Improving preservice teachers' scientific argumentative writing through epistemic practices: a learning progression approach

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Abstract

Improving preservice teachers' argumentative competence is a social and educational imperative. This study focuses on the contribution of a sequence of learning tasks, designed as epistemic practices and following a learning progression approach, to enhancing student teachers' scientific argumentative writing. The participants are 47 preservice primary teachers who enrolled in a Developmental Psychology course, and one lecturer. Preservice teachers progressively acquire the vast majority of aspects involved in scientific argumentative writing. The most important difficulties experienced by preservice teachers revolve around intertextuality and the creation of theses. Key conclusions on this teacher education experience are presented in the final section.

Keywords: scientific argumentation; argumentative writing; learning progression preservice teachers; epistemic practices

Introduction

Argumentative skills are key for educational success (Rapanta, Garcia-Milà and Gilabert 2013). Education should promote argumentative skills that help students make and justify beneficial decisions in their lives (Kuhn 2005). Argumentation is basic for developing "scientific thinking", defined as the coordination between causal claims and evidence that bears on them. The term "Science" in this paper refers to the particular kinds of empirical research that embrace both the natural and social sciences.

Although science educators have started to view argumentation as a central practice that students should learn (Sandoval and Millwood 2005), research shows that classroom daily practices are far from engaging students in meaningful scientific argumentation, and that teachers need better training to understand how to implement such practices (Henderson et al. 2017; Sandoval et al.2016). As Shulman (1986, 9) stated: "the teacher need not only understand that something is so; the teacher must further understand why it is so."

If we want to improve teachers' development on argumentation, we must first understand how they acquire those skills. Most of the research on argumentation in classrooms has focused on argumentative discourse of teachers (e.g., Sampson and Blanchard 2012; Simon, Erduran, and Osborne 2006), while only a few studies have examined how students develop their argumentative skills through practice over time. However, in order to improve teachers' professional development, it is important to understand how teachers understand and engage in argumentation themselves (Zohar 2007), and the support they need to improve such skills. More research is needed to examine how future teachers acquire argumentative skills over time, and the support they need. Unlike oral argumentation, research on argumentative writing allows detailed examination of how students interiorise the epistemic norms of science (Sampson and Clark 2008), as well as the difficulties they experience and the support they need to construct high quality scientific arguments (Osborne et al. 2013).

In order to respond to these challenges, our study focuses on the progression of preservice teachers' argumentative competence in the field of Psychology. This study analyses the progression throughout three argumentation writing tasks in a course on Developmental Psychology. The tasks were designed as epistemic practices, following a learning progression approach.

Research background

Scientific argumentation

Scientific argumentation results from validating or rejecting ideas according to reasons that reflect the knowledge, procedures and values of the scientific community (Norris, Philips, and Osborne 2007). The argumentative competence is a complex one that requires prior competences. It leads to elaborating claims with the aim of convincing other people about a certain conclusion, opinion, or system of values (Jorba, Gómez, and Prat 2000).

Arguing leads to presenting and defending a thesis through reasoning. Semantically, it presents a statement on a certain controversy, and in text it usually communicates a stance on a given topic (Cordero 2000).

Scientific arguments must be sufficiently justified. Justification is based on three operations (Jorba, Gómez, and Prat 2000):

- Producing arguments or claims;
- Establishing relationships that modify the epistemic value of arguments according to available knowledge;
- Examining the validity of arguments according to available scientific knowledge.

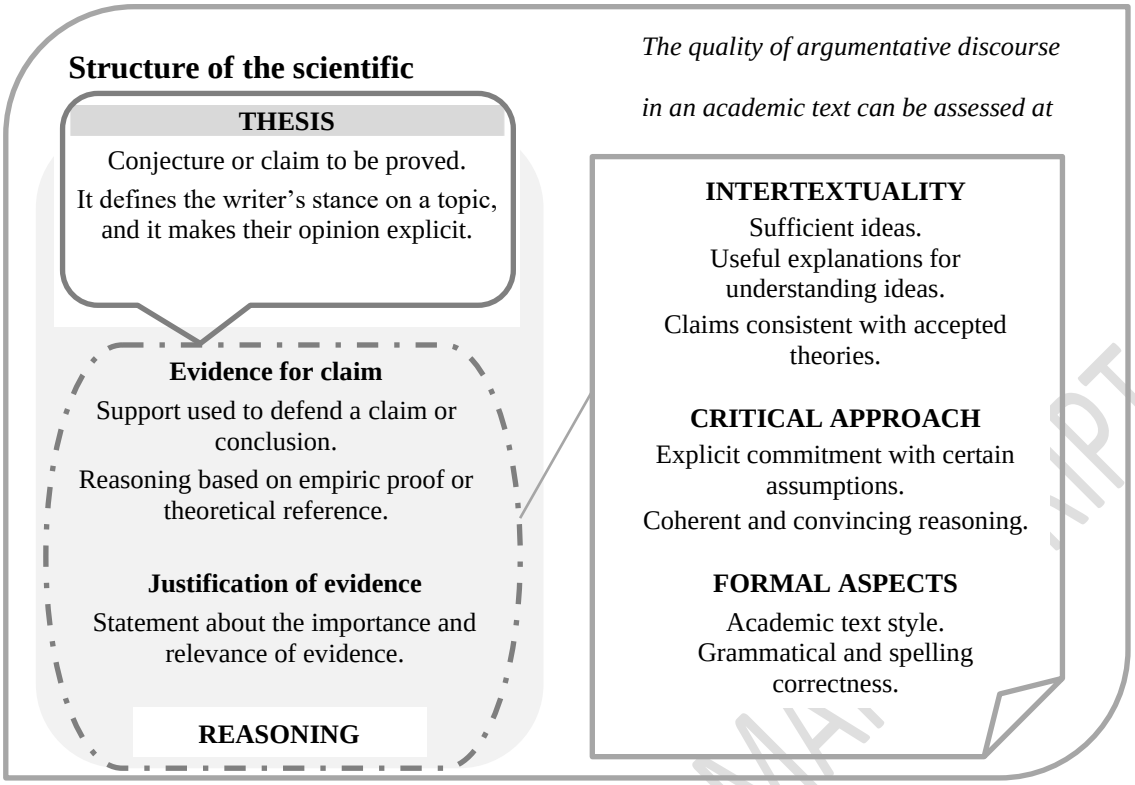
Teachers and students must understand how a scientific argument is different from an argument used in an everyday, non-scientific context. From a scientific epistemology viewpoint, justifying implies assessing the validity and sufficiency of scientific evidence and the logical reasoning used to support a claim.

The quality of scientific argumentative writing can be assessed according to its structure and the argumentative nature of academic texts (Castelló et al. 2011). The latter is assessed according to three criteria:

- Intertextuality; it refers to dialogue established with other texts and authors used as explicit reference. This includes: (i) sufficiency, clarity and relevance of statements; (ii) evaluative comments on statements, use of other texts or voices with that purpose; (iii) convergence with other accepted theories, laws or models.
- Critical approach; it refers to the writer's stance and the use of discursive resources for: (i) making personal attitudes and choices explicit according to assumptions and evidence; (ii) achieving coherence between arguments and ideas to convince a given audience.
- Formal aspects; academic texts follow specific rules on formal aspects of discourse. Such aspects include command of technical language, and grammatical and spelling correctness.

Figure 1 summarises the main components of a scientific argument, along with some criteria that students and instructors may use to assess the quality of their scientific argumentative writing.

Figure 1. Components of a scientific argument and criteria used to assess its quality in argumentative texts.



Source: prepared by the authors, based on Castelló et al. 2011; Cordero 2000; Jorba et al. 2000.

In accordance with the above ideas and criteria, a rubric (see appendix A) was constructed. This rubric was used to assess the students' progress in the acquisition of scientific argumentative competence in academic texts.

Epistemic practices to promote argumentative writing

Research on acquisition of scientific argumentative writing has pointed out typical weaknesses such as: lack of evidence to support claims (e.g., Lillis and Turner 2001; Sandoval and Millwood, 2005); linguistic errors (e.g., semantic) and lack of text integration (e.g., Castelló and Donahue 2012; Di Stéfano and Pereira 2004); and adopting descriptive and superficial approaches to the text, instead of focusing on arguing and explaining (e.g., Carlino 2004, Driver, Newton, and Osborne 2000). Some research suggests that teachers have an understanding of scientific argumentation that reveals roughly the same difficulties, although on another level of expertise, as students' arguments (Sandoval et al. 2016), like crafting arguments but providing no real support for them (Sampson and Blanchard 2012).

As stated by Wells (2001) texts are highly powerful tools for developing better insight on knowledge acquisition processes, for exploring new ideas, and analysing them carefully. For this purpose, epistemic practices are highly recommendable pedagogical settings for acquiring scientific argumentative competence (Kelly 2008). Epistemic practices denote the specific ways in which knowledge is constructed and shared in a given culture. This concept was first introduced by Knorr Cetina (1999) in her study of knowledge construction in science, but has later been applied to further contexts (see Nerland and Jensen 2014).

Epistemic practices are those where learners propose certain ideas or arguments, and justify and assess these ideas considering arguments and counterarguments according to available evidence. Sandoval, Bell, Coleman, Enyedy, and Suthers (2000) suggest that

epistemic practices are cognitive and discursive activities where students are expected to reach and demonstrate scientific knowledge comprehension. Epistemic practices allow students to articulate theory and evidence, promoting insight on scientific knowledge and procedures. These learning settings usually lead the students to define new concepts and propose new solutions to certain problems (Mercer et al. 2004). Students may be challenged to explain why certain attitudes lead some citizens to vote for one party or another, or why the air pollution of their town varies according to specific times and how to solve this problem.

For instance, Nilssen and Solheim (2015) develop a project where Norwegian preservice student teachers are encouraged to bridge theory and practice by following-up pupils' learning processes over time, and by writing papers based on empirical data and relevant subject theory. The findings are discussed in the light of the importance of understanding pupils' knowledge, and the role of scientific writing in inquiry-based learning processes. Sá Ibrahim and Justi (2016) find that preservice teachers can overcome their difficulties in using evidence to support their claims by participating in an innovative practice to promote argumentative writing in a science subject (Chemistry). Student teachers were better able to understand the argumentation structure, especially the role of evidence.

Some studies suggest that in-service training may very well be used to increase teachers' scientific argumentative writing. For instance, McNeill and Knight (2013) find that in-service teachers are eventually better able to understand the relevance of claims and justification in argumentation.

Other studies find that scientific argumentation might be improved through long-term learning initiatives, adopting a "learning progression" approach. In such experiences, participants progress from novice to expert levels throughout long sequences of learning tasks (Heritage 2008). For example, Kutluca and Aydin (2016) suggest that future science teachers improve their perception of argumentative discourse in Physics when they participate in a learning progression experience. Likewise, they are more aware of the complexity of building valid arguments based on evidence (Takao and Kelly 2003).

Learning progression settings can be used to promote in students metacognitive reflection about their own learning and the scientific knowledge construction process (Akkus, Gunel, and Han 2007; Authors 2016). Thus, preservice teachers may leverage learning progression approaches to have better insight on how scientific knowledge is produced and the rationality of science (Driver et al. 2000). However, more evidence is required to understand how the different aspects of teachers' scientific argumentative writing quality evolve over time. According to this framework, our study focuses on a case of preservice primary school teachers in the field of Psychology. The following question guides our analysis: *How does preservice teachers' scientific argumentative writing progress throughout a series of tasks designed as epistemic practices?* In the discussion and conclusions section the reader may find instructional features that may help improve future professional development scenarios for teachers on scientific argumentative writing.

Method

Context and Participants

This study was conducted at the Faculty of Educational Sciences at a public university in Barcelona, Spain. The participants were 50 students (35 female, 15 male, *M*= 22.5 years, *SD*= 5.1; range= 20-43) of the Bachelor's Degree in Primary Education, who enrolled in a

Developmental Psychology course that lasted four months. Three participants were excluded from the sample because they did abandon the course at some point. The teacher who implemented the intervention was a Senior Lecturer, with five years of teaching experience in this course.

Intervention

The students did three argumentative tasks as continuous assessment work, throughout a period of four months (see Table 1). These tasks demanded student analysis and reflection on educational scenarios related to three content blocks of the subject. The three tasks posed cognitive demands of similar difficulty, but they varied in the resources used. The first study case was introduced through a brief text illustrated with vignettes; the second case used an article from an educational journal; and the third case was based on a video clip.

Prior to each of these tasks, the students did a similar task during the content block (not assessed by the teacher), in which they practised their scientific argumentative writing in an intentional fashion. In those tasks the students worked collaboratively with the support of the instructor. The instructor helped the students become aware of the requirements of scientific argumentative writing, focusing the attention on the rubric that was later used to assess their writing (see Appendix A).

Table1. Timeline and argumentation tasks

	Week	Topic and task context	Task instructions
Task 1	3	**Biological, social and cultural foundations of human development.** Fictional case about an adopted Chinese girl that recently arrived in the school. The case describes behaviours of the teacher and peers that aim to facilitate her social integration into the school.	1. How would you explain this case according to the determinist approach? And the sociocultural approach? 2. Explain how «meaningful others» (peers, family, teachers…) promote Cai Lin's learning. 3. Explain how the principles of Guided Participation and the Zone of Proximal Development operate to facilitate Cai Lin's integration into her new social context.
Task 2	7	**Cognitive and linguistic development during school age** Brief paper on an educational project published in an educational journal. Reference: Castelltort, A., N. Sanmartí, and D. 2014. Actividades en el entorno: una oportunidad para aprender sobre el agua [Activities in the Environment: An Opportunity to Learn about Water]. *Alambique. Didáctica de las Ciencias Experimentales, 77*: 54-61.	1. According to Piaget's theory, explain which features of children's thinking are activated by this educational project. 2. According to the Information Processing approach, explain what the executive function is, and how this educational project might promote its development. 3. In one year, the teachers are planning to assess the student retained knowledge, and if they can use it for analysing and solving new situations. What assessment activities would you recommend? Why?
Task 3	11	**Socio-affective development during school age** Video depicting a non-formal educational experience entitled "L'equip petit" [The little team]. It tells the story of a soccer team composed of kids, who explain their views and experiences on practising soccer. Discussions revolve around respect for peers and opponents, perseverance, their friendship, and the joy of playing. Retrieved from http://aula.grao.com/recursos/equip-petit	1. Explain some key dimensions of children's identity construction, using some examples from the video. Explain the influence of peer groups, and their positive and negative effects. 2. Reflect on how affective attachment may influence the attitudes, feelings and emotional experiences of these children. 3. The children from the video have generally positive experiences. However, sometimes frustration, fear, and anger may generate violence, inside and outside the classroom. What strategies would you use to work on conflict resolution in the classroom?

Unlike the practice tasks, the assessment tasks were individually solved. The maximum extension of each writing was 3 pages, and they had to be submitted after one week of their presentation. One week after submitting the paper, every student received individual feedback in the form of a grade based on the rubric, and comments anchored in their own writing.

The last day of the course, the students completed a brief text where they reflected on their overall learning experience, answering a couple of questions: "how did I start this course?" and "how do I leave it now?"

Ethical issues

Educational research conducted by classroom teachers can offer valuable insight into the experience of teaching and the nature of student learning. The activity of teaching is so dependent on human intention and the specifics of each situation, that it can best be understood by those who do it (Elliott, 1990). However, research by classroom teachers can also lead to distortion or interference of their analyses (Wong, 1995). In our case, distortion was prevented by first informing all the students about the intention of observing and analysing the evolution of their argumentative writing competence. The participants' consent was obtained, granting absolute confidentiality of the data collected in the classroom. More importantly, to avoid analysis biases, an inter-judge coding of the students' writing quality was conducted. The first coding was carried out by the first author, who was also the course teacher. The second author (who created the rubric alongside the first author) provided his independent coding in order to assure sufficient inter-judge reliability. A few discrepancies were noticed, which were solved through discussion until reaching full agreement.

Data Collection and Analyses

The students' writings were corrected using the rubric presented earlier (see Appendix A). This allowed us to ascertain the student achievement on every criterion of argumentative writing. First, a global analysis led us to consider the student grades on the three tasks to see the progression in their argumentative writing. "Global analysis" means assessing the overall quality of their argumentative writing; this is in contrast with a second and more detailed analysis on the quality of the different aspects involved in scientific argumentation (see Appendix A). Third, qualitative data from the student last-day reflection were analysed. The aim of this analysis was to provide an overview of our participants' experiences and perceptions. In the following section the reader may find the main findings in that order.

Results

Progression from novice to expert. Global analysis

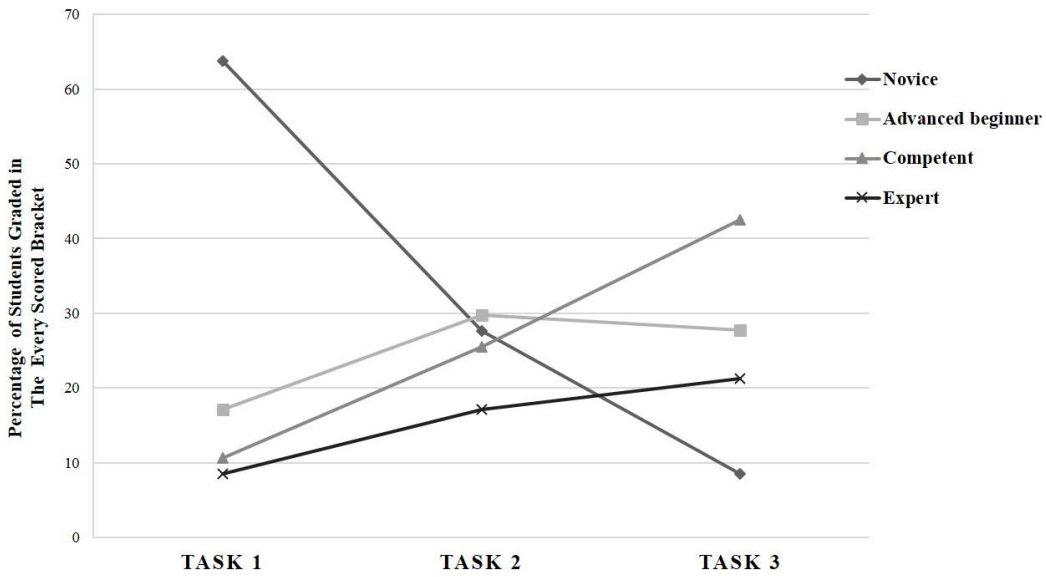
As shown in Table 2, most of the students got a novice grade in the first task (n=30; 63.8%) according to the rubric indications. In the following tasks, the ratio of novice students dramatically dropped. Likewise, the ratio of students with competent or expert grades increased over time. In the last task, more than half of the students got either a competent (42.5%) or expert (21.3%) grade. Figure 2 shows the learning progression of students according to their grades.

Table 2. Student grades on the three tasks

	Task 1		Task 2		Task 3	
Level	n	%	N	%	n	%
Novice	30	63.8	13	27.6	4	8.5
Advanced beginner	8	17.1	14	29.8	13	27.7
Competent	5	10.6	12	25.5	20	42.5
Expert	4	8.5	8	17.1	10	21.3

Note. The table shows frequency and percentage of students graded in every score bracket, per assessment task. N=47.

Figure 2. Percentage of students graded in every score bracket, per assessment task.



Advances and difficulties in the different aspects of scientific argumentation

A more detailed analysis throughout the three tasks shows the student outcomes on each criterion used to assess the quality of their scientific argumentation.

Table 3. Progress of results on quality of argumentation criteria.

	Task 1	Task 2	Task 3
Criteria			
Intertextuality	1.85 (.6)	2.13 (.71)	2.66 (.94)
Thesis	2.45 (.95)	2.89 (.89)	2.94 (.57)
Reasoning	2.43 (.68)	2.92 (.65)	3.11 (.73)
Academic language	2.64 (.79)	3.23 (.6)	3.32 (.7)
Cohesion	2.36 (.76)	3.11 (.6)	3.3 (.6)
Coherence	2.6 (.76)	3.3 (.51)	3.34 (.56)

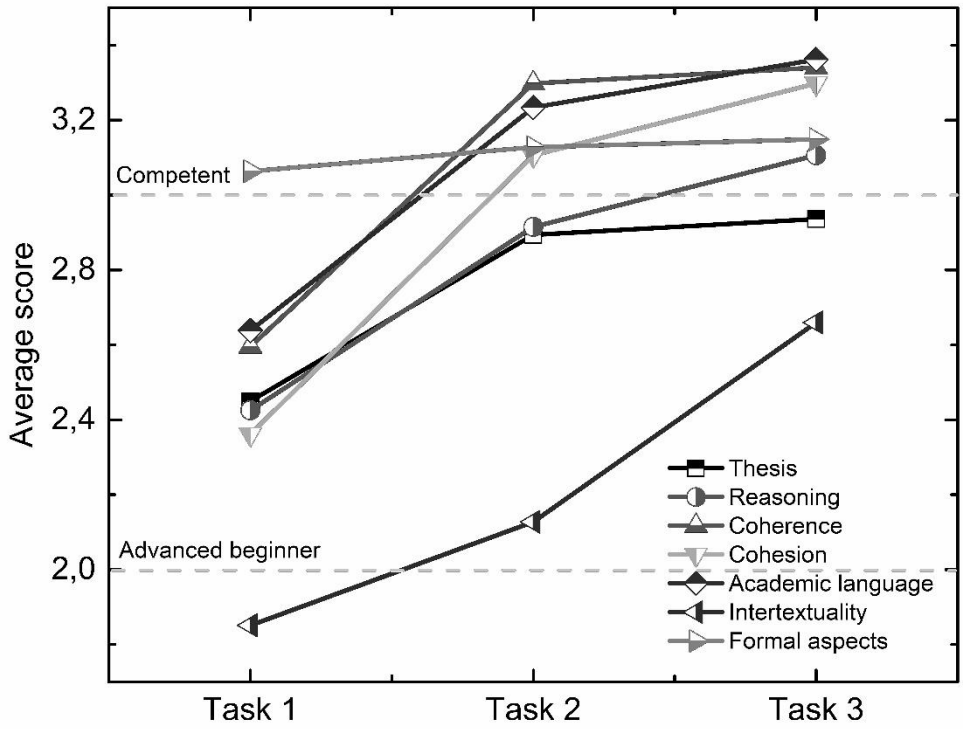
Formal aspects	3.06 (.5)	3.13 (.5)	3.15 (.36)

Note. The table shows average scores for every criterion, arranged from lower to higher. Standard deviation is indicated in brackets

Table 3 shows that in the first task students struggled to establish dialogue with other texts and authors to support their claims –i.e., intertextuality. Even in the last task, the average score of this item was clearly below the competent level (3 points). Students also experienced difficulties in establishing theses and reasoning. The students' texts showed important discursive problems –i.e., insufficient coherence and cohesion, as well as difficulties to use appropriate disciplinary language. The mean scores of these items improved with further tasks.

Figure 3 shows how the different aspects of argumentative writing quality progressed over time, from task 1 to 3.

Figure 3. Progress of results on quality of argumentation criteria



In task 1 most of the average scores were on the advanced beginner level (level 2). Formal aspects of writing (i.e., grammatical and spelling correctness) were above this level, and intertextuality scores were below that level.

In task 2, students apparently reacted positively to feedback provided and improved their competence to argue since four of the seven criteria were above the competent level. The improvement took place in key areas of argumentative discourse such as cohesion–i.e., enhancing their discourse for making choices explicit according to assumptions and evidence, and coherence –i.e., improving their consistency between arguments and ideas. Although students experienced some improvement, the criteria related to the structure of scientific argument (presenting and defending thesis) stayed below the competent level.

In task 3, the main difficulties were presenting thesis and, especially, intertextuality which is an essential quality of academic texts. Students especially struggled establishing a dialogue with other texts and authors to build their arguments. Intertextuality scored well below in the three tasks and never caught up with the rest of argumentative aspects.

Last, when the differences between the first and the last task were analysed, the results showed that students meaningfully improved in all the criteria except for one (formal aspects). These results are summarised in Table 4.

Table 4. *Paired sample t–test comparing task 1 and task 3 scores.*

	Mean	*SD*	*t*-value	*p*	95% CI
Criteria					
Intertextuality	-.81	.99	-5.587	.000	[-1,10, -.52]
Reasoning	-.68	.84	-5.578	.000	[-.93, -.94]
Thesis	-.49	.91	-3.704	.001	[-.76, -.22]
Academic language	-.72	.74	-6.674	.000	[-.94, -.51]
Coherence	-.74	.74	-6.934	.000	[-.96, -.53]
Cohesion	-.94	.87	-7.378	.000	[-1.19, -.68]
Formal aspects	-.09	.54	-1.071	.290	[-.25, .07]

Note. CI = Confidence Interval

Students' opinions

To complement the previous analyses, the students' opinions were taken into account. In their last-day reflection, students conveyed great satisfaction about the learning experience. They were generally optimistic about the reach of their learning, and they highly valued the systematic work done in the classroom and the support received throughout the course.

> *At first I was pretty lost. I struggled to understand the contents. I used to get lost during the class, and felt demotivated, and after the first grade I just crumbled. But over time I adapted, I got to better understand the concepts and started to feel better. With my second grade, I felt much more engaged. The third grade was excellent, and I felt on top the world! I leave the course very happy, because I believe that I've learned a lot. I'm happy with my work and my progress all along the semester. I think this was useful.* [Student 32. This testimony is representative of those students that started the course with many difficulties. Grades of the three tasks: 4.8; 6.8 and 8.9]

> *During the course I felt a bit lost, even stressed because I couldn't meet the requirements. Little by little I felt more confident and motivated. Content-wise, I can say that I have learned a lot on identifying and understanding concepts about the psychological development of children. I have also done a "mini Masters" in academic writing, thanks to the feedback received. Class-wise, I have done a "mini Masters" on how to engage students and the importance of*

group dynamics in learning. I think that thanks to that I'll be a better teacher and person in the future.

[Student 17, representative of those students that got a good result from the start. Grades of the three tasks: 8.5; 9.0 and 9.8]

The feedback I got made me realise the weaknesses of my texts. For instance, the need to further clarify ideas, relate them, separate them, conclude them, to bring up examples, etc.

[Student 43. Grades of the three tasks: 7.0; 7.5; 8.0]

The opinions here shown suggest that the students generally show awareness of having improved both their content learning (e.g., 'concepts'), and their scientific writing (e.g., 'academic writing'). The students knew that all the tasks were graded using the rubric (see Appendix A) that encompasses different aspects of scientific writing; thus, students' comments about having improved their 'grades' or met the tasks 'requirements' imply, to a certain extent, awareness of enhancing their argumentative writing. Some students specifically point that they are more aware of the role of evidence ('examples') and making claims ('relate' and 'clarify ideas') in improving their argumentative writing. Comments on the 'usefulness' of this experience and how this would make them 'a better teacher and person in the future' hint at the potential of our instructional setting to promote a more personal and functional learning. Likewise, students' comments on their 'progress throughout the semester' and the usefulness of teacher's 'feedback' suggest the relevance of following a learning progression approach and scaffolding students throughout their learning process. On the other hand, students' opinions about initial struggles ('I was pretty lost', 'I just crumbled') also suggest important difficulties involved in mastering scientific argumentation.

Discussion and Conclusion

As a general remark, our epistemic practices designed according to a learning progression framework have a positive impact both on the acquisition of epistemic norms in discursive argumentation, and on Psychology content knowledge. This result suggests that scientific argumentation may not only be a valuable competence to enhance general skills (e.g., thinking and metacognitive processes), but it may also enrich, if used appropriately, content knowledge learning (Mercer et al. 2004; Sampson et al. 2013). In our case, preservice teachers better interiorise Developmental Psychology content knowledge, which put them in a better position to understand and deal with certain situations that they may encounter in their future teaching.

This study confirms some results of previous research but it is innovative in the sense of providing a zoom-in approach on how the different aspects of preservice teachers' argumentative writing evolve within a few weeks. It is not enough to say that preservice teachers have a low level of such competence (Lillis and Turner 2001), which our study corroborates; we need to see how the different aspects of scientific argumentative writing evolve over time, and which are more easy or difficult to learn.

Our study aligns with previous research that finds that higher education students struggle to establish intertextual dialogue in their writing and a thesis in their argument (Carlino 2004; Castelló and Donahue 2012; Di Stéfano and Pereira 2004). However, our analyses provide new insight: our preservice teachers start with a low level of intertextuality, and the evolution of this aspect is quite flat throughout the learning

tasks. This suggests that, among all argumentative skills, intertextuality may be the most difficult-to-achieve skill. More studies with other student populations are needed to confirm this. In our study, student teachers' difficulties are expressed through the common use of direct citations, which they do not integrate into their reflections, and the use of other authors' citations presented as their own ideas.

Our analyses also highlight that students can especially improve in aspects like cohesion and coherence of their argumentation with appropriate support (Castelló et al. 2011). These would be easier-to-achieve skills, as students are able to make significant progress throughout the learning experience. Students do not improve in the area of formal aspects; however, our analysis throughout time suggest that the initial outcomes on this criterion were already high in the first task, so they did not need to improve it much further. Overall, our study suggests that the different aspects of scientific argumentative writing evolve at different paces.

When an overall perspective is taken comparing the starting level of students –as revealed by the first task– with the last task, our study shows that students meaningfully improve in the vast majority of criteria. These results highlight that despite difficulties experienced by student teachers throughout the course, the final outcome regarding scientific argumentative writing is clearly satisfactory.

Therefore, our study suggests the positive impact of epistemic practices and a learning progression approach to facilitate scientific argumentative writing for student teachers (e.g., Kutluca and Aydin 2016). According to students' own opinions, they are aware of having improved their scientific writing: 'I have also done a "mini Masters" in academic writing', claims one student. In their last-day reflection, the students generally emphasise that they are more aware of the importance of evidence and making claims. These results align with prior research about the benefits of argumentation learning for student teachers (de Sá Ibraim and Justi 2016; McNeill and Knight 2013).

According to students' opinions, the instructional experience lead them to better understand and construct situated knowledge related to teaching: 'I have learned a lot about identifying and understanding concepts about the psychological development of children […]. I think that, thanks to that, I'll be a better teacher […] in the future', states one student. Such metacognitive insights on the learned contents and how to apply them in their future practice should be highlighted, as they are an essential component of teacher education (Authors 2016).

Thus, our study suggests the following conclusions:

1) In a positive sense:

- Epistemic practices (Kelly 2008) and academic writing practices may be valuable tools to enhance argumentative competence of student teachers (Nilssen and Solheim 2015). This study shows the value of using an epistemic approach where student teachers have to categorise and define new concepts (Mercer et al. 2004). In our case, they are able to contextualise psychology content knowledge into their future teaching.
- Learning progression approaches may help student teachers improve their critical argumentation; our analyses suggest that students can especially ameliorate cohesion and coherence of their writing through appropriate support (Carlino 2004).

2) In a negative sense:

- Academic writing is an actual cognitive challenge for preservice teachers (Sandoval and Millwood 2005). Our student teachers need continuous support and scaffolding to improve in almost all aspects involved in scientific argumentative writing.
- Student teachers struggle to establish argumentative thesis (Carlino 2004), and, especially, to create intertextual dialogue. In our study, the progress of intertextuality throughout the learning sequence is poor.

Improving scientific argumentation of teachers is a challenge that we must meet. Preservice teachers must know how scientific knowledge is constructed, and how to use argument in the field of scientific disciplines (Kuhn 2010). Once that competence is acquired by teachers, they are in a better position to use it in their classes (Zohar 2007). They can use it both as a pedagogical strategy (e.g., in their lectures), and as a procedure to be learned by their students.

Some take-away points with practice and policy implications can be drawn from our study:

- Student teachers require well-designed learning environments to acquire scientific argumentative writing. This means designing environments with a clear learning sequence where students have to apply and contextualise scientific knowledge.
- Well-designed learning environments should consider that the different skills involved in scientific argumentative writing require different types of support as they progress at different paces. While formal aspects like grammar and spelling may require little focus, intertextuality demands stronger support.
- Scientific argumentative skills are not developed over-night. A transversal and multi-year approach to argumentation learning might be an ideal setting for student teachers to master it and be able to apply it in different contexts. Although such an approach usually demands high levels of coordination by teaching staff (e.g., sharing rubrics, epistemic scripts, software…), eventually the learning benefits for student teachers may outweigh these initial efforts. More research is needed to confirm this.

Our study faces important limitations, such as not having a control group to compare the efficacy of our instructional approach to other approaches. The methodology used in this study provides detailed information on the learning process, but this is limited to the study of this particular case, with a limited sample of students. Therefore, such methodology does not permit automatic generalisation of results.

Beyond such limitations, this study illustrates the positive impact of combining learning progressions and epistemic practices for engaging student teachers in scientific discourse (Heritage 2008; Kutluca and Aydin 2016), which is a cornerstone of future teachers' education (Shulman 1986).

References

Akkus, R., M. Gunel, and B. Hand. 2007. "Comparing an Inquiry-based Approach known as the Science Writing Heuristic to Traditional Science Teaching Practices: Are there differences?" *International Journal of Science Education* 29 (14): 1745-1765. doi:10.1080/09500690601075629

Carlino, P. 2004. “El proceso de escritura académica: Cuatro dificultades de la enseñanza universitaria” [Academic Writing Process: Four Difficulties of Higher Education Teaching]. *Educare* 8 (26): 321-327.

Castelló, Montserrat, and Christiane Donahue, eds. 2012. *University writing: Selves and Texts in Academic Societies*. Bradford, UK: Emerald.

Castelló, M., M. Corcelles, A. Iñesta, G. Bañales, and N. Vega. 2011. “Authorial Voice in Academic Writing: A Methodological Proposal for its Analysis.” *Revista Signos* 44 (76): 105-117. doi:10.4067/S0718-09342011000200001

Cordero, M. 2000. “El componente 'tesis' en los textos argumentativos escolares” [The ‘Thesis’ Component of Argumentative Scholar Texts]. *Revista Signos* 33 (48): 87-96. doi:10.4067/S0718-09342000004800007

de Sá Ibraim, S., and R. Justi. 2016. “Teachers' Knowledge in Argumentation: Contributions from an Explicit Teaching in an Initial Teacher Education Programme.” *International Journal of Science Education* 38 (12): 1996-2025. doi:10.1080/09500693.2016.1221546

Di Stéfano, María and Cecilia Pereira. 2004. “La enseñanza de la lectura y la escritura en el nivel superior: procesos, prácticas y representaciones sociales” [Reading and Writing Teaching in Higher Education: Processes, Practices and Social Representations]. In *Leer y escribir en la universidad. Textos en Contexto 6,* edited by Paula Carlino, 23-39. Buenos Aires: Asociación Internacional de Lectura.

Driver, R., P. Newton, and J. Osborne. 2000. “Establishing the Norms of Scientific Argumentation in Classrooms”. *Science Education* 84 (3): 287-312.

Elliott, J. 1990. “Teachers as Researchers: Implications for Supervision and for Teacher Education”. *Teaching and Teacher Education* 6: 1-26.

Heritage, M. 2008. *Learning progressions: Supporting Instruction and Formative Assessment*. Washington, DC: Council of Chief State School Officers.

Henderson, J. B., K. L. McNeill, M. González−Howard, K. Close, and M. Evans. 2017. “Key Challenges and Future Directions for Educational Research on Scientific Argumentation”. *Journal of Research in Science Teaching.* Advance online publication. doi: 10.1002/tea.21412

Jorba, J., I. Gómez, and A. Prat. 2000. *Hablar y escribir para aprender* [Speaking and Writing for Learning]. Madrid: Síntesis.

Kelly, G. 2008. “Inquiry, Activity, and Epistemic Practice”. In *Teaching Scientific Inquiry: Recommendations for Research and Implementation,* edited by Richard Duschl and Richard Grandy, 99-117. Rotterdam, Netherlands: Sense.

Knorr Cetina, K. 1999. *Epistemic cultures: How the sciences make knowledge*. Cambridge, MA: Harvard University Press.

Kuhn, D. 2005. *Education for Thinking*. Cambridge, MA: Harvard University Press.

Kuhn, D. 2010. “Teaching and Learning Science as Argument”. *Science Education* 94 (5): 810-824. doi:10.1002/sce.20395

Kutluca, A. Y., and A. Aydin. 2016. “An Examination of Prospective Elementary Science Teachers’ Perspective towards Socio-scientific Argumentation.” *Science Education International* 27 (3): 320-343.

Lafuente, M. and I. M. Alvarez. 2016. "Promoting Student Metacognition through the Analysis of Their Own Debates. Is it Better with Text or with Graphics?" *Journal of Educational Technology & Society* 19 (4): 167-177.

Lillis, T., and J. Turner. 2001. "Student Writing in Higher Education: Contemporary Confusion, Traditional Concerns." *Teaching in Higher Education* 6 (1): 57-68. doi:10.1080/13562510020029608

McNeill, K. L., and A. M. Knight. 2013. "Teachers' Pedagogical Content Knowledge of Scientific Argumentation: The Impact of Professional Development on K-12 Teachers." *Science Education* 97 (6): 936-972. doi:10.1002/sce.21081

McNeill, K. L., and D. S. Pimentel. 2010. "Scientific Discourse in Three Urban Classrooms: The Role of the Teacher in Engaging High School Students in Argumentation." *Science Education* 94 (2): 203-229. doi:10.1002/sce.20364

Mercer, N., L. Dawes, R. Wegerif, and C. Sams. 2004. "Reasoning as a Scientist: Ways of Helping Children to Use Language to Learn Science." *British Educational Research Journal* 30 (3): 359-377. doi:10.1080/01411920410001689689

Nerland, M, and K. Jensen. 2014. "Changing cultures of knowledge and professional learning." In *International handbook of research in professional and practice-based learning,* edited by Stephen Billett, Christian Harteis, and Hans Gruber, 611-640. Dordrecht: Springer.

Nilssen, V. and R. Solheim. 2015. "'I See What I See from the Theory I Have Read'. Student teachers learning through theory in practice." *Journal of Education for Teaching* 41 (4): 404-416. doi: 10.1080/02607476.2015.1080423

Norris, S., L. Philips, and J. Osborne. 2007. "Scientific Inquiry: The Place of Interpretation and Argumentation." In *Science as Inquiry in the Secondary Setting,* edited by Julie Luft, Randy Bell, and Julie Gess, 87-98. Washington, DC: National Science Foundation.

Osborne, J., S. Simon, A. Christodoulou, C. Howell-Richardson, and K. Richardson. 2013. "Learning to Argue: A Study of Four Schools and Their Attempt to Develop the Use of Argumentation as a Common Instructional Practice and its Impact on Students." *Journal of Research in Science Teaching* 50 (3): 315-347. doi:10.1002/tea.21073

Rapanta, C., M. Garcia-Milà, and S. Gilabert. 2013. "What is Meant by Argumentative Competence? An Integrative Review of Methods of Analysis and Assessment in Education." *Review of Educational Research* 83 (4): 483-520. doi:10.3102/0034654313487606

Sandoval, W.A., P. Bell, E. Coleman, N. Enyedy, and D. Suthers. 2000, April. *"Designing knowledge representations for learning epistemic practices of science".* Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

Sampson, V., and M. R. Blanchard. 2012. "Science Teachers and Scientific Argumentation: Trends in Views and Practice". *Journal of Research in Science Teaching* 49: 1122-1148. doi:10.1002/tea.21037

Sampson, V., and D. B. Clark. 2008. "Assessment of the Ways students Generate Arguments in Science Education: Current Perspectives and Recommendations for Future Directions." *Science Education* 92: 447-472. doi:10.1002/sce.20276

Sampson, V., P. Enderle, J. Grooms, and S. Witte. 2013. "Writing to Learn and Learning to Write during the School Science Laboratory: Helping Middle and High School Students Develop Argumentative Writing skills as They Learn Core Ideas." *Science Education* 97 (5): 643-670. doi:10.1002/sce.21069

Sandoval, W. A., and K. Millwood. 2005. "The Quality of Students' Use of Evidence in Written Scientific Explanations." *Cognition and Instruction* 23*:* 23-55. doi:10.1207/s1532690xci2301_2

Sandoval, W. A., J. Kawasaki, N. Cournoyer, and L. Rodriguez. 2016. "Secondary Teachers' Emergent Understanding of Teaching Science Practices. Transforming Learning, Empowering Learners." In *The International Conference of the Learning Sciences (ICLS) 2016, Volume 2,* edited by L. Chee-Kit, J. Polman, U. Cress, and P. Reimann, 737-744. Singapore: International Society of the Learning Sciences.

Shulman, L. S. 1986. "Those Who Understand: Knowledge Growth in Teaching." *Educational Researcher* 15 (2): 4-14.

Simon, S., S. Erduran, and J. Osborne. 2006. "Learning to Teach: Research and Development in the Science Classroom." *International Journal of Science Education* 28 (2): 235-260.

Takao, A. Y., and G. J. Kelly. 2003. "Assessment of Evidence in University Students' Scientific Writing. *Science and Education,* 12 (4): 341-363. doi:10.1023/A:1024450509847

Wells, G. 2001. *Indagación dialógica: Hacia una teoría y una práctica socioculturales de la educación* [Dialogic Inquiry: Towards a Sociocultural Theory and Practice in Education]. Barcelona: Paidós.

Wong, E. D. 1995. "Challenges Confronting the Researcher/Teacher: Conflicts of Purpose and Conduct." *Educational Researcher,* 24 (3): 22-28.

Zohar, A. 2007. "Science Teacher Education and Professional Development in Argumentation." In *Argumentation in Science Education*. Science and Technology Education Library, edited by Sibel Erduran, and María Pilar Jiménez-Aleixandre, 245-268. Dordrecht: Springer.

Appendix A

CRITERIA	EXPERT 4	COMPETENT 3	ADVANCED BEGINNER 2	NOVICE 1	*Weight*
Ideas	They state essential ideas (theses) in a precise and appropriate fashion according to the task instructions.	Most of the ideas cover the task questions, but other ideas seem irrelevant to the task instructions.	They omit essential ideas and/or some ideas are not related to the task questions.	Most of the ideas are not precise and/or they are contradictory. Decontextualised discourse.	15%
Reasoning	Convincing reflection, based on essential and relevant content; it deepens into topics and provides complementary ideas.	The reasoning shows comprehension and commitment to content; however, some ideas are not sufficiently developed.	The text contains convincing arguments, although some topics are covered superficially.	In the text we find abundant, simplistic arguments and/or they are naïve or not convincing.	20%
Intertextuality	Intertextuality is appropriate, convincing and updated. Efficient use of citations and APA norms.	Intertextuality based on basic bibliography. Balance between direct and indirect citations, integrated into the reasoning. Attention to APA norms.	Abundant direct citations; some of them are not well integrated into the reflection; sometimes they are reproduced as the student's voice.	Scarce or inadequate citations. Absence of correct references. Signs of plagiarism.	15%
Coherence	Well-achieved coherence: the text is structured through thematic ideas that facilitate reasoning progression and construction of meanings.	Although coherence is generally good, sometimes there is no connection between primary and complementary ideas, which limits the reasoning progression and production of ideas.	There is a series of isolated or little relevant ideas that affects the meaning of the whole text, which is mainly reproductive.	The text has no logic. There are ambiguities and reiterations. Discourse not understandable.	15%
Cohesion	Sufficient cohesion: ideas are grouped within clear blocks, related and contrasted through textual markers. All ideas are concluded.	The grouping of ideas is sometimes not appropriate and/or textual markers are insufficient or inappropriate. Some ideas are not concluded.	Lack of markers and/or they are monotonous. Lack of concordance and the reference is missing. Many ideas are not concluded.	Sentences are too long, and expressions are meaningless, with the use of unfinished sentences.	15%
Academic language	Sufficient command of disciplinary language, wide and precise vocabulary, adjusted to the formality of argumentative texts.	Appropriate use of disciplinary language, although sometimes the vocabulary is not precise. The format is appropriate to the formality of argumentative texts.	There are some term-related errors, sometimes pet words are used. They omit some formalities of argumentative texts.	The terms are unspecific and inappropriate. Limited vocabulary. They omit basic formalities.	10%
Formal aspects	Strictly correct grammar and spelling.	There are some grammatical and spelling mistakes that do not affect text comprehension.	Repeated grammatical and spelling mistakes that affect text comprehension.	Grammatical and spelling mistakes unacceptable in a higher education text.	10%