2), 151-170.

da Silva, J. A., & Bartelmebs, R. C. (2013). A Comunidade de Prática como Possibilidade de Inovações na Pesquisa em Ensino de Ciências nos Anos Iniciais/The Community of Practice as possible innovations in research in science education in the primary school. *Acta Scientiae*, *15*(1), 191-208.

Dankenbring, C., & Capobianco, B. M. (2016). Examining elementary school students' mental models of sun-earth relationships as a result of engaging in engineering design. *International Journal of Science and*

Mathematics Education, *14*(5), 825-845. https://doi.org/10.1007/s10763-015-9626-5

DiSessa, A. A. (1993). Toward an epistemology of physics. *Cognition and instruction*, *10*(2-3), 105-225. https://doi.org/10.1080/07370008.1985.9649008

Duit, R., & Treagust, D. F. (2003). Conceptual change: A powerful framework for improving science teaching and learning. *International journal of science education*, *25*(6), 671-688. https://doi.org/10.1080/09500690305016

Greca, I. M., & Moreira, M. A. (2002). Mental, physical, and mathematical models in the teaching and learning of physics. *Science education*, *86*(1), 106-121. https://doi.org/10.1002/sce.10013

Isik-Ercan, Z., Zeynep Inan, H., Nowak, J. A., & Kim, B. (2014). 'We put on the glasses and Moon comes closer!'Urban Second Graders Exploring the Earth, the Sun and Moon Through 3D Technologies in a Science and Literacy Unit. *International Journal of Science Education*, *36*(1), 129-156. https://doi.org/10.1080/09500693.2012.739718

Jankowska, D. M., Gajda, A., & Karwowski, M. (2019). How children's creative visual imagination and creative thinking relate to their representation of space. *International Journal of Science Education*, *41*(8), 1096-1117. https://doi.org/10.1080/09500693.2019.1594441

Kallery, M. (2011). Astronomical concepts and events awareness for young children. *International Journal of Science Education*, *33*(3), 341-369. https://doi.org/10.1080/09500690903469082

Kurz, D. L., Bedin, E., & Groenwald, C. L. O. (2021). The Teaching of Natural Sciences in the Early Years of Elementary School to Educate a Scientifically Literate Individual. *Acta Scientiae*, *23*(1), 53-79. https://doi.org/10.17648/acta.scientiae.6204

Lelliott, A., & Rollnick, M. (2010). Big ideas: A review of astronomy education research 1974–2008. *International Journal of Science Education*, *32*(13), 1771-1799. https://doi.org/10.1080/09500690903214546

Lidar, M., Almqvist, J., & Östman, L. (2010). A pragmatist approach to meaning making in children's discussions about gravity and the shape of the earth. *Science Education*, *94*(4), 689-709. https://doi.org/10.1002/sce.20384

Lindell, R. S., & Olsen, J. P. (2002). Developing the lunar phases concept inventory. *In Proceedings of the 2002 Physics Education Research Conference*.

López, R. A., González, C. B., López, M., Fábrega, M. D. M., & Palmero, M. L. R. (1995). Una aproximación a las representaciones del alumnado sobre el Universo. *Enseñanza de las ciencias: revista de investigación y experiencias didácticas*, 327-335.

Nussbaum, J., & Novak, J. (1976). An assessment of children's concepts of the earth utilizing structured interviews. *Science Education*, *60*(4), 685-691. https://doi.org/10.1002/sce.3730600414

Piaget, J. (1929). *The child's concept of the world*. Routldge & Kegan Paul.

Piaget, J. (1972). *The child's conception of physical causality* (Vol. 212). Transaction.

Pirnay-Dummer, P., Ifenthaler, D., & Seel, N. M. (2012). Designing model-based learning environments to support mental models for learning. *Theoretical foundations of learning environments*, *2*, 66-94.

Plummer, J. D. (2009a). A cross-age study of children's knowledge of apparent celestial motion. *International Journal of Science Education*, *31*(12), 1571-1605. https://doi.org/10.1080/09500690802126635

Plummer, J. D. (2009b). Early elementary students' development of astronomy concepts in the planetarium. *Journal of Research in Science Teaching*, *46*(2), 192-209. https://doi.org/10.1002/tea.20280

Plummer, J. D. (2014). Spatial thinking as the dimension of progress in an astronomy learning progression. *Studies in Science Education*, *50*(1), 1-45. https://doi.org/10.1080/03057267.2013.869039

Plummer, J. D., Bower, C. A., & Liben, L. S. (2016). The role of perspective taking in how children connect reference frames when explaining astronomical phenomena. *International Journal of Science Education*, *38*(3), 345-365. https://doi.org/10.1080/09500693.2016.1140921

Plummer, J. D., Kocareli, A., & Slagle, C. (2014). Learning to explain astronomy across moving frames of reference: Exploring the role of classroom and planetarium-based instructional contexts. *International*

Journal of Science Education, *36*(7), 1083-1106. https://doi.org/10.1080/09500693.2013.843211

Plummer, J. D., & Krajcik, J. (2010). Building a learning progression for celestial motion: Elementary levels from an earth-based perspective. *Journal of Research in Science Teaching*, *47*(7), 768-787. https://doi.org/10.1002/tea.20355

Plummer, J. D., Wasko, K. D., & Slagle, C. (2011). Children learning to explain daily celestial motion: Understanding astronomy across moving frames of reference. *International Journal of Science Education*, *33*(14), 1963-1992. https://doi.org/10.1080/09500693.2010.537707

Saçkes, M., Smith, M. M., & Trundle, K. C. (2016). US and Turkish preschoolers' observational knowledge of astronomy. *International Journal of Science Education*, *38*(1), 116-129. https://doi.org/10.1080/09500693.2015.1132858

Santos, R. C. M., & Mackedanz, L. F. (2019). Physics Teaching for Children: A Bibliographic Review. *Acta Scientiae*, *21*(3), 213-230. https://doi.org/10.17648/acta.scientiae.v21iss3id4628

Scarinci, A. L., & Pacca, J. L. de A. (2006). Um curso de astronomia e as pré-concepções dos alunos. *Revista Brasileira de Ensino de Física*, *28*(1), 89-99. https://doi.org/10.1590/s0102-47442006000100012

Schneps, M., & Sadler, P. M. (1989). A private universe [Video]. *Santa Monica, CA: Pyramid Film and Video*.

Sharp, J. (1995). Children's astronomy: Implications for curriculum developments at Key Stage 1 and the future of infant science in England and Wales. *International Journal of Early Years Education*, *3*(3), 17-49. https://doi.org/10.1080/0966976950030302

Sharp, J. (1999). Young children's ideas about the earth in space. *International Journal of Early Years Education*, *7*(2), 159-172. https://doi.org/10.1080/0966976990070204

Shen, J., & Confrey, J. (2007). From conceptual change to transformative modeling: A case study of an elementary teacher in learning astronomy. *Science Education*, *91*(6), 948-966. https://doi.org/10.1002/sce.20224

Sherrod, S. E., & Wilhelm, J. (2009). A study of how classroom dialogue facilitates the development of geometric spatial concepts related to understanding the cause of moon phases. *International Journal of Science Education*, *31*(7), 873-894. https://doi.org/10.1080/09500690801975768

Solbes, J., & Palomar, R. (2013). Dificultades en el aprendizaje de la astronomía en secundaria. *Revista Brasileira de Ensino de Física*, *35*(1), 01-12. https://doi.org/10.1590/s1806-11172013000100016

Stahly, L. L., Krockover, G. H., & Shepardson, D. P. (1999). Third grade students' ideas about the lunar phases. *Journal of Research in Science Teaching*, *36*(2), 159-177. https://doi.org/10.1002/(sici)1098-2736(199902)36:2%3C159::aid-tea4%3E3.0.co;2-y

Trumper, R. (2006). Teaching future teachers basic astronomy concepts—Seasonal changes—At a time of reform in science education. *Journal of Research in Science Teaching*, *43*(9), 879-906. https://doi.org/10.1002/tea.20138

van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, *84*(2), 523-538. https://doi.org/10.1007/s11192-009-0146-3

Venville, G. J., Louisell, R. D., & Wilhelm, J. A. (2012). Young children's knowledge about the moon: A complex dynamic system. *Research in Science Education*, *42*(4), 729-752. https://doi.org/10.1007/s11165-011-9220-y

Vosniadou, S., & Brewer, W. F. (1992). Mental models of the earth: A study of conceptual change in childhood. *Cognitive psychology*, *24*(4), 535-585. https://doi.org/10.1016/0010-0285(92)90018-w

Vosniadou, S., & Brewer, W. F. (1994). Mental models of the day/night cycle. *Cognitive science*, *18*(1), 123-183. https://doi.org/10.1207/s15516709cog1801_4

Vosniadou, S., & Skopeliti, I. (2017). Is it the Earth that turns or the Sun that goes behind the mountains? Students' misconceptions about the day/night cycle after reading a science text. *International Journal of Science Education*, *39*(15), 2027-2051. https://doi.org/10.1080/09500693.2017.1361557

Vosniadou, S., Vamvakoussi, X., & Skopeliti, I. (2008). The framework theory approach to the problem of conceptual change. *International handbook of research on conceptual change*, 3-34. https://doi.org/10.4324/9780203154472.ch16

Wilhelm, J. (2009). Gender differences in lunar-related scientific and mathematical understandings. *International Journal of Science Education*, *31*(15), 2105-2122. https://doi.org/10.1080/09500690802483093

APPENDIX

Descriptive Data Coding Instrument

Section A: Study identification

A.1. Journal: ___________________
A.2. Authorship: ___________________
A.3. Year of publication: _________

Section B: Data about the study

B.1. Type of study:

☐ Qualitative
☐ Qualitative/intervention
☐ Quantitative focused on the educational stages of early childhood and/or primary education
☐ Quantitative/intervention
☐ Intervention
☐ Other

B.2 Educational level

☐ Early childhood education
☐ Primary education

B.3. Big Ideas covered

☐ Earth concept
☐ Phases of the Moon
☐ Earth-Sun-Moon system

☐ Stars and Sun
☐ Solar system
☐ Day-Night
☐ Seasons
☐ Concepts of size and distance

Section C. Content of the study

C.1. Theoretical framework
☐ Conceptions
☐ Mental models
☐ Conceptual change
☐ Intercultural
☐ Sociocultural
☐ Attitudinal
☐ Other
C.2. Instrument/s: ______________
C.3. Objective/s: _________________

Section D. Study results

D.1. Achievement of study objective/s
☐ Satisfactory
☐ Non-satisfactory
D.2. Conclusions/Implications
____