Part 13 / Strand 13
Pre-service Science Teacher Education

Editors: *Maria Evagorou & María Ruth Jimenez Liso*

Part 13. Pre-service Science Teacher Education

Professional knowledge of teachers, pre-service teacher preparation, instructional methods in pre-service teacher education, programs and policy, field experience, relation of theory with practice, and issues related to pre-service teacher education reform.

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Introduction

The recent changes around the world, with the COVID-19 pandemic and the war appearing in Europe again after decades, have once more brought our attention to the importance of understanding uncertainty in science, being able to navigate in a changing world and supporting our students, as science educators, to become active and responsible citizens. Becoming active and responsible citizens entails focusing on social justice (Cho, 2017), developing critical consciousness, engaging in dialogue and taking action (Blackmore, 2016) and understanding the uncertainties of science (i.e., Osborne et al., 2022). Further changes in our field include the emphasis on interdisciplinarity, especially as this emerges from the new emphasis on STEM education (Alvargonzález, 2011) and the effort to support integrated STEM teaching. Therefore, as science educators working with pre-service teachers, we are called to support them: in (trans)forming their pedagogical skills, understanding and teaching in interdisciplinary STEM settings, and preparing them to enter the classroom as autonomous educators.

Strand 13 of the ESERA 2021 online conference invited science educators to submit research work focusing on pre-service teacher preparation, instructional methods in pre-service teaching, field experience studies and programs linked to science teacher preparation. This volume of the e-proceedings brings together 12 papers from across the world. The work included in this part of the volume provides an overview of pre-service science teacher education trends. Furthermore, it highlights how research in our Strand has adapted because of the changes in our world during the last two years. The topics are similar to previous years (modelling, argumentation, inquiry), but methods have shifted to accommodate the pandemic. Specifically, papers in this volume for Strand 13 include themes of digital media with an emphasis on COVID-19 as triggers, some of the studies on teacher identities and expectations to be teachers, whilst others focus on scientific competencies (i.e., modelling, argumentation, inquiry) and curriculum effects.

We hope that this group of selected papers will support us as science educators as we continue our conversations about how to assist future teachers in providing their students with the knowledge, skills and dispositions that will enable them to become scientifically literate and responsible citizens.

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DISCIPLINARY IDENTITIES IN INTERDISCIPLINARY TOPICS: CHALLENGES AND OPPORTUNITIES FOR TEACHER EDUCATION

Eleonora Barelli[1], Berta Barquero[2], Oscar Romero[2], Maria Rosa Aguada[2], Joaquim Giménez[2], Carolina Pipitone[2], Gemma Sala-Sebastià[2], Argyris Nipyrakis[3], Athanasia Kokolaki[3], Ioannis Metaxas[3], Emily Michailidi[3], Dimitris Stavrou[3], Michael Lodi[1], Marco Sbaraglia[1], Evmorfia-Iro Bartzia[4], Simon Modeste[4], Simone Martini[1], Viviane Durand-Guerrier[4], Sara Satanassi[1], Paola Fantini[1], Veronica Bagaglini[1], Shulamit Kapon[5], Laura Branchetti[6], Olivia Levrini[1]

[1]Alma Mater Studiorum - University of Bologna, Bologna, Italy

[2]University of Barcelona, Barcelona, Spain

[3]University of Crete, Rethymno, Greece

[4]University of Montpellier, Montpellier, France

[5]Technion - Israel Institute of Technology, Haifa, Israel

[6]University of Milan, Milan, Italy

Interdisciplinarity (ID) represents nowadays a complex, multi-dimensional and timely challenge in STEM and, more in general, in STEAM education. If on one side ID is at the core of the most urgent societal issues, in schools and universities disciplines are almost exclusively taught separately and rigid boundaries are created. After a long period of good practices, researchers are more and more perceiving the need to develop theoretical frameworks to rigorously define what ID is and to recognize if and how interdisciplinary knowledge and skills can be developed in teaching. In this paper, four theoretically-oriented studies are presented as outcomes of the IDENTITIES Erasmus+ project aimed to develop an approach to design interdisciplinary teaching modules for pre-service teacher education.

Keywords: interdisciplinarity, pre-service teacher education, STEM education.

INTRODUCTION

The confrontation of the most urgent problems we face today, such as the pandemic and global warming, requires deep collaboration and integration between STEM disciplines. The emergence of new interdisciplinary fields like biomedical engineering, materials engineering, and artificial intelligence reflects this point as well. However, even though the increasing predominance of interdisciplinary discourses not only in professional and academic realms but also at the societal level, STEM education has been criticised for the disconnected teaching in schools and universities that perpetuates sharp separations between disciplines.

To face this challenge, one of the primary actions that need to be undertaken is a profound re-thinking of pre-service teacher education. Indeed, teachers and teacher educators have a disciplinary background and, usually, they are not educated to a fruitful interdisciplinary dialogue that is required to enter the recent emerging societal challenges. That is why innovating the path through which university students are prepared to become teachers deserves specific attention, first of all from the research community. This is the goal of the IDENTITIES

Erasmus+ Project (www.identitiesproject.eu) that has developed innovative and transferable teaching modules and courses to be used in contexts of pre-service teacher education. The modules' main objective is unpacking interdisciplinarity (ID) in STEM fields, illuminating the links and interweaving between physics, mathematics, and computer science.

Philosophers of science have discussed a lot on what ID is and how it can be characterised with respect to other forms of interplay among disciplines. The IDENTITIES theoretical approach considers the following definitions of inter-, multi-, and trans-disciplinarity: "Multidisciplinarity involves encyclopedic, additive juxtaposition or, at most, some kind of coordination, but it lacks intercommunication and disciplines remain separate [...]. True interdisciplinarity is integrating, interacting, linking, and focusing. […]. Transdisciplinarity is transcending, transgressing, and transforming, it is theoretical, critical, integrative, and restructuring but, as a consequence of that, it is also broader and more exogenous" (Thompson Klein, 2010 in Alvarogonzález, 2011). In the IDENTITIES' conceptualization of ID, it is crucial the metaphor of *boundary*, borrowed from the metatheory by Akkerman and Bakker (2011). It introduces two crucial terms in our framework: *boundary objects*, i.e., "objects that enact the boundary by addressing and articulating meanings and perspectives of various intersecting worlds" (p. 150) and *boundary-crossing mechanisms*, i.e. types of interaction between disciplines (collaboration, identification, reflection, and transformation) that lead to a scale of interdisciplinary learning potential.

In this paper, we present four research contributions that refer to modules developed within the IDENTITIES project and already implemented in local and international contexts. They differ and complement each other for several aspects. First of all, they focus on themes that deal with different types of ID. Two studies focus on advanced, intrinsically interdisciplinary, STEM topics that are societally relevant but difficult to include in official curricula: coronavirus evolution and nanotechnologies. Other two focus on curricular themes that curricula and teaching tend to separate in different fields: cryptography and parabola and parabolic motion. In the former cases, the studies discuss the role of S-T-E-M disciplines to unpack and exploit the complexity of the STEM themes. In the latter cases, ID is used as a *lever* to uncover the epistemological cores of the disciplines by confronting them on a common *boundary theme*. The four studies complement each other also for their research approach to didactics. The studies on coronavirus and cryptography implement research approaches elaborated within the didactics of mathematics: the Anthropological Theory to the Didactic and the Theory of Didactical Situation. The studies on nanotechnologies and parabola are, instead, influenced by approaches developed in science education: the Model of Education Reconstruction or the Family Resemblance Approach.

INTERDISCIPLINARITY IN ADVANCED STEM TOPICS

Design of an interdisciplinary module about modelling coronavirus evolution

The topic of modelling the evolution of coronavirus was chosen in part due to its intrusion into our daily lives at the beginning of 2020. We recognized in it an authentic example of STEM advanced ID, i.e., a major issue for the society that required the collective effort of putting different disciplines to react in front of unexpected questions. Indeed, the COVID-19 pandemic has shown more than ever that students and, more in general, citizens need to understand how mathematics and scientific advances contribute to the understanding of societal phenomena. In addition, "the pandemic illustrates perfectly how the operation of science changes when questions of urgency, stakes, values, and uncertainty collide" (Saltelli et al., 2020). Specifically, it has emerged the need to explore what kind of knowledge can models and modelling provide, how we may interpret their predictions, and more in general, what contribution they provide to the understanding of such a complex issue.

To present the design principles at the basis of the module, we use some notions proposed in the framework of Anthropological Theory to the Didactic (ATD). Within the ATD, the step toward a change of paradigm in teacher education in the so-called "paradigm of questioning the world" (Chevallard, 2015) is approached using the "study and research paths for teacher education" (SRP-TE) (Barquero et al., 2018). The SRP-TE is an inquiry-based process combining practical and theoretical questioning of outside- and inside-school scientific activities. The approach is mainly characterised by: i) the formulation of questions that are rich and relevant enough to be placed at the heart of pre-service teacher education programmes; ii) the facilitation, through the questions, of epistemological and didactic analysis tools of disciplinary and interdisciplinary knowledge at stake; iii) the detection of boundary objects and boundary-crossing mechanisms to switch on links between the disciplines and foster the analysis of interdisciplinary knowledge. In the case of the present module, the SRP-TE is structured in four submodules. Each of them asks participants to assume different roles with regard to their interdisciplinary inquiry.

In submodule 1, we start from a professional question related to ID in scientific practices and their conditions for transposition to school. Participants act here as "ID explorers", reading a set of selected pieces of news and discussing questions like: *How have STEM disciplines contributed to the societal understanding of the evolution of COVID-19? How can this interdisciplinary practice be transposed to secondary schools?* From this first analysis, educators guide the participants to delimit possible lines of inquiry involving models and modelling as well as the interaction among different disciplines. These lines are the main object of Submodule 2 that asks participants to experience an interdisciplinary project, under the role of "ID student", about: (1) The complexity of delimiting the system to model: analysing data; (2) The role of the equation-based models: what can we consider a 'good' model? what are models for?; (3) Agent-based models and simulations: Simulating scenarios to help to make decisions about societal restrictions. The main goal of this submodule is to make participants carry out an unfamiliar interdisciplinary activity that could take place also in the classroom. In particular, the participants explore the issue of COVID-19 evolution from three different (but complementary) points of view: the real data processing, selection of variables, and their statistical analysis; the use of equation-based mathematical models for disease diffusion and the interpretation of the models' coefficients, accordingly to the data; and the implementation of an agent-based simulation using methods inspired by statistical physics to evaluate different types of social intervention.

In submodule 3, the participants become "ID analysts" since, in groups, carry out a meta-reflection on the previous activity on three different levels. The first level, using the tool of questions-answers maps (Winsløw et al., 2013), aims to sketch the process followed through the dialectics between the specific questions that the group has faced, and the answers obtained. The second level requires recognizing in the lines of inquiry examples of boundary objects. Finally, participants analyse the kind of interaction among disciplines (i.e. boundary-crossing mechanisms) that happens when boundaries are at stake and eventually overcome. In Submodule 4 some secondary school experiences linked to each line of inquiry are shared with participants. Then, they are expected to use the tools previously developed for interdisciplinary analysis to discuss the conditions to facilitate the implementation of ID in real classrooms, as well as the constraints hindering the chances for ID to happen.

STEM student teachers analysing ID in the field of nanotechnology

Nanoscience-Nanotechnology (NST) is one of the most contemporary and promising research fields in STEM. NST is a wide topic that relates to studying and manipulating matter at the atomic, molecular, and macromolecular levels in order to create materials, devices, systems in the nanoscale (approximately 1-100nm), with fundamentally new properties and functions (Roco, 2001). The rationale for choosing NST for STEM teaching relies on the fact that: a) NST is by nature an interdisciplinary field, in which many disciplines interact, b) NST is related to many contemporary real-world applications and breakthroughs, c) being an ongoing field of research, it gives the opportunity to students to discover new methods and new ways of thinking as well as to cultivate views of Nature of Science and Nature of Technology, and d) it can engage students in relevant socio-scientific issues and issues of responsible citizenship (Kähkönen et al., 2016; Stavrou et al., 2018).

The theoretical framework for designing this module is the Model of Educational Reconstruction for Teacher Education (Van Dijk & Kattmann, 2007), adapted to the needs of the present study. Therefore, studies concerning Pedagogical Content Knowledge and ID interact dynamically with the design and development of educationally reconstructed STEM learning environments from the student teachers in order to develop learning environments for STEM pre-service teacher training. Furthermore, the educational reconstruction of STEM learning environments has been carried out according to the Model of Educational Reconstruction (Duit et al., 2012), in which school students' ideas and attitudes, as well as empirical studies on teaching and learning, are also taken into account. Specifically, studies concerning ID include i) the taxonomy of ID by Thompson Klein (2010) to define ID, as well as ii) the boundary objects framework (Akkerman & Bakker, 2011) as a facilitating means to foster student teachers' views and understandings of ID. The module was divided into four main submodules following the rationale of SRP-TE (Barquero et al., 2018).

In the first submodule, student teachers are called upon to act as "ID explorers", by engaging in open discussions about contemporary real-world problems that NST research aims to address. Moreover, they are asked to give their initial views on concepts/methods/artifacts in which multiple disciplines are involved, as well as 'linguistic activators', i.e., terms that gain different meanings across different disciplines/communities. Subsequently, in the second submodule, student teachers take the role of "ID students", by engaging in interactive activities which include STEM artifacts related to cutting-edge NST applications, such as smart housing, alternative energy sources, metallic nanoparticles for medical treatment, and NST microscopes. The student teachers are then called upon to design the first draft of their own STEM teaching activities concerning NST, present it to peers in terms of microteaching, discuss, and take feedback.

In the third submodule, student teachers take the "ID analyst" role. The goal in this submodule is twofold: on the one hand, student teachers are called upon to recognise disciplinary knowledge and skills from each S-T-E-M discipline that derive from nanotechnology concepts/phenomena/applications in the STEM activities presented previously. Particularly, student teachers analyse the complex phenomena by using their existing "disciplinary lenses" in order to connect them to their already obtained areas of understanding, and, hence, foster a feeling of *comfort*. On the other hand, student teachers are called upon to recognise several *incidents* where disciplines interact in the STEM activities presented. In order to concretise this process, the module implements indicative concepts/methods/artifacts that were considered to act as boundary objects in NST, such as modelling (Develaki, 2020), instrumentation (Stevens et al., 2009), and biomimicry (Krohs, 2022). Hence, students reflect on how different disciplines coexist, interact, and interconnect through these boundary objects which are used as "interdisciplinary lenses". Subsequently, the module leaves space for student teachers to discuss further incidents of ID regarding their own developed teaching material that can also act as boundary objects. In the last submodule, student teachers are invited to revise their STEM teaching material through a second iteration as "ID designers" in which they reflect from an epistemological point of view on the model of STEM Integration (Ring et al., 2017) that they implemented.

INTERDISCIPLINARITY IN CURRICULAR TOPICS

Teaching cryptography to foster ID between mathematics and computer science

We choose cryptography as an example of a domain at the interface between Mathematics and Computer Science (CS). Both mathematical elements (like proofs, number theory) and CS elements (like computational complexity, systems design, programming) are fundamental to solving the relevant social, technological, and scientific challenges cryptography poses. Moreover, some cryptography elements encompass intertwined aspects of CS and Mathematics (for example, one-way functions are both well-defined mathematical functions and programs that satisfy specific security and efficiency criteria). In the current research, this stimulates a dialectic between the two disciplines, both from CS to Mathematics (e.g., requiring new research in elliptic curves) and in reverse (e.g., using theorem provers to verify cryptographic properties). On the other hand, cryptography allows for "disciplinary projections": inside the field, elements of the two disciplines are still recognisable. Learning about all this is relevant for those secondary teachers who may have to teach some cryptography either in Mathematics, CS, or interdisciplinary courses.

The design of the module relies on two main pillars. First, we consider the need to introduce cryptography as a social issue of contemporary society (ENISA, 2016) following a long-term presence in human history from ancient Greece to nowadays. The development of CS has put forward an increasing number of encryption methods, most of them relying on Mathematics and CS's close intertwining. Second, we choose the didactical engineering methodology relying on the Theory of Didactical Situations. As stressed by Artigue (2014), didactical engineering is structured into four main phases: (i) preliminary analysis; (ii) design and *a priori* analysis; (iii) realisation, observation, and data collection; (iv) *a posteriori* analysis and validation. Validation is internal, based on the contrast between *a priori* and *a posteriori* analysis, not comparing experimental and control groups. In the design of tasks and situations, particular attention is put on: the search for situations that capture the epistemological essence of the mathematics to be learned; the optimisation of the *milieu* to provide relevant retroactions for students' autonomous learning (*a-didactic* potential); the management of *devolution* and *institutionalisation* processes. Following Durand-Guerrier, Meyer, and Modeste (2019), we consider this relevant also for CS and, hence, for designing interdisciplinary teaching modules involving both disciplines. Inspired by the STP-TE (Barquero et al., 2018), the module is structured into five submodules.

Submodule 1 starts from a current social debate (pros and cons of end-to-end encryption in widely used instant messaging services) to make participants (i.e., student teachers) initiate the discussion on cryptography, get in touch with basic principles and terminology, and begin to reflect on ID by analysing a historical piece on the birth of asymmetric cryptography. Submodule 2, designed according to the Theory of Didactical Situations, makes the participants experience as students a didactical situation (a group activity based on the *Dominating Set Perfect Code* cryptosystem (Bell et al., 2003)), with a *milieu* where the students autonomously verify if they have solved a given problem (i.e., deciphering a message). We designed a different organisation of the *milieu* for each participants' group to lead to different perspectives and approaches to the task and help student teachers think about the interdisciplinary objects encountered (graphs, functions, algorithms, complexity). In Submodule 3, participants analyse the previous teaching proposal in light of didactic and epistemological aspects, engaging in interdisciplinary analysis. They make disciplinary projections (recognising CS and Mathematics fundamental concepts in cryptography) and identify interdisciplinary elements (like boundary objects and boundary-crossing mechanisms (Akkerman & Bakker, 2011) or what we call linguistic and epistemological activators - e.g., the different meanings associated with 'function' in CS and Mathematics, or the difference between a non-invertible and a one-way function) to explore the borders between the two. In submodules 4 and 5, participants design, implement and analyse *a posteriori* a new didactical situation on other proposed cryptography concepts.

In the whole module, we designed activities where disciplinary projections can shed light on important disciplinary concepts, like computational complexity for CS and graphs for Mathematics. Disciplinary projections can stimulate exploration and learning of some relevant topics and ideas of each discipline, not only in the specific scope of cryptography but also in other CS and Mathematics areas. Together with the work on boundaries, this can also foster the exploration of other interactions between the two disciplines.

Parabola and parabolic motion to cross boundaries between physics and mathematics

The topic of parabola and parabolic motion was chosen as very prototypical of what happens to ID in school transposition. The two are, of course, intrinsically related. However, school science, through habits, textbooks, and school practices, has consolidated two different disciplinary narratives that separate the two themes into disciplinary enclaves created by artificial barriers. On the contrary, the discovery of parabolic motion represents a crucial step in the historical co-evolution of physics and mathematics, and in the establishment of physics as a discipline (Renn et al., 2011). It led humanity to overcome the medieval distinction of "violent and natural motions" and to admit that mathematics can be applied to the imperfect sublunar world. Vice versa, Kepler and his studies in geometrical optics provided a fundamental contribution to reconceptualize parabola as *locus* and to pave the way for projective geometry. Despite their crucial roles in history, parabola and parabolic motion do not have, in class, a special role in defining the epistemic identity of physics and mathematics.

The module has been designed with the goal to base the search for a theoretical-based model of ID on a concrete example. The model is expected to orient the design of teaching materials able to: a) break down artificial school barriers between disciplines and b) exploit ID as a way to give back mathematics and physics their disciplinary identities. In order to reach these goals, we chose a historical approach that implies the analyses of historical cases through "ID lenses". The interdisciplinary lenses for the analysis have been built as a combination of three main frameworks: the Family Resemblance Approach (FRA) for the NOS by Dagher and Erduran (2016); the Thomson Klein taxonomy of ID (2010); the metatheory developed by Akkerman and Bakker on the metaphor of the boundary (2011). Since the latter have already been introduced, we provide some details about the FRA. It has been used to switch on, in the historical texts by Guidobaldo and Galileo, the dimensions that characterise the epistemic core of a scientific discipline: its aims and values, scientific practices, methods and methodological rules, knowledge (Dagher & Erduran, 2016). The application of the framework to the analysis of the history of parabola and parabolic motion led us to recognize two special cases of boundary objects – symmetry and proof – that, through mechanisms of identification and reflection, activated the appearance of the epistemic cores of the two disciplines. For this reason, the concepts were emphasised as epistemological activators.

The module is articulated in six submodules. In phase 1 the student teachers are asked to reflect on the metaphor of the *boundary* and on examples of boundary objects to position themselves on the theme of ID. Then the phases 2 and 3 concern both the historical analysis of the discovery of the parabolic motion and a two-pronged analysis of historical texts from Guidobaldo and Galileo: the FRA model is used to recognise the epistemological elements of the discourse; the Akkerman and Bakker's metatheory is used to point out the role of boundary object and epistemological activator played by the symmetry that Guidolbaldo experimentally discovered. Phase 4 regards the analysis of the different meanings of proof in mathematics so as to define criteria to analyse Galileo's proof of the parabolic motion and to exploit the structural role of mathematics in the establishment of physics as a discipline. In phase 5, different definitions of parabola as a mathematical object were given, influenced by the interaction between mathematics and physics over many centuries and to symmetry as a boundary object. In phase

6, a wrapping up lesson was designed to rethink the questions opened in phase 1 after the interdisciplinary activities.

DISCUSSION AND CONCLUSION

The four perspectives presented in the paper allow us to sketch common features of the approach to ID that the IDENTITIES project carries out. The first issue that deserves discussion is related to the importance of grounding an interdisciplinary reflection on the *identities of the disciplines* at stake. While acknowledging the limits of the sharp separation between STEM disciplines in schools and universities, disciplines are still fundamental for interdisciplinary education. A "discipline" is indeed a body of knowledge that has been historically organised to be taught and learned (the very same etymology of the term "discipline" refers to the Latin "discere", whose meaning is "to learn"); moreover, a discipline reflects a didactical organisation of knowledge that supports the development of a particular set of epistemic skills such as modelling, explaining, arguing, which take somewhat different forms in different STEM disciplines. These sets of epistemic skills are the basis of productive collaborations between disciplines in real-life problems, and the generation of productive ID. Hence, learning in the disciplines is crucial for maintaining productive ID. Learning in schools is institutionally organized around separate disciplines. Fostering interdisciplinary learning in this educational context is challenging, since teachers and students often misinterpret the institutionalized separation between classes of different disciplines in school, as an intrinsic feature of the topics they learn in each discipline.

When focused on disciplines, students should be guided to recognize the types of *interactions between disciplines* that occur in interdisciplinary contexts. The shift from separate disciplines to ID in the four modules was afforded by the focus on boundary objects, boundary-crossing mechanisms (Akkerman & Bakker, 2011), and "epistemological activators" i.e., key concepts, methods, or themes that characterise each discipline and invite meaningful reflective comparisons between and across disciplines (Ravaioli, 2020). Additional support for this shift was achieved by supporting students in identifying "linguistic activators" i.e., concepts, categories, or forms of linguistic representations that are used differently in different disciplines. The explicit comparisons of the entailed meanings ascribed in each discipline, help students unpack additional layers of the interaction between disciplines.

The last point that we want to stress is related to the protagonists of the IDENTITIES approach: the *student teachers*. Teachers are the most important agents of change in students' learning. Hence, if we want students to develop interdisciplinary skills, we should start by teaching this in our pre-service teacher education programs. That is why the design process not only includes the reconstruction of disciplinary and interdisciplinary issues in the modules, but also implementations in teacher education that require the preservice teachers to take different roles with respect to what is learned. Student teachers engage in exploring case studies of ID through explicit discussion of boundary crossing, epistemological activators, and linguistic activators, then in instructional design that highlight aspects of ID, in collective reflections on this design, followed by microteaching and further reflections.

Notes

The four sections of the paper have been authored by the team of designers of the four IDENTITIES modules. For the COVID-19 module: B. Barquero, E. Barelli, O. Romero, M. R. Aguada, J. Giménez, C. Pipitone, and G. Sala-Sebastià; for the nanotechnologies module: A. Nipyrakis, A. Kokolaki, I. Metaxas, E. Michailidi, and D. Stavrou; for the cryptography module: M. Lodi, M. Sbaraglia, E. Bartzia, S. Modeste, S. Martini, and V. Durand-Guerrier; for the parabola module: S. Satanassi, L. Branchetti, O. Levrini, P. Fantini, and V. Bagaglini. Kapon's contribution has been included as the discussant at the symposium that was chaired by Levrini and Branchetti.

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SUPPORTING PRE-SERVICE ELEMENTARY TEACHERS TO PLAN MODELING-BASED INVESTIGATIONS

María Esther Téllez-Acosta[1]*, Andrés Acher*[2] *and Scott McDonald*[3]

[1]Martin-Luther-Universität, Halle-Wittenberg, Germany,

[2]Universität Bielefeld, Bielefeld, Germany,

[3]Pennsylvania State University, State College, United States

Learning to plan science lessons to engage young students in modeling-based investigations (MBI) is challenging for pre-service elementary teachers (ePSTs). We designed a set of three teacher education pedagogies grounded in biology-specific work to support ePSTs in planning MBI. The study aims to characterize how ePSTs learn with this support in the context of a science teacher education course. Using professional vision as the theoretical framework, we examined ePSTs highlighting, coding, creating, or using material representations to understand biology core ideas, scientific modeling, and the teaching practice of planning MBI. Findings illustrate two learning characteristics: a) the integration of biology core ideas into explanatory models of biological phenomena, b) the delineation of learning targets for students by deconstructing those models. We discuss these findings, emphasizing how pedagogies grounded in biology-specific work supported the groups' epistemic and pedagogical negotiation of meanings to build shared understandings of planning MBI.

Keywords: Teacher Education Pedagogies, Pre-service Elementary Teachers, Modeling-based Investigations

INTRODUCTION

Learning how to plan science instruction to engage young students in MBI entails three main challenges for ePSTs. These challenges are particularly relevant when they use online videos as resources to deepen their understanding of disciplinary core ideas (Baltaci-Goktalay & Ozdilek, 2010). First, ePSTs need to see these ideas not as isolated entities but linked with how they are generated, for example, through participating in the scientific practice of modeling (Acher et al., 2007; Manz, 2012). Second, ePSTs need to see that for students to participate productively in scientific modeling and learning disciplinary core ideas; it is necessary to structure an investigation where they can develop their explanatory models of phenomena (Campbell, Gray, & Fazio, 2019). Third, it is important they see themselves as professionals, defining their goals as a community and making sense of their experiences (Gunckel, 2013). This implies they can negotiate meanings through discourse to shape and contest understandings of planning MBI (Goodwin, 1994). These challenges suggest it is critical to design supports like teacher education pedagogies that effectively aid ePSTs learning of disciplinary ideas and practices associated with planning (Davis, 2020).

BACKGROUND

Pedagogies designed by teacher educators have been used to support pre-service teachers to engage more directly in teaching, enacting particular components of the practice to learn in, from, and through practice (McDonald, Kazemi, & Kavanagh, 2013; Windschitl, Thompson, Braaten, & Stroupe, 2012). Based on this practice-based view, our stance is towards teacher education pedagogies as supports for ePSTs learning to plan MBI. First, pedagogies are *authentic* approximations for pre-service teachers to enact key teaching practices and to make their own decisions with some professional purpose (Grossman et al., 2009). This authentic character provides pre-service teachers with the opportunity to enact "real" teaching activities and manage specific situations and thus gain the experience they need for future practice (Forzani, 2014). Second, these pedagogies entail a *situated* way of learning. Pre-service teachers' enactment of pedagogies depends on the social situations that they create in a context. Inside this context, pre-service teachers as learners construct meanings and define goals through negotiations (Brown, Collins, & Duguid, 1989). From this perspective, authentic and situated pedagogies have the potential to support ePSTs to collaboratively enact and co-construct their professional understandings of the practice, specifically concerning planning MBI. These pedagogies include the activities ePSTs undertake based on critical components of this practice, so they learn from their own experiences (Grossman, Schneider, & Pupik, 2018).

Teacher Education Pedagogies for planning modeling-based investigations

Planning a modeling-based investigation is a key teaching practice that consists of structuring science lessons to support and maintain students' engagement in investigations of natural phenomena by developing explanatory models. Within designed pedagogies, teacher educators can coordinate particular activities that focus on essential components of planning a MBI to help ePSTs engage in deliberate practice (Grossman et al., 2009). At the earliest stage of planning a MBI, it is important to help ePSTs define a natural phenomenon, so they learn to pose the goals students will achieve throughout the investigation (Campbell et al., 2019). It is also important to help them frame modeling-based questions so they are prepared to guide students to understand what they need to investigate (Passmore, Schwarz, & Mankowski, 2017) and facilitate students' posing questions by themselves when developing models (Manz, 2012). Furthermore, ePSTs need help for establishing a coherent sequence of the activities that looks for students' engagement throughout modeling-based investigations (Schwarz, Passmore, & Reiser, 2017). In addition to supporting ePSTs in these three components of planning a MBI, pedagogies can guide their participation in the modeling practice. This firsthand experience allows them to identify the issues and problems they would face in their future classroom and understand how to address them appropriately.

Discipline-Specific Epistemic Tools

We conceptualize scientific modeling as an epistemic practice that consists of building knowledge as the integration of disciplinary ideas with the process of developing models to explain natural phenomena (Schwarz et al., 2009; Berland & Crucet, 2016; Louca & Zacharia, 2015). In this context, we build upon the work advanced in science education and the use of epistemic tools to support ePSTs' participation in the modeling practice as part of their learning to plan MBI. Epistemic tools are resources that support collaborative knowledge construction while students are engaged in scientific discourses and processes consistent with scientific practices (Ke, Sadler, Zangori, & Friedrichsen, 2020; Kelly & Cunningham, 2019). In this study, we emphasize that discipline-specific epistemic tools have the potential to help ePSTs participate in the modeling practice. With the support of epistemic tools, they can learn to integrate disciplinary core ideas into explanatory models, which serve as a foundation for planning how to engage and support students in this practice. *Transformation Boxes (TBs)* (Acher & Arcà, 2020) is a discipline-specific epistemic tool that guides ePSTs to integrate biology core ideas into explanatory models of biological phenomena. TBs are the "uses" of a simple representational form (See Figure 1) that guide ePSTs to explain biological phenomena by putting biological transformations at the center of the dynamic exchanges of matter, energy, and information between organisms and their environments.

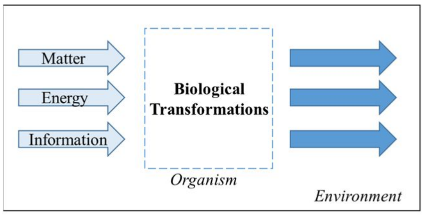

Figure 25. Simple representation of a TB: an organism in a dynamic exchange of matter, energy, and information with its environment. (From Acher & Arcà, 2020).

THEORETICAL FRAMEWORK

We take a sociocultural perspective and consider that learning implies a process that involves negotiation of meanings through discourse. Therefore, we use professional vision (PV) as a framework (Goodwin, 1994) to theoretically and analytically examine ePSTs' discourses around planning a MBI. In particular, we use the three discursive practices of this framework: highlighting, coding, and material representations (MRs). Highlighting refers to making prominent aspects that concern the profession. Coding constitutes ways of making meaning of what is highlighted. Material representations are the external objects that embody an intentional organization of the meanings made. We specifically address the following question: How do ePSTs learn to plan a MBI with the support of teacher education pedagogies grounded in a biology-specific epistemic tool?

METHODS

Context

This qualitative study examines ePSTs learning to plan MBI through designed teacher education pedagogies. Twenty-four ePSTs enrolled in a science teaching education course participated in the study. They worked in groups, and for this manuscript, we selected one group to analyze their discourses in detail to better characterize their learning to plan a MBI. Four ePSTs (under the pseudonyms Anne, Ellen, Hallie, and Kali) constituted the selected group. They worked on the biology core idea concerning the interdependent relationship of organisms in an ecosystem (National Research Council [NRC], 2012, pp.147-148) and the specific phenomenon "how some plums that hang on the same tree and change, while others do not".

Design Study

Table 1 specifies the features of our intervention. Our ePSTs enacted each of the designed pedagogies, working independently during three different sessions. We provided a paper-based object (i.e., a document) with the activities ePSTs had to undertake in each pedagogy, but we did not intervene. These activities in each pedagogy focus on one component of planning a MBI and embedded elements of the biology-specific epistemic tool. Finally, ePST used online videos as content resources. For the selected group, we provided two videos[11] to help ePSTs focus on the main aspects of the biology core idea they were working on in their planning. We expected that ePSTs enacting each pedagogy engage them in discourses. These discourses emerge as the process through which ePSTs negotiate meanings to build understandings regarding their profession.

Table 39. Intervention features.

ePSTs' work	Designed pedagogies	Processes emerging from the supported learning	Professional learning
Engagement in one pedagogy at a time **Use of a paper-based object**	Session 1: Pedagogy for characterizing stability-change features of biological phenomena.	Discourses around: a) defining a phenomenon, b) framing a productive driving question.	Understandings of biology core ideas and scientific modeling.
	Session 2: Pedagogy for constructing an explanatory model via TBs.	Discourses around: a) generating a concrete interpretive form of the phenomenon.	
Focus on a planning component and participation in scientific modeling via TBs **Use of online videos as science content resources**	Session 3: Pedagogy for structuring a coherent modeling-based sequence.	Discourses around: a) establishing a sequence of intermediate questions, b) establishing a sequence of partial models/explanations.	Understandings of structuring and sequencing coherently a MBI.

Data Collection

Since we were interested in the ePSTs discourses, we video recorded the entire time the groups were engaged in each pedagogy and interacting with each paper-based object. We also collected the models as the material representations the group created while they were video recorded.

Data Analysis

We use the discursive practices of professional vision (Goodwin, 1994) as analytical categories: *highlighting* refers to the components identified as relevant for the group about the biology core idea, the modeling practice, or planning the MBI. For example, a group participant uses gestures to point something out, use colored markers, or accentuate specific words while speaking. *Coding* refers to the meaning that they negotiate or construct concerning the relevant aspects highlighted. *Materializing representations* refers to the creation or use of models.

FINDINGS

Two important characteristics emerged from our analysis of ePSTs discourses. First, ePST integrated biology core ideas into their explanatory models of natural phenomena through TBs. Second, ePSTs delineated learning targets for students by deconstructing those models. In order

[11] https://www.youtube.com/watch?v=_Yb3up2Iacs, https://www.youtube.com/watch?v=uagBeKYBBvI

to illustrate these two characteristics, we provide examples of the discourses (Table 2) and a explantory model (Figure 2) that the selected group created and used. We have added some descriptions of our interpretation, from which we have characterized ePSTs negotiation of meanings to shape professional understandings around planning a MBI.

Table 40. Examples of ePST discourses for delineating learning targets in a MBI and integrating aspects of the biology core ideas into explanatory models.

Lines	Discourses	Description
1 2 3 4 5 6 7 8 9 10 11	**Anne:** [While she starts drawing] So in the second model they [maggot and fungus] are still inside [the plum], so this [the second model] is a little bit connected [to the first model]. I draw the fungus right here and the maggot on the other side... (1) The feces (2) and the food (3). Do we also take different kinds of nutrients into account? (…) Okay, just wait. Nutrients in the form of vitamins, we can define them now more precisely. **Ellen:** I think that's not really important. **Hallie:** But they [kids], do not have to know which concrete sugar it is, but that it's sugar.	**Highlighting** a specific aspect for the second model: fungi and maggot benefit with food from plum. **Coding** this aspect as a coherent continuation of the sequence without going into the details. It helps to interpret key changes: how the plum serves as an environment; and how fungi and maggot take nutrients from the plum. **Using the model** to establish the second step of the MBI.
12 13 14 15 16 17 18	**Anne:** Ok, So C1, I had denoted the consumer 1 [maggot (4)]. Are there anything else left? **Hallie:** We only had the feces. **Ellen:** And how about CO_2, because it [maggot] breathes too. **Anne:** If it [maggot] absorbs oxygen, yes [draws and arrow to indicate maggot takes in oxygen and takes out carbon dioxide (5)] **Ellen:** There is a transformation from there… (6)	**Highlighting** maggot as a TB. **Coding and materializing** the transformation in the maggot as it is interacting with its environment and surroundings. Maggot takes in food and O_2 then gives out feces. Association between the transformation of matter (from O_2 to CO_2) and the transformation of energy maggot need to grow and develop.

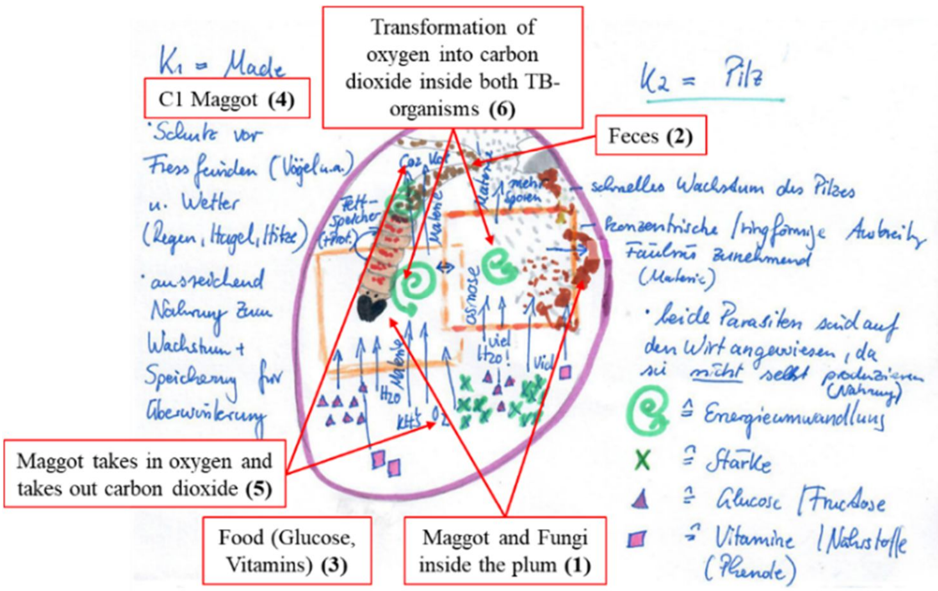

Figure 26. Model the group created and used to: a) delineate a learning target of the MBI; b) explain the second key ongoing transformation in the phenomenon.

During the first part of the discourses (lines 1-10), the group was working on one of the proposed activities for the third session: "*Look at the final model/explanation you reached and re-organize it into 3-4 partial models/explanations. Write short indicative sentences for each partial model that help to communicate the new organization."* By following the prompts related to the epistemic tool that supports this activity, such as: *Are the TBs, the connections/exchanges among TBs, the inputs or outputs of TBs, or the overall flux among TBs telling you how to chunk/re-organize the model?* the group was constructing the partial model on Figure 2. The group used this model to guide their negotiation of meanings to structure this part of the MBI. Anne's comment in lines 2 to 5 highlights that fungi and maggot are inside the plum, where both organisms have food and nutrients. Since she refers to the *"second model"* in her comment, the highlighted aspect corresponds to the learning target in the second step of the MBI. Then, when she says: *"so this* [the second model] *is a little bit connected* [to the first model]*"* she codes this step as keeping a coherent continuation to the first step. Anne leads the group towards a pedagogical purpose: how to structure the steps of the MBI coherently to help students interpret key changes of the phenomenon. In this case, they aim students can interpret changes in the plum, which serves as an environment from which fungi and maggot take nutrients. As the group discussed in lines 6-11, it was not appropriate for the MBI structure to detail the kind of food (e.g., sugars). Hallie's comment: *"But they [kids], do not have to know which concrete sugar it is, but that it's sugar"* reinforces the group's coding to help students interpret with the model the changes happening, rather than help them to learn detailed and disconnected disciplinary aspects. With this negotiation following the provided support, the group advanced in understanding the MBI for their future students as a coherent structure of well-delineated learning targets.

Then, in the second part of the discourses (lines 12-18), as the group went further in the discussion supported by the same prompt above, there was a change in the focus. This time the group focuses on the explanatory potential of the second model under development. In this case, they aim to interpret the plum, maggot, and fungi changes as biological transformations through TBs. They associated the maggot and fungi with TBs because, inside them, biological transformations occur (see the squares in Figure 2). Anne highlights in line 12 the biological role of the maggot as a "consumer" in relation to the plum. When she adds "*Are there anything else left?"* And Hallie replies: *"We only had the feces,"* their coding is for interpreting a biological transformation inside the maggot: the food into feces. Here, they integrated into the explanatory model the biology aspect that organisms grow and develop as they interact with their environment. In this case, the maggot is taking food from its environment, which can be used to maintain life functions.

From lines 15 to 18, the group continued with the interpretation of the maggot biological transformation. When Ellen says: *"And how about* CO_2*, because it [maggot] breathes too"* and Anne adds: *"If it [maggot] absorbs oxygen,"* they highlight the ongoing transformation of oxygen into carbon dioxide (matter). Then with Ellen's comment: "*There is a transformation from there…"* the group's coding was for associating the highlighted aspect with the transformation of the stored energy in the nutrients from plum into useful energy for the maggot. The spirals drawn inside the squares in Figure 2 represent the integration of the biology aspects regarding the relationship between the oxygen and nutrients transformation inside organisms to produce the energy they need. The group's negotiation in this second part of the discourses indicates advances in understanding biology aspects integrated into models used to explain a phenomenon. In this case, understandings around the dependence of the organisms (maggot and fungi) from their environment (plum) to obtain the matter and energy they need to grow and develop.

DISCUSSION

Integrating biology core ideas into explanatory models of biological phenomena and delineating learning targets for students by deconstructing those models was possible for ePST with the support of pedagogies grounded in biology-specific work. The proposed activities in each pedagogy guided ePST to negotiate meanings and advance their professional learning for planning a modeling-based investigation. Gunckel (2013) suggests that it is important to provide ePSTs with opportunities to understand science content as they learn to plan a sequence that engages students in scientific practices. Campbell et al. (2019) and Kenyon et al. (2011) suggest that ePST knowledge of scientific modeling is crucial. We suggest that ePSTs construct shared understandings that integrate biology core ideas when participating in scientific modeling. This co-construction could be supported by discipline-specific epistemic tools like TBs for biology (Acher & Arcà, 2020). The biology-specific epistemic tool of TBs have the potential to guide ePSTs' negotiation of biology and modeling meanings when using content resources like online videos. TBs also supported the negotiation of meanings regarding the delineation of learning targets for students throughout the investigation. The activities and prompts based on TBs guided ePSTs to understand how to structure a MBI for students to interpret key changes in the phenomenon. We argue that disicipline-specific epistemic tools have the potential to support ePSTs in integrating a biology core idea into their explanatory models and open up multiple possibilities to structure the MBI delineating learning targets for students.

Davis (2020) suggests that teacher education pedagogies or authentic approximations of practice support PSTs learning in a way close to the genuine work of classroom teaching. We found that activities focused on components of planning a MBI (e.g., re-organizing a final explanatory model into 3-4 partial models/explanations) supported the group in managing this practice favorably. We advocate for teacher education pedagogies that serve as the foci for PSTs to engage in the teaching work so that they can enact and co-construct meanings in collaboration with others (Forzani, 2014; Wickman, 2012). In such cases, through designed pedagogies that focus on key components of teaching practices, pre-service teachers not only enact these practices but engage in negotiations in authentic ways and for situated purposes.

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SCIENCE TEACHERS TRAINING PROPOSALS FOR THE DEVELOPMENT OF SCIENTIFIC COMPETENCES IN SECONDARY EDUCATION

Luisa López-Banet[1], Gabriel Enrique Ayuso Fernández[1], Marina Marínez-Carmona[1], Francisco Javier Robles Moral[1], María Araceli García Yeguas[2] and Verónica Guilarte[2]

[1]University of Murcia, Murcia, Spain

[2]University of Granada, Granada, Spain

Research focused on learning through scientific practices to develop scientific literacy is increasing. The acquisition of scientific competences enables students to use knowledge to identify problems, acquire new knowledge, explain scientific phenomena, and draw evidence-based conclusions on science-related issues. However, science teaching-learning is still characterized by teacher-centered approaches and absence of innovation, affecting not only teachers but also the curriculum. Therefore, this study aims at analysing a collection of current educational articles on strategies to improve teacher training with the goal to promote scientific inquiry skills in secondary science students. In our work, the current state of educational research on the acquisition of scientific competences in the field of science at secondary education levels has been reviewed. Thus, a systematized bibliographic search on the contributions collected in the Web of Science database has been carried out. There are a total of 154 articles, among them 47 papers have been selected according to inclusion and exclusion criteria. These works address the need for training of secondary science teachers in the teaching of scientific competences. In addition, it provides different approaches to achieve this issue, such as: the nature of science, the use of educational methodologies that promote the active participation of students through the resolution of problematic situations while stimulating critical reasoning and argumentation, or the use of activities that raise social controversies with scientific links, among others. Finally, we consider the need for science teacher training in these aspects that highlight the importance of inquiry as a way of experiencing science in the classroom and developing scientific literacy.

Keywords: Scientific Competences, Secondary School, Teacher Professional Development

INTRODUCTION

Scientific literacy is one of the main aspects that students must acquire and develop during their education to understand natural sciences and be able to use this knowledge as perceptive, critical and sensible citizens (García-Carmona & Acevedo-Díaz, 2018). This literacy should allow students to reflect, reason and establish connections that will enable them to respond to all those situations they may face in their daily lives (Mkimbili & Ødegaard, 2019).

This perspective requires to build strong links between the content taught in class and the problems of the community; that is, between school science and their daily experiences. In this regard, it is usually intended that students understand the cause and effect of the phenomena that surround them, ask questions about complex problems that compromise their future, make predictions and develop their logical part from a scientific point of view to start functional learning through the development of scientific competence (Levrini et al., 2019).

It should be noted that the OECD includes in the term "scientific competence" both the capacity of inquiry in specific contexts and the integration of knowledge. Thus, it is considered the use that individuals make of scientific knowledge to identify problems, acquire new knowledge, explain phenomena and draw conclusions based on evidence (OECD, 2017).

More recently, the Next Generation Scientific Standards (NGSS) are committed to a vision of science teaching and learning that promotes the integration of scientific knowledge, that is, content knowledge, and practices necessary to participate in scientific research (Tekkumru-Kisa et al., 2019). The number of educational investigations and curriculum reforms that include scientific practices are emerging in many countries. Teaching 'scientific practice' is based on learning activities in which students are engaged. It implies the knowledge and skills combination in each practice and the recognition of a broad spectrum of scientific methods rather than a single or particular one (Halawa, Hsu, Zhang, Kuo, & Wu, 2020).

According to the National Reseach Council, NRC (2012), students learn and show proficiency through knowledge-building practices to make scientifically-based decisions. Therefore, learning science is a combination of knowledge and practice that cannot be completely appreciated by students without directly experiencing those scientific practices. Moreover, effective learning promotes students' motivation, being of great importance the use of socio-scientific issue-based teaching materials (Laius, Kask, & Rannikmäe, 2009).

Unfortunately, the situation in the classrooms in many countries is still far from achieving these targets and this perspective of work differs significantly from that usually followed in classes. As a consequence, the inquiry capacities are not developed as they should (Banet, 2010). Secondary teachers do not always include scientific practices in laboratory sessions (Boesdorfer & Livermore, 2018) or align classroom activity structures with the NGSS recommendations (Criswell & Rushton, 2014). Factors, such as lack of time for critical reflection and lack of knowledge about new teaching techniques may lead to teachers' scarcity for innovation. Thus, future teacher training should focus on disciplinary knowledge, socio-historical knowledge (i.e., proper contextualization of knowledge), and finally pedagogical skills.

It is suggested that the most successful method for Science teaching is inquiry-based learning, which is focused on the development of scientific capabilities, content knowledge understanding, knowledge contextualization, scientific literacy and professional Science practice (Busquets, Silva, & Larrosa, 2016). Innovative approaches, such as the Science–Technology–Society or inquiry-based curriculum approaches, have shown benefits not only in science teaching, improving teachers' attitudes towards teaching Science and their quality, but also in student outcomes (Zhang & Campbell, 2012). It is necessary to consider that the motivation to be a science teacher can vary not only from one person to another, but also from the different scientific disciplines (secondary chemistry, secondary biology, secondary physics, and primary science education) of the science teacher (Markic y Eilks, 2008).

Given its importance at an educational, social and personal level, different aspects of teacher training improvement to promote appropriate teaching goals and strategies in secondary education were examined. Hence, the particular question addressed in this research is as follows: What was the trend of science teacher training investigations in the reviewed articles?

Thus, it has been considered convenient 1) to know and analyse the research carried out on the training of teachers in scientific competences when working on some specific contents at the compulsory education levels; 2) to compare the strategies implemented in the training of teachers of science subjects of different disciplines such as biology, chemistry, physics and geology; and 3) to be able to advance on their teaching difficulties and the most appropriate strategies for their acquisition by students. A systematic review to address these issues has been carried out.

DATA COLLECTION METHODOLOGY

The authors of the research were involved in the data collection and analysis, as they are academics in Science Education from two Spanish universities. It was agreed on the following equations for the target article search in the Web of Science database:

Equation 1: TS = ("scientific competence" OR "scientific competencies" OR "scientific practices" OR "scientific competency" OR “learning skills” OR “scientific evidence” OR “PISA” OR “OCDE” OR “scientific literacy”) AND TS=(“inquiry” OR “assessment” OR "evaluation") AND TS=(“science” OR “sciences”)

To this first selection, the expressions "teacher" OR "teachers" were added to focus the search on those who address the participation or training of teachers in their contents:

Equation 2: TS = ("scientific competence" OR "scientific competencies" OR "scientific practices" OR "scientific competency" OR “learning skills” OR “scientific evidence” OR “PISA” OR “OCDE” OR “scientific literacy”) AND TS=(“inquiry” OR “assessment” OR "evaluation") AND TS=(“science” OR “sciences”) AND TS=(“teacher" OR "teachers”)

With the aim of comparing the number of published papers in each discipline, the term “science” was substituted for biology, chemistry, geology and physics. The results obtained by the second equation were filtered in order to include only social science articles and reviews written in Spanish or English. No restriction was applied on the temporality and the databases consulted (Wos, CCC, DIIDW, KJD, MEDLINE, RSCI, SciELO). After screening the title, abstract and keywords, a number of articles / reviews about teacher training based on scientific practices were selected.

RESULTS

The initial search identified a certain number of papers related to scientific literacy/scientific practices/inquiry teaching (table 1).

Table 1. Results of each discipline obtained in the initial search*.

	Science/sciences	Biology	Chemistry	Geology	Physics
Equation 1	4520	1849	561	23	253
Equation 2	668	83	69	3	72

*Accessed on 1 January 2022

After applying the aforementioned selection criteria to the results, articles related to the disciplines teacher training were selected (Table 2).

Table 2. The results of each discipline after including the aforementioned criteria.

	Science/sciences	Biology	Chemistry	Geology	Physics
Selection criteria	465	58	43	3	50

Articles related to the four science disciplines (biology, chemistry, geology and physics) were carefully analyzed by reading the title, abstract, keywords and full content, leaving the final sample showed in table 3.

Table 3. Selection of articles finally analyzed.

	Biology	Chemistry	Geology	Physics
Screening	16	18	1	12

The aforementioned steps are summarize in the figure 1.

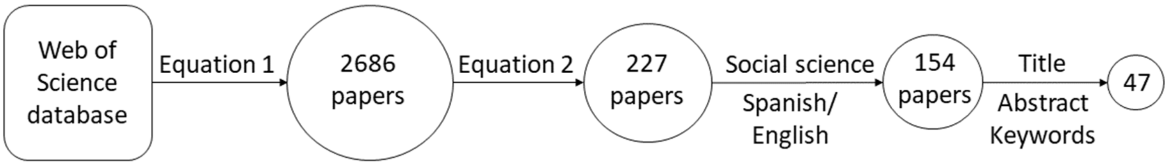

Figure 1. Flowchart through the different phases of the systematized bibliographic search.

The obtained works were published in different journals (Table 4).

Table 4. Summary of the articles based on the discipline and the publication journal.

	Biology	Chemistry	Geology	Physics
AIP Conference Proceedings				2
Asia Pacific Educational Technology Journal	1			
Asia-Pacific Education Researcher		1		
Biological Education Journal	1			
CBE Life Sciences Education	2			
Chemistry Education Research and Practice		3		
Enseñanza de las Ciencias		2		
International Journal of Assessment Tools in Education		1		
International Journal of Science and Mathematics Education		1		
International Journal of Science Education	3	4		
IOP Conf. Series: Journal of Physics				1
Journal of Baltic Science Education				1
Journal of Physics: Conference Series				1
Journal of Research in Science Teaching	1			
Journal of Science Education and Technology		1		
Journal of Science Teacher Education		1		2
Physical Review Physics Education Research				1
Research in Science & Technological Education		1		1

Research in Science Education	2	1		1
Research in Science Technology Education	1			
Revista Brasileira de Ensino de Física				1
Science & Education	2	1		1
Science Education	2		1	
Teacher Education and Training	1			
Tecné, Episteme y Didaxis: TED		1		

The studies came from different contexts since were performed in several countries (Table 5).

Table 5. Categorization of articles by disciplne and country of publication.

	Biology	Chemistry	Geology	Physics
Chile	1			
China		1		
Colombia		1		
Denmark	1			
Estonia		1		
Finland		1		
France				1
Germany	2	2		
Indonesia				3
Israel	1	2		
Korea		1		
Netherlands		2		
Slovakia	1	1		1
Spain		2		1
Thailand	1	1		
Turkey		1		2
United Kingdom	1			
USA	8	2	1	4

Table 5. *Cont.*

In further analysis, the definition of scientific competence used in each proposal, the subject matter, the objectives, the methodology, the instruments and conclusions, the number of participants, the geographical scope of the work and aspects, such as the economic funding received, public or private centers and the level of education at which the teachers work, together with the stage and course of the students that may be involved, were reviewed.

In this work we decided to focus on the approaches proposed to promote the acquisition of scientific competences by secondary school students in biology, chemistry, geology and physics (table 6).

Table 6. Approaches of the analyzed papers and its main features.

		Biology	Chemistry	Geology	Physics
Nature of Science	Influence on science teaching of approaches that take into account the nature of science (NOS) or orientation towards to teaching science (OTS) or the importance of the history of science (HOS)	6	3	1	1
Argumentation and Reasoning Strategies	Influence of strategies that promote reasoning and argumentation (SRA), thinking skills, use of argumentation templates, such as Science Writing Heuristic (SWH), or promote evidence-based reasoning	3	2		3
Problematic situations	Inquiry Based Science Education (IBSE)	1	5		1
	Inquiry-oriented Laboratory		1		

Table 6. *Cont.*

Problematic situations	Problem-Based Learning (PBL)	1	4		4
	Investigation-Relation Experiences (IRE) in which students participated	1	1		1
	Laboratory Activities		1		
Social conflicts of a scientific nature	Activities based on controversial socio-scientific issues (SSI) in the classroom	1			
Other methodological proposals	Literature adapted from scientific or popular articles	1			
	Scientific skills assessment instruments used by students	1			
	Feedback between content knowledge and scientific research	1			1
	Improve attitudes towards science				1
	Analysing activity structures		1		

A considerable part of the contributions to promote the acquisition of scientific competences by students refer to the convenience of teaching approaches that take into account the nature of science in the classroom. On the other hand, it is also noteworthy the number of proposals that refer to the use of problematic situations (research activities, experiments or problems), the approach to controversial situations of social interest, the use of adapted scientific texts or the use of instruments that allow the assessment of the acquisition of research skills.

DISCUSSION AND CONCLUSIONS

A new challenge for teacher professional development should be focused on changing teachers' beliefs to develop scientific literacy. In general, appropriate methodologies for science inquiry should emphasize not only the content knowledge but also procedural skills and understanding in order to promote motivation to learn science (Busquets, Silva, & Larrosa, 2016). In this context, educational research on teacher training in the development of scientific competencies at secondary education levels has been reviewed.

In accordance with our objective 1, the selected articles include objectives focused on several aspects. Regarding the methodology used, scientific practices, inquiry-based learning activities, argumentation, problem-based learning (PBL), reasoning and creative thinking skills, the use of laboratory activities in the classroom or Science – Technology –Society instruction, among others, have been studied. Regarding the teacher competences, several articles have shown interest in analysing the teacher's strategies to guide participants in task-solving process and investigations, their question-asking ability or the teachers' views towards several learning and teaching strategies.

On the other hand, we have been able to establish that, although the interest in the development of scientific competence in students is common to all sciences worldwide, the effort dedicated to training teachers in their acquisition varies depending on the discipline. Thus, for example, of the articles selected, the majority belonged to the fields of chemistry (17) and biology (16), followed by physics (12) and far below geology, for which there was only one article.

With regard to the second of our objectives, there are also clear differences among the methodology used to promote scientific competence depending on the discipline. For example, in disciplines such as biology and geology (which only includes one article according to the selected criteria) the nature of science approach dominates, whereas the resolution of problematic situations is the most mentioned in chemistry or no preferences emerge in physics.

Inquiry experiences in high school science classrooms tend towards experimentation in dicordant methods between the different areas of science. Therefore, in some areas, the use of experimental methodologies is less frequent (for example, geology) and they are often not included in the experiences of inquiry that our students receive (Gray, 2014).

Finally, with regard to our third objective, despite the variety of proposed objectives in the studies analyzed, they coincide in the need that science teachers present to move from direct instruction towards student-centered scientific research and science-technology-society frameworks (Zhang & Campbell, 2012).

According to the main conclusions, there is a need to conduct special professional courses to encourage teachers to change their teacher-centered approach to a more student-centered orientation. Some difficulties were found to transform relevant theoretical knowledge into practical actions. Thus, teachers need training to support students for planning and carrying out investigations, especially in open processes which could benefit more the engaging in argument from evidence. Preservice teachers frequently guide science teaching between direct and guided inquiry and they hold heterogeneous beliefs about science teaching and learning, being Chemistry teaching more traditional than other disciplines. Inquiry- based teaching is effective on the preservice teachers' perceptions about their learning.

It is recommended for teachers to focus not only on content knowledge, but also on procedural and epistemic knowledge as well as on scientific understanding/explanation of phenomena with its proper interpretation. Nevertheless, the frequency of laboratory activities depends on teachers' ideas and monetary and time expenses impact on the specific choice of laboratory activities. Moreover, Teaching Nature of Scientific Inquiry is not a primary goal for teachers, although critical testing, hypothesis and prediction seem to be easily incorporated in the Chemistry classroom. The activity-based instructional framework in line with cultural historic activity theory is highly appreciated and it provides useful guidelines for the transformation of the scientific practices into high-quality context-based curriculum materials.

Regarding the improvements in teacher training, many teachers recognized their progress in developing inquiry, reasoning and creative thinking skills and appreciated real-life modelling scenarios. Moreover, PBL courses could have positive effects on creative thinking ability of preservice teachers and on the use of self-regulated learning strategies. On the other hand, the progressive construction of a Content Representation result to be optimal to help teachers with initial training, such as the development of pedagogical content knowledge (PCK). An Integrated Experiential Learning Curriculum improves teachers' attitudes on teaching science and its quality. Teachers' assessment knowledge was found to be a relenant stage in teachers' professional growth, thus being proposed as an instrument to determine their professional growth.

Teacher training should highlight the importance of inquiry as a way of experiencing science in the classroom and developing scientific literacy. In this respect, the bibliographic review carried out allows us to confirm that the use of teaching proposals based on scientific competences must begin in the first educational stages, bringing science and society closer to students. Studies aimed at proposing how training units and methods can be used to change the beliefs of preservice teachers are necessary, since the beliefs of teachers will determine the approaches used in the classroom (Markic y Eilks, 2008).

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EVALUATION OF A TEACHER EDUCATION PROGRAMME TO CONSTRUCT ARGUMENTS BASED ON ADEQUATE AND SUFFICIENT EVIDENCE

Tomokazu Yamamoto[1] *and Shinichi Kamiyama*[2]

[1]Hyogo University of Teacher Education, Kato, Japan

[1]Osaka University of Health and Sport Sciences, Sennan, Japan

A teacher's ability to construct an argument is said to also be important when introducing an argumentation (Zohar, 2008). Yamamoto and Kamiyama (2020) developed a teacher education programme for teaching argumentation in Japan and reported improvements in teachers' own ability to construct and assess arguments. However, there is currently no programme for increasing the level of argumentation in teacher education yet, despite the need for developing a coherent programme for stepwise instruction. To address this problem, a teacher education programme was developed to construct complex arguments without using experimental results that do not lead to one's own claims (adequacy) and by selecting as evidence all experimental results that lead to one's claims (sufficiency). A programme was conducted for sixteen pre-service teachers of the Japanese national university graduate school of teaching who plan on becoming primary school teachers. The programme was based on the activity by Yamamoto and Kamiyama (2020), and included an activity wherein teachers constructed their own arguments by examining the adequacy and sufficiency of evidence. The results of the pre- and post-programme analysis of the argument construction task showed that although there was no significant improvement in the adequacy of the evidence, about 3/4 of the pre-service teachers scored full marks in both the pre- and post-tests. Furthermore, there was a significant improvement in the sufficiency of the evidence ($p<.05$ $Z=-2.539$). Pre-service teachers were able to construct complex arguments about the post-test evidence by selecting several experimental results as evidence leading to a claim, instead of using the experimental results that did not lead to their own claim. This could be attributed to the effect of the programme activities wherein the pre-service teachers themselves examine the evidence, construct the arguments, and assess the learners' arguments.

Keywords: pre-service teachers, argument construction, stepwise instruction

INTRODUCTION

Argumentation in science is an important process, with one of the scientific literacies in PISA 2015 being 'Interpret data and evidence scientifically: Aanalyse and evaluate data, claims and arguments in a variety of representations and draw appropriate scientific conclusions.' (OECD, 2016: 20). Scientific knowledge is built on the explanations and agreements of scientists. Therefore, it is essential for science to persuade others by using data as evidence and reasoning about why it leads to one's claims, and there are many practices that introduce argumentation into this process (e.g., Iordanou & Constantinou, 2015; McNeill & Krajcik, 2011). In Japan, the course of study emphasises the importance of language activities of the children in accordance with the characteristics of the subjects, and using scientific terms and concepts to think and explain. (Ministry of Education, Culture, Sports, Science and Technology, 2017).

A teacher's ability to construct an argument is said to also be important when introducing an argumentation (Zohar, 2008). Yamamoto and Kamiyama (2020) have developed a teacher education programme for teaching argumentation in Japan, and have reported improvements in teachers' own ability to construct and assess argument. However, it only dealt with the simplest argument, which consisted of the following components: claim, evidence and reasoning. McNeill and Krajcik (2011) reported that there are levels (variations) of argumentation and suggested that they be taught in stages according to one's level of proficiency. They are based on the claim-evidence-reasoning component, with more complex arguments having more than one piece of evidence or reasoning, or a rebuttal. In fact, practical studies on Japanese primary school children have, in turn, raised this level to achieve more complex arguments for children (e.g., Kamiyama et al., 2016). However, there is currently no teacher education preogramme for increasing the level of argumentation yet, despite the need to develop a coherent programme for stepwise instruction.

To address this problem, we developed a teacher education programme to construct complex arguments without using experimental results that do not lead to one's own claims (hereinafter referred to as 'adequacy') and by selecting as evidence all experimental results that lead to one's claims (hereinafter referred to as 'sufficiency').

The research question was as follows;

Was the teacher education programme aimed at the stepwise teaching of the arguments effective in developing the teachers' ability to construct arguments based on adequate and sufficient evidence?

METHOD

Subject

The subjects of this study consisted of sixteen pre-service teachers of the Japanese national university graduate school of teaching who plan on becoming primary school teachers. A 90-minute programme by Zoom was conducted four times from May to June 2020 for a total of 360 minutes.

The programme

Table 1 shows the overview of the programme. The programme is based on activities proposed by Yamamoto and Kamiyama (2020) and includes an activity (Activity 7) wherein the teacher constructs an argument by examining the adequacy and sufficiency of evidence. This activity was based on the theme that water increases in volume when it freezes and that things dissolved in water do not disappear. The pre-service teachers were asked to select two or three pieces of evidence from the several experimental results as adequate and sufficient evidence to support their claims, and to describe their arguments by means of reasoning.

Test and survey

The sixteen pre-service teachers who participated in the programme were asked to complete an argument construction task before and after the programme. The duration of the task was approximately 10 minutes.

Table 1. The overview of the programme.

Time	Activity
1	Introduction
	Activity1: Lecture on the definition and significance of argument.
2	Activity2: Lectures and exercises on the realities of children's argument.
	Activity3: Exercises to give an experiential understanding of the teaching and assessment of argument.
	Activity4: Overview of actual augmentation teaching in primary school classes.
3	Activity5: Planning of teaching with the introduction of the argument.
	Activity6: Exchange and discussion of teaching plans with the introduction of the argument.
4	Activity7: Lectures and exercises on arguing for the adequacy and sufficiency of evidence.

The argument construction task was based on the one in the study by Yamamoto et al. (2013). Table 2 shows the results of the experiments presented and their adequacy. Pre-service teachers were presented with the results of six experiments on plant germination and growth conditions, and were subsequently asked to write an argument to answer the question: 'Is it correct to assume that germination requires water, air, adequate temperature, and also fertiliser from outside?' The answer to the question was the claim, and the scientific principle that 'germination requires water, air, and appropriate temperature' was the reasonig. As for the evidence, the participants were asked to select the experimental results which satisfied 'adequacy' and 'sufficiency' as evidence. Three cases related to the claim (germination condition) and three cases unrelated to the claim (growth condition) were prepared as options. The participants were asked to choose three adequate and sufficient pieces of evidence from the results of these six experiments, and to write their arguments freely.

Table 2. The results of the experiments presented and their adequacy.

Experiment	Experimental results	Adequacy
Germination conditions	Result 1: Green beans A and B germinated with and without fertiliser in the experiment with controlled conditions (table of results is presented).	Adequate
Growth conditions	Result 2: The germinated maize A and B grew more when fertiliser was applied (table of results is presented).	Inadequate
Germination conditions	Result 3: Maize C and D germinated with and without fertilizer in the experiment with controlled conditions (table of results is presented).	Adequate
Growth conditions	Result 4: The germinated beans C and D grew larger when fertilised (table of results is presented).	Inadequate
Germination conditions	Result 5: When the seeds of bean E were cut horizontally and dipped in iodine solution, they were found to contain a lot of starch, but the cotyledons, which had shrunk some time after germination, did not contain any starch.	Adequate
Growth conditions	Result 6: Loofah A has grown a bit bigger, so we replanted it in the field with fertiliser.	Inadequate

Table 3 shows the rubric for scoring the free statements. Participants with correct answers to the question (claim) and the scientific principle (reasoning) were awarded one point for each claim and reasoning. In evidence, as 'adequacy' from each of the six experimental results, one point was deducted from a maximum of three points to be scored according to the number of uses of the three inappropriate pieces of evidence for growth conditions. For 'sufficiency', the number of the three inappropriate pieces of evidence for germination conditions was scored on a 3-point scale. The judgements were made by two independent persons, and the agreement rate was 96.9%.

Table 3. The rubric for scoring the free statements.

Element	Score	Adequacy
Claim	1	There are the following claims.
		Masako is wrong.
	0	There is no claim to the above.
Evidence	3	Not a single piece of inappropriate evidence was used, such as
(Adequacy)		(In result 2), maize A grew more.
		(In result 4), green beans C grew more.
		(In result 6) Loofah A was replanted in a field with fertilizer.
	2	One inadequte piece of evidence has been adopted as described above.
	1	Two inadequte piece of evidence has been adopted as described above.
	0	Three inadequte piece of evidence has been adopted as described above.
Evidence	3	The following three pieces of evidence are all correct.
(sufficiency)		(In result 1), both beans A and beans B germinated.
		(In result 3) both maize C and maize D germinated.
		(In result 5), the seeds of kidney bean E contained a lot of starch, but the cotyledons after germination did not contain any starch.
	2	Two of the above pieces of evidence have been adopted.
	1	One of the above pieces of evidence have been adopted.
	0	Not one of the above evidence has been adopted.
Reasoning	1	The following reasons can be given
		Germination needs only water, air and the right temperature (no fertilizer).
	0	There is no reasoning for the above.

RESULTS

Table 4 presents the distribution of scores for the argument construction task. Based on the McNemar test for claim and reasoning and Wilcoxon's signed rank sum test for evidence, the constructs for which the improvement in the distribution of scores between pre- and post-test were found to be significant and shown in bold. In the case of 'claim', most of the pre-service teachers obtained full marks in both the pre- and the post-tests. Although there was no significant improvement in the adequacy of the evidence, about 3/4 of the pre-service teachers scored full marks in both the pre- and post-tests, and there was also a significant improvement in the sufficiency of the evidence ($p<.05$ $Z=-2.539$). Around half of the pre-service teachers had correct answers for 'reasoning'.

Table 4. The distribution of scores for the argument construction task.

	Pre-test				Post-test				
Score	3	2	1	0	3	2	1	0	
Claim	--	--	13	3	--	--	14	2	
Evidence (Adequacy)	11	1	4	0	12	2	2	0	
Evidence (sufficiency)	**0**	**6**	**2**	**8**	**3**	**9**	**2**	**2**	*
Reasoning	--	--	6	10	--	--	7	9	

DISCUSSION AND CONCLUSIONS

As a result of the analysis of the programme's argument construction task, the pre-service teachers were able to construct complex arguments about the post-test evidence by selecting several experimental results as evidence leading to the claim, instead of using the experimental results that did not lead to their own claim. This could be attributed to the effect of the programme activities wherein the pre-service teachers themselves examine the evidence, construct the arguments, and assess the learners' arguments.

However, although there was a significant improvement in the sufficiency of evidence, only 3 of the 16 pre-service teachers were able to correctly select all the experimental results that led to their claim. In order to strengthen a claim, there should be more awareness regarding the need to select all possible evidence, not just those with more than one piece of evidence to support it. Increasing this awareness in the selection of evidence is necessary to improve the programme.

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IMPACT OF INITIAL TRAINING ON CONCEPTIONS ABOUT "MEASUREMENT" AND "ATTRIBUTE" OF PRE-SERVICE PRIMARY SCHOOL TEACHERS

Clément Maisch[1]

[1] CY Cergy Paris Université, Cergy, France

The teaching of the "attribute" and "measurement" concepts at primary school in France is an interdisciplinary issue shared by mathematics and physics teaching. In a previous study presented at ESERA 2019, we confirmed that at the end of their initial training Pre-Service Teachers (PSTs) related the attribute concept to something vague and the measurement concept to something precise. They generally believed that several values are needed to define a measurement value. They noticed that error sources are necessary to be taken into account to enhance the measurement process and obtain better measurement values. In this second study, we investigate the impact of the initial training these trainees received a test similar to the one use in the previous study. The PSTs' responses are analysed at the beginning of the training in order to compare them with previous results obtained at the end of a similar training. Additionally, a specific pedagogical situation dedicated to the concepts involved in this study has been conceived. We look at the evolution of the understanding of the trainees who have taken this specific session. The results indicate a very small effect of the initial training on the trainees' understanding of the attribute and measurement concepts. Beside the specific situation appears to have only a slight effect on their understanding of data collection.

Keywords: Initial Teacher Education (Pre-service), Measurement, Primary School

ATTRIBUTE[12] AND MEASUREMENT IN LITERATURE

The 14th conference of the ESERA spotlighted the uncertainty of the world and moreover this issue in science education from different perspectives. Yet uncertainty is a main issue of the metrology, which is the dedicated field studying measurement for science and technologies. This concept is defined in a guide establishing rules for evaluating and expressing uncertainty in measurement (JCGM, 2008). Although the access to the concepts of uncertainty and error in a measurement issue needs to fully understand the concept of measurement and thus the one of attribute. The main goal of a measurement is to quantify interactions and relationships between objects and phenomena to build mathermatical models. The International Vocabulary of Meausrement (JCGM, 2012) defines Attribute (Quantity) as "Property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed as a number and a reference" (p.2) and Measurement as a "Process of experimentally obtaining one or more quantity values that can reasonably be attributed to a quantity" (p.16). Teaching those concepts

[12] The concept of "grandeur" in French could be translated in English as quantity, magnitude or attribute. The choice to use the term "attribute" is consistent with many English language standards and with research on mathematics education as described by Passelaigue and Munier (2015).

at primary school should enable pupils to get access and to observe the reality of the world but also to introduce that the validity of those observations are limited.

Literature in mathematics and physics education raises the question of the status of attribute and measurement in primary teaching. Since 2015, French curriculum of mathematics spotlights both concepts. It focuses particularly on the building of the number (MEN, 2015). Brousseau (2002) explains that teaching the attribute concept at primary level is valuable as it is linked to fundamental knowledge of mathematics. Then Chesnais and Munier (2015) set out that the practical concepts of measurement and the uncertainties are often set aside during the teaching of mathematics. Those two notions are mostly linked with the experimental sciences education. They appear in the curriculum at the end of primary school for pupils of ten years old. Chesnais and Munier (2015) explain that a differential treatment of the reality between physics and mathematics still exists at primary school. Yet, teachers at primary school in France are shortlisted by a national competitive exam. Then they become teacher trainees attending a Master 2 in which they spend half time in class and half time at a training centre (INSPE[13]). Majority of them did not have a previous specific science or mathematic education at university before this training. Then we can imagine that the teaching of both concepts could be difficult task to them.

In a previous study, presented in the ESERA 19 conference, we wondered how Pre-Service Teachers (PSTs) of primary school understood attribute and measurement concepts by the end of the training year 2017-2018. We first confirmed previous results obtained by Passelaigue and Munier (2015) that French PSTs have a lack of understanding of those concepts at the end of their initial training. They often described the concept of attribute as “something vague, ill defined, not very precise” (p.332). Trainees also explained that “an attribute is only an approximate quality” (p.332) until it is measured. This interpretation is deviated from the nature of the concepts they would have to teach. Second, we studied the way they reasoned about collecting data linked to a measurement. We obtained that they mostly had ideas of statistical processes (average calculus) and seemed to look for error sources to deal with variations in the data collected. Thus, we wonder if this lack of understanding is due to very strong misconceptions which already exist before the training or if this one changes their way of understanding both of those concepts. Thus, we think it is important to learn more about the effects of the initial training on those concepts by comparing trainees’ understanding at the beginning of the training and its end. In addition, we wonder if a specific teaching linked to experimental sciences situations focusing on both concepts could help trainees to develop their understanding. Thus, we conceived such a training session and we looked which could be its effects on PSTs’ understanding.

METHODOLOGY

Data collection procedure

The training received by PSTs in the INSPE is focused on the teaching aspects of their future job. Most of them had a non-scientific education before their training. Thus, we assume the

[13] Institut National Supérieur du Professorat et de l’Education

group of trainees of the year 2017-2018 and the one involved in this study (year 2019-2020), have similar competences since they pass the same competitive exam before accessing to this initial training. Moreover, we assume the training given in a same site is similar from one year to another. Thus, our methodology deals with two comparisons: A) the comparison of different PSTs' views at the beginning of the training and its end; and B) the comparison of similar PSTs' understanding having a specific training in an experimental sciences education course. This methodology is represented in the figure 1.

Consequently, we use for the comparison A the results obtained with 60 PSTs during the previous study in June 2018 at the end of the training year. We compare them to new results obtained with 89 PSTs (4 groups) at the beginning of the year 2019-2020 (in October and November).

Concerning the comparison B, 61 PSTs (3 groups on 4) of the 89 previous ones attended the specific training situation in the form of a 3 hours course. They dealt first with the place of the concepts of measurement and attribute in curriculum and the definition of specific vocabulary. Later PSTs had to manage two situations of estimation and measurement: the mass determination of a small earth globe with modelling dough sticks and a Roberval scale, and the width determination of the classroom with paper stripes. Finally, PSTs watched a video of an in-practice science session in classroom dealing with the measurement of the temperature of melting ice[14]. This specific training situation targets issues such as : the introduction of specific vocabulary link to "attribute" and "measurement", the concept and the procedure of estimation, the implementation of measuring procedure for several attributes, the data processing, the notion of errors and uncertainties, and the statistical treatment and probabilistic aspects. 3 to 4 months later (March or April, depending the group), a similar questionnaire was filled by 40 PSTs. 34 of them filled the one at beginning of the training year.[15]

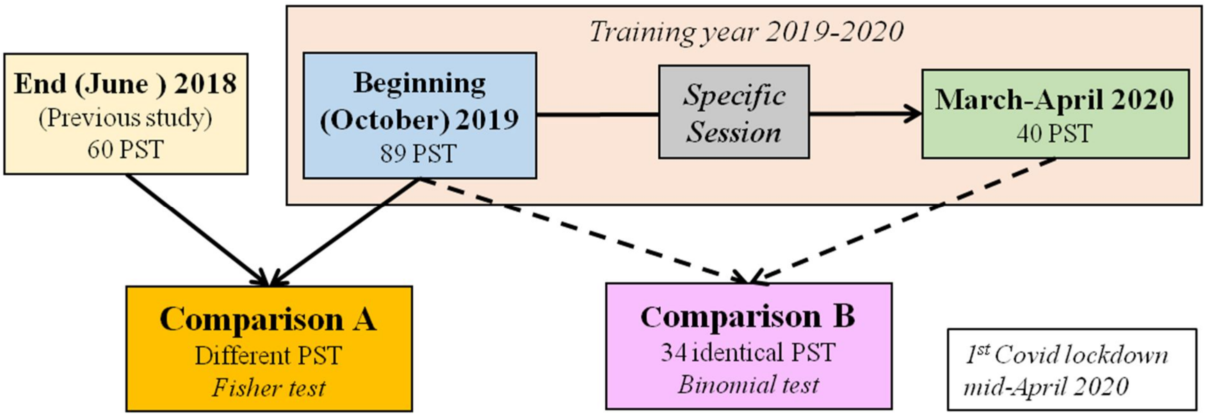

Figure 1. Data collection procedure.

Questionnaire

To assess the understanding of those concepts by the trainees in each of the situations, they complete a similar questionnaire. This questionnaire is based on the one given on the previous

[14] https://www.reseau-canope.fr/bsd/sequence.aspx?bloc=197043

[15] One group (25 PST) filled the questionnaire during a training course, when the 15 others filled it on-line due to the COVID lockdown situation. This explains the weak rate of answers for the last sample.

study (in June 2018, Maisch, 2019). This paper-and-pencil form is composed of two parts based on two surveys. In one hand, we used the test designed by Passelaigue and Munier (2015). Trainees have to define the attribute and the measurement terms and next to make a stand about a list of words referring to those concepts[16]: length, volume, comparison, equivalence, estimation, instrument, gram, decimetre, unit, standard, uncertainty, precision, and number. They also have to provide a justification for each word in order to explain their choice. In the second survey, we passed a three questions test defined by Buffler et al. (2001) to obtain student's idea about the way to think of a data collection. Three fictional characters are discussing about the way to consider the distance covered by a ball dropped from a table (figure 2). Three situations are described: the ball is dropped once, two times, and 5 times. The height of the ball dropped is the same but distances of impacts on the ground change. In the two first situations, each character suggests either to keep the value obtained as a result, or to collect a new value, or to collect several new values. In the last situation, the trainees had to decide which result for the distance they could give. Thus, they could choose one or several values of the list or they could do a calculation. In each situation, the trainees had to justify their choices.

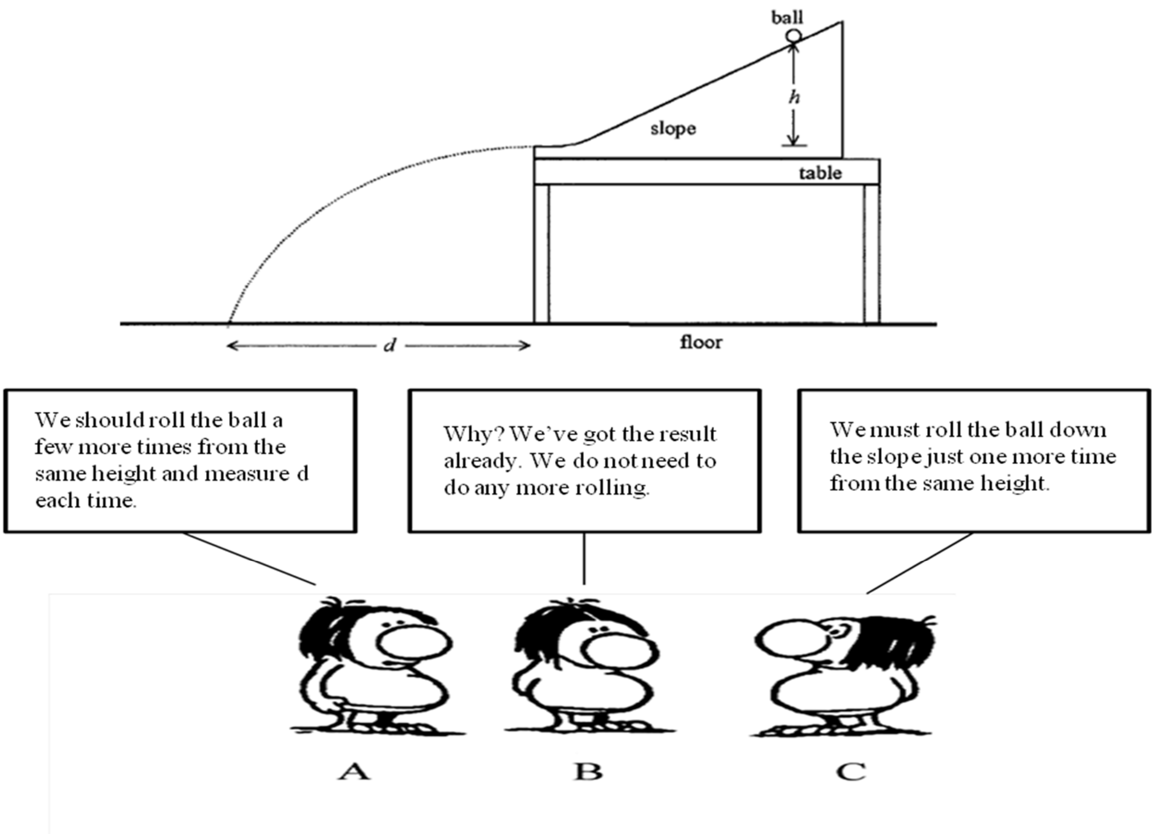

Figure 2. Situation and example of debate (Q1) in the data collecting test (Buffler et al., 2001).

Analysis framework

Regarding the analysis of the questionnaire, we look first at the way PSTs defined both concept following categories obtained in the previous studies (Maisch, 2019). Second, we look at the validity of their ranking linked to the definition they gave. To this end, we use a categorization

[16] They have to choose if each word is more linked to the attribute or to the measurement concept.

under the form of a table defined by Passelaigue and Munier (2015) and implemented with results of our previous study. Regarding the measurement survey with the data collecting part, we classify PSTs' answers in items depending on issues such as the iterations of the data, the variations, the estimation, the errors, the precision, the average, the spread and the uncertainties. Those items are also classified as valid or non-valid regarding to expert definitions obtained in the International Vocabulary of Metrology (JCGM, 2012).

Our first goal is to know if the general training given at INSPE helps PSTs to change their views about the concepts of measurement and attribute and with related concepts. Secondly, we look if a specific training session in a science education context could help them to improve such changes. This means the necessity to compare their results to the questionnaires at different times of the training year. In order to determine the effect of those situations, we use statistical analysis. Regarding the comparison A, we use a Fisher test to compare the answers as PSTs tested are different for each questionnaire. Whereas for the comparison B, PSTs are similar, thus we can use a binomial test to look at possible links between their answers.

RESULTS AND DISCUSSION

Comparison A

In the comparison A situation, we compare the distribution (in percentage) of trainees' answers of the last study obtained at the end of their training to the answers of trainees at the beginning of it. First, we observe in figure 3 and 4 that both sets of PSTs defined "Attribute" and "Measurement" in a similar way without focusing on a valid answer (framed in green in figures). This result is corroborated by statistical results obtain with fisher tests.

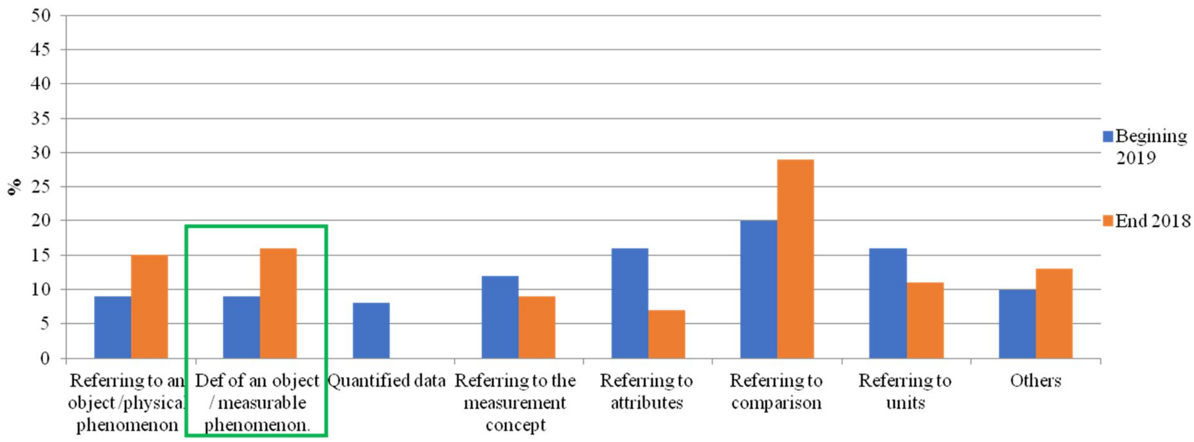

Figure 3. Definition of Attribute beginning 2019-end 2018.

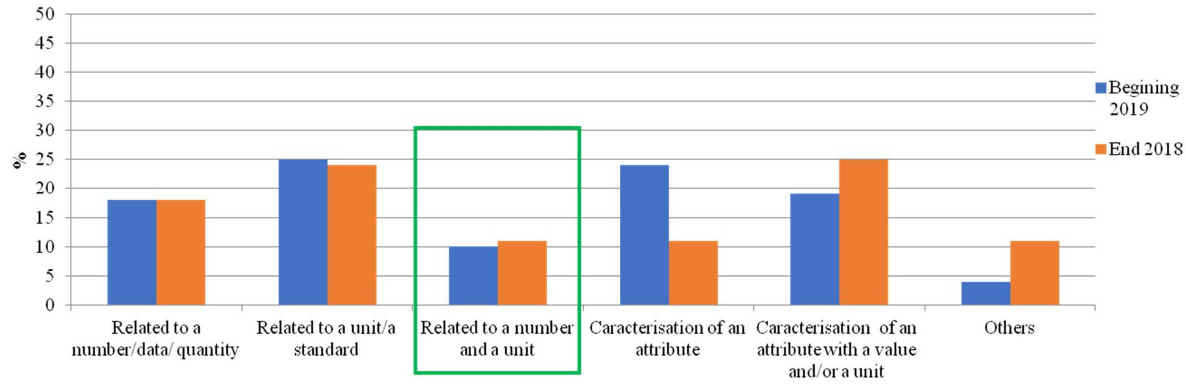

Figure 4. Definition of Measurement beginning 2019-end 2018.

A similar statement can be made on the validity of their classification of the list of words but with slight differences (figure 5). Indeed, Fisher tests show significant differences for the notions of Lentgh (p = 0.0009) and Volume (p = 0,0038) (circled in red in figure 5). Trainees use more unclassified answers (/) at the end of the training than at the begining but do not seem to use more valid answers. But this statement is limited to both notions. Concerning the other notions, the validity of their justifications follows a similar trend in both cases.

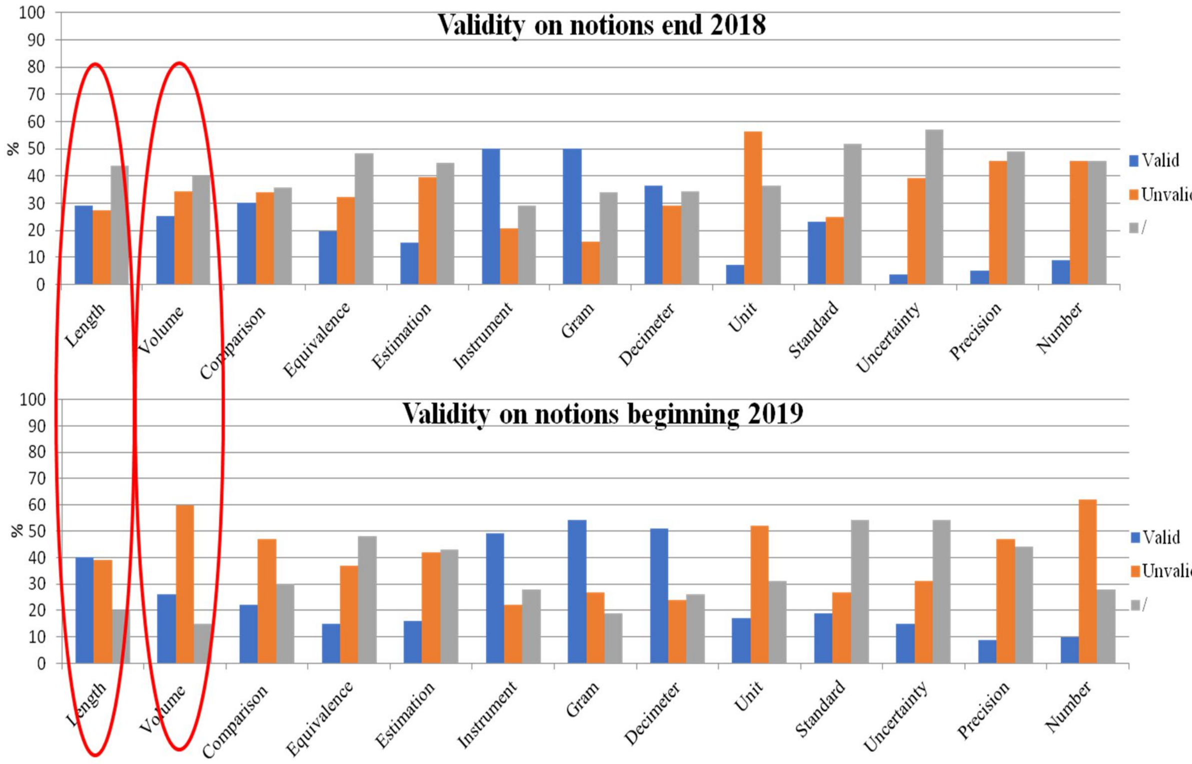

Figure 5. Comparison of validity on notions beginning 2019-end 2018.

Concerning the way to deal with a data set (measurement survey) (figure 6), the trainees used different reasoning to answer to first and second question as showed Fisher test (circled in red, Q1, p = 0,0034; Q2, p = 0,0036). Those results seem to show a change from valid answers to unclassified ones (/). Moreover, PSTs seem to use more valid answers when they have to treat several data.

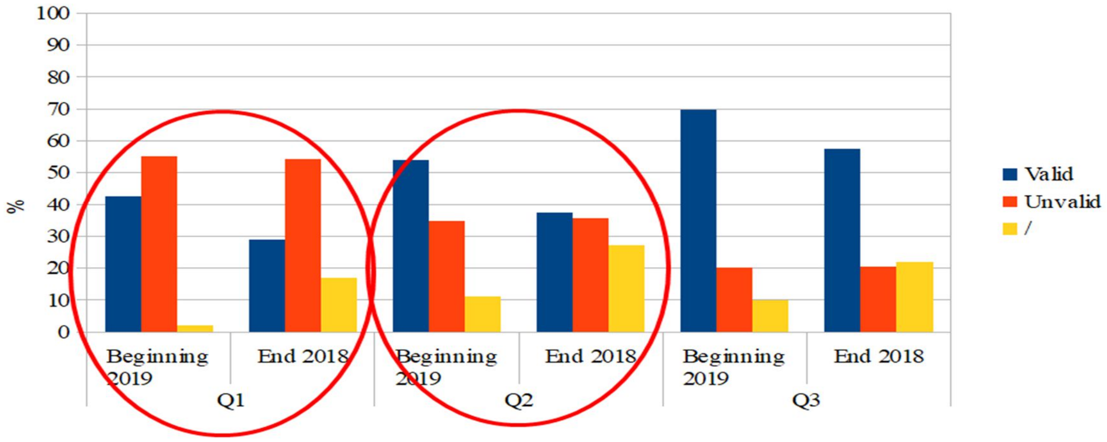

Figure 6. Validity on measurement survey beginning 2019-end 2018.

Comparison B

In comparison B, we search for impacts of the specific session on PSTs' reasoning. Thus, we compare their answers at the beginning of the training year and few months after the specific session. Their ways to define the attribute and measurement concepts (figures 7 and 8) do not show statistical significant differences. But trainees seem to use a better definition of attribute linked to the expert point of view after the specific session.

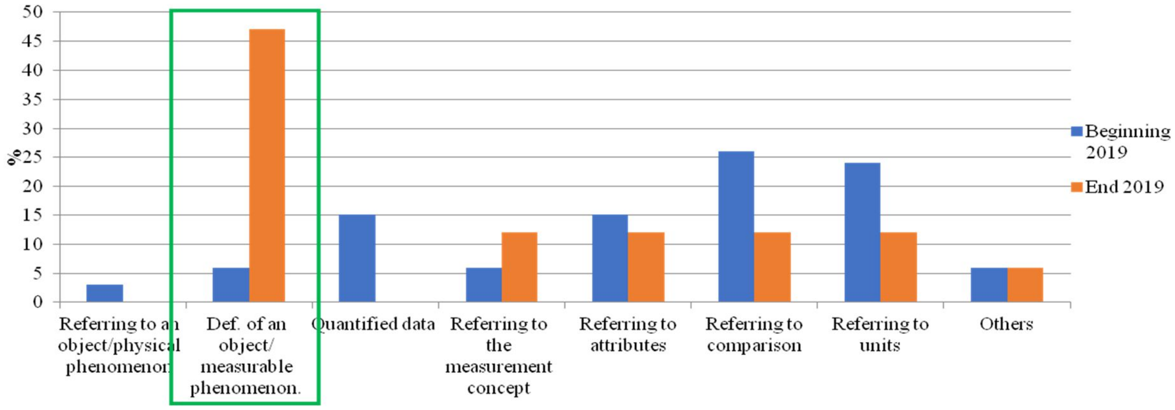

Figure 7. Definition of Attribute beginning 2019-end 2020.

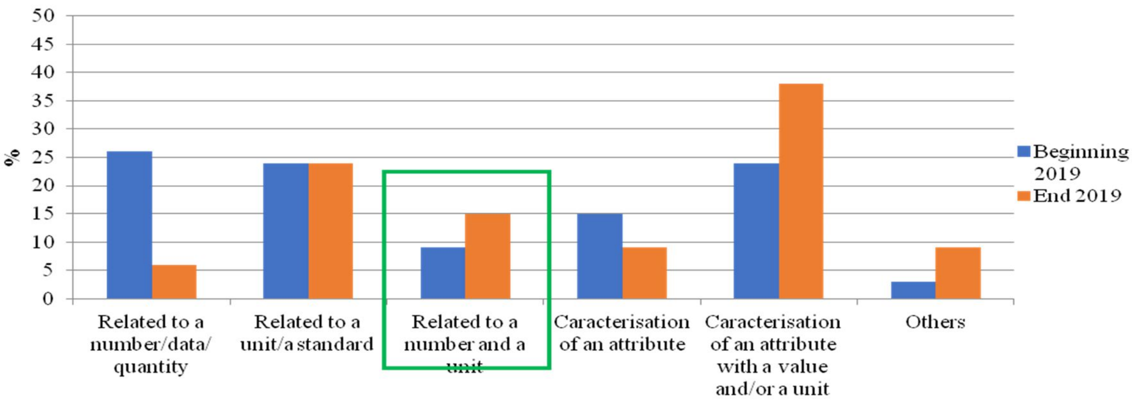

Figure 8. Definition of Measurement beginning 2019-end 2020.

When they have to rank the vocabulary linked to both concepts (figure 9), once again no statistical significant differences appear. We can notice that PSTs seem more inclined giving answers which could be classified after taken the specific course. But those answers seem more recognised as invalid than valid.

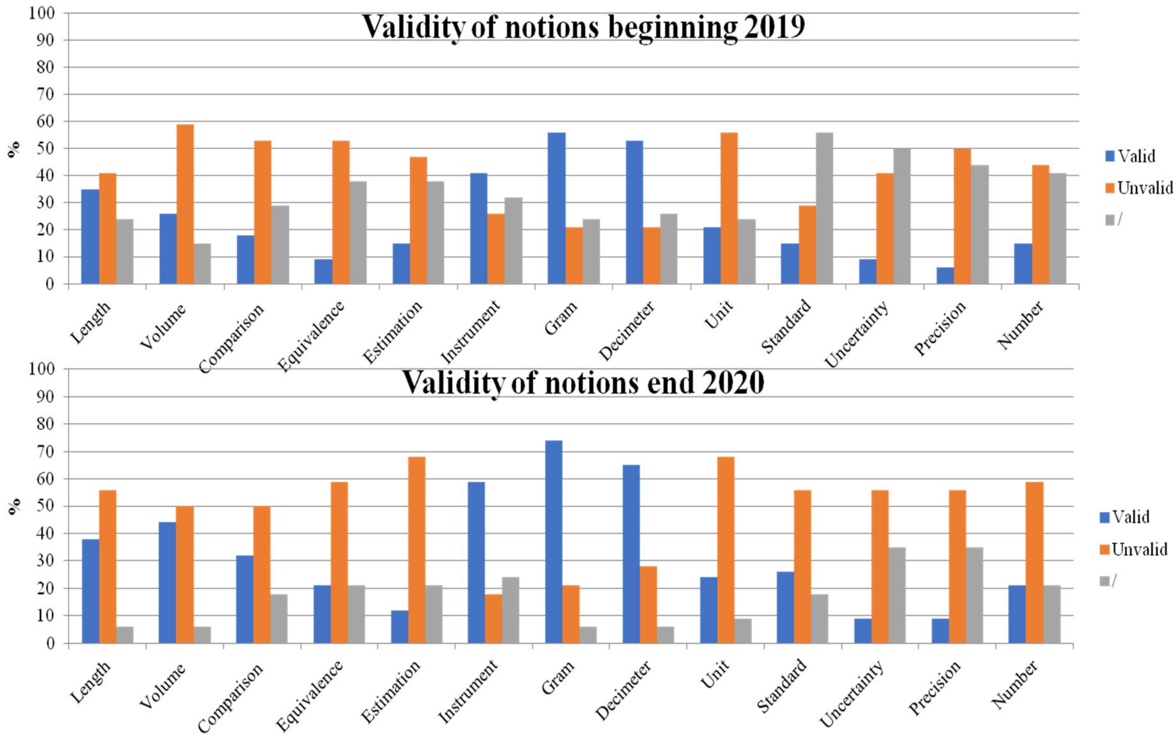

Figure 9. Comparison of validity on notions beginning 2019-end 2020.

Finally, regarding the measurement survey (figure 10), there is a significant difference only on their answers to the first question (circled in red, Q1, p = 0,0001). This result put forward a change from invalid reasoning to valid ones when they answer to this question. For the two other questions, only slight changes seem to occur improving valid reasoning without to be significant.

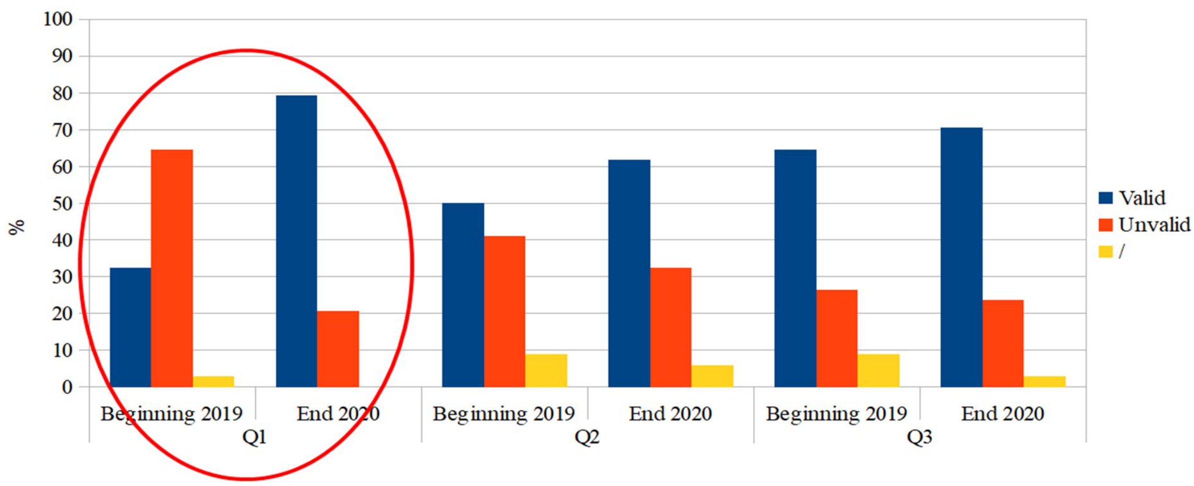

Figure 10. Validity on measurement survey beginning 2019-end 2020.

DISCUSSION

Comparison A

This comparison shows almost no change in the PSTs' understanding of the concepts of attibute and measurement and only a change in their view of the notions of length and volume linked to the concept of attribute. We can suggest those changes are due to specificities of mathematical education training focused on those two attributes with geometrical and units' issues (which could be also linked to the attribute of area, as explained by Clements and Stephan, 2004). The measurement survey shows also changes in their way to reason about collecting data. These changes seems to show more unclassified answers when the number of valid one is reducing. This result does not fit with what we could wait. This means that the INSPE education do not improve their understanding and even seem to obscure its.

Finally, results obtained in the previous study (and fitting with previous results of Passelaigue and Munier, 2015) show a consistency with what trainees think about the measurement and attribute issues before training. This confirms that INSPE training in science and mathematics education is ineffective to help students to better understand both concepts and other issues related to.

Comparison B

We lead a specific session about measurement and attributes concepts in science education training in order to help PSTs to improve their understanding. Results obtained about their understanding of the concepts and notions do not show statistically any significant improvement. However, they seem to shift toward better understanding of the concept of attribute and to use less unclassified definition of the notions. Results obtained on their way to reason about data collecting show a significant improvement when they have to answer to the first question, namely when they have to decide to collect several data. The trend in the following questions seems to be different from results obtained with comparison A. Eventually, we could say the specific session seems to have slight effects and especially on their way to collect data. The low impact of this situation may be explained by its shortness in time. It can be linked to the Brousseau's explanation that the attribute concept is "taught through an early and extended natural and scholar process" (2001, p.2).

CONCLUSION

Finally, it seems relevant to confront the trainees to the concepts of measurement and attribute all along their initial training, and not only with specific sessions. This training has to be an interdisciplinary goal, involving instructors of experimental sciences education and mathematics education. Thus, they have to lead trainees to provide a meaning to the different concepts whether to build the concept of number or for geometry in mathematics education, or to measure physical objects and to deal with errors or uncertainties in experimental science education.

Future analysis of trainees' practices in classroom will provide an understanding of the choices they make in the design and the implementation of teaching situations involving the concepts of measurement and attribute in mathematics and physics.

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DIGITAL MEDIA IN PRE-SERVICE TEACHER EDUCATION – A QUESTION OF IMPLEMENTATION

Lisa Stinken-Rösner[1]

[1]Leuphana University Lüneburg, Lüneburg, Germany

STEM education has, due to its technology-related topics, many potentials for a multifaced use of digital media. Integrating these tools into the classroom requires (pre-service) teachers to develop additional knowledge about the technologies themselves and their purposeful implementation in practice. In contrast to approaches that treat ICT separately, digital media were integrated systematically into the existing study program at the Leuphana University Lüneburg (Germany) by linking fundamental science education topics explicitly with the purposeful application of digital media in practice. The designed course has a (significantly) positive influence on pre-service teachers' behavioural intentions (TPB; Ajzen, 1991) and professional knowledge (TPACK; Koehler et al., 2014). Additionally, content analysis of lesson plans showed that after attending the course, pre-service teachers are able to design multimedia enriched learning situations, which go beyond the mere substitution of 'classical' media (SAMR; Puentedura, 2006).

Keywords: Science Education, Teaching Innovations, ICT Enhanced Teaching and Learning

INTRODUCTION

The digital transformation has proceeded rapidly during the last decades not only in daily life but also in school. Especially science education has due to its technology-related topics many potentials for a multifaceted use of ICT. Digital media are not only tools for teaching and learning but can be used to e.g., avoid dangerous experiments, or to visualize abstract relations – potentials that can be supportive especially in diverse classrooms to allow for participation of all students (Stinken-Rösner & Abels, 2021). In order to prepare preservice teachers to design learning activities and environments, which support individual learning processes with digital media, up-to-date pre-service teacher education programs are necessary which foster pre-service teachers' professional knowledge (in particular TPACK; Koehler et al., 2014), behavioural intentions (according to TPB; Ajzen, 1991), and to illustrate subject-specific usefulness.

METHOD

Following the transformative view of TPACK (Mishra & Koehler, 2006; Angeli & Valanides, 2009; Jang & Chen, 2010; Jin, 2019; Schmid, Brianza & Petko, 2020, Stinken-Rösner, 2021b) digital media were implemented systematically in the pre-service science teacher education program at the Leuphana University Lüneburg by linking fundamental science education topics (e.g. scientific language, Nature of Science, experiments, etc.) explicitly with digital media and its usage opportunities in science education. Accompanying research was carried out to evaluate the impact of the course on pre-service teachers' professional knowledge, behavioural intentions, and their ability to plan learning activities with digital media in science classes.

Course Design

The university course is embedded in the second year of the Bachelor's program and consists of a lecture and a complementary seminar of two hours per week each. Pre-service teachers for primary science and secondary biology and/or chemistry education attend the course.

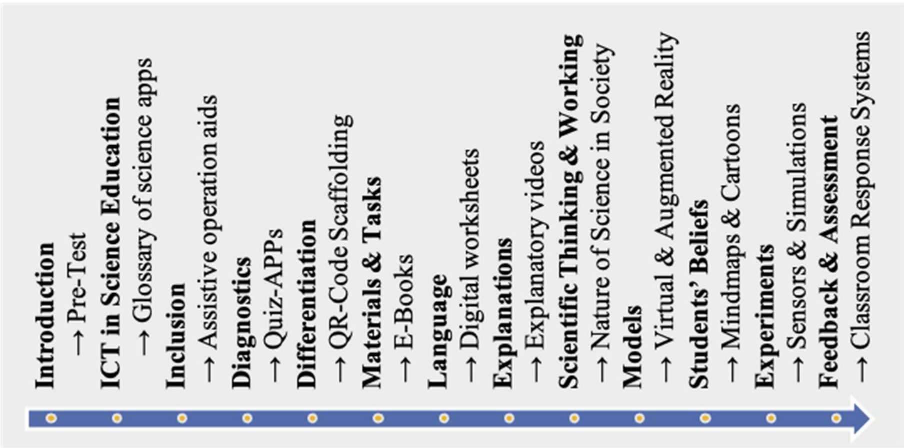

Figure 1. Course design: Each week, a fundamental science education topic is linked explicitly with possible digital media applications.

Each week (altogether 13), a fundamental science education topic is supplemented by implementation possibilities of digital media in class related to the respective topic (see Figure 1).

Research Design and Instruments

The aim of the course is to implement digital media systematically into the science education program at the Leuphana University Lüneburg to increase pre-service teachers' professional knowledge and their behavioural intentions towards the use of digital media in science education at school. This leads to the following questions:

(i) How do pre-service teachers' professional knowledge and their behavioural intentions develop during the course?
(ii) How pronounced are technology exploitations in pre-service teachers' lesson plans in terms of quantity and quality after attending the course?

The accompanying research follows a mixed-methods approach. At two measuring points (pre/post) pre-service teachers' behavioural intentions in terms of attitudes, perceived constraints, self-efficacy, and motivational orientation, as well as their professional knowledge (TPACK and sub-dimensions), are captured on a 5-point Likert scale by self-reports. Therefore, already established test instruments by Chai et al. (2013) and Vogelsang et al. (2019) were adopted. Corresponding scale reliabilities in terms of Cronbach's alpha are acceptable to good ($\alpha > 0.7$) for all scales (Stinken-Rösner, 2021a; 2021b). Further evidence of reliability is given by confirmatory factor analysis (CFA). In CFA results, the model fit indices are acceptable (RMSEA = 0.066) or slightly less than the good fit values (CFI = 0.889, TLI = 0.875) (Stinken-Rösner, in preparation).

Additionally, a (stepwise) linear regression analysis was performed to compare the integrative and transformative views of TPACK (Stinken-Rösner, 2021b). In accordance with previous studies, two of the three hybrids of first-order proved to be positive predictors for TPACK, mainly PCK and TPK (Angeli & Valanides, 2009; Jang & Chen, 2010; Jin, 2019; Schmid et al., 2020). These results strengthen the transformative view of TPACK and thus the chosen course design.

Lesson plans are analysed by qualitative content analysis in terms of quantity and quality of technology exploration (Backfisch et al., 2020). The number and frequency of digital media which are described in the lesson plans as well as the quality of their use based on conceptualizations by Puentedura (2006) were assessed on four hierarchical dimensions: substitution, augmentation, modification, and redefinition (SAMR-Model).

Participants

The sample contains 58 pre-service teachers (9 male and 49 female) who attended the course. 26 (1 male, 25 female) of them participated voluntarily in the questionnaire survey at both measuring points. The participants are on average 21.8 (SD = 2.8) years old, the majority of them has none to little teaching experience. 16 participants study science for primary, eight biology, and three chemistry for secondary education. Note that one participant studies both biology and chemistry. There are no significant differences for any of the scales in relation to the sample characteristics of gender, age, subject, and teaching experience before participating in the course (Stinken-Rösner, 2021a). Lesson plans of all 58 course participants could be analysed.

RESULTS

The results are presented in two parts according to the research questions.

Behavioural Intentions and Professional Knowledge

While the course generally seems to have a positive influence on pre-service teachers' behavioural intentions, significant differences between pre- and post-test only occur in their reported self-efficacy ($t(25) = -4.492$, $p < .001$), as shown in Figure 2.

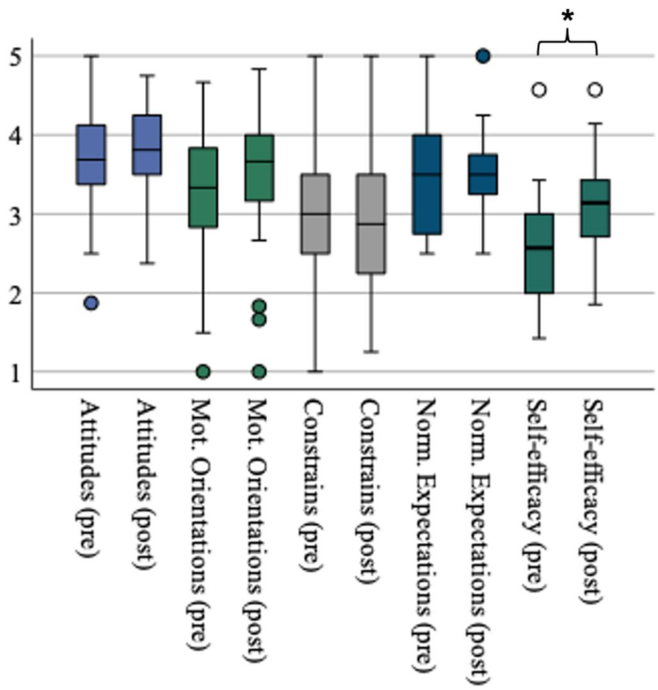

Figure 2. Box-plots of behavioural intentions before and after attending the course. Significant differences are marked with an asterisk.

With regard to pre-service teachers' professional knowledge a (highly) significant increase could be proven for TK ($t(25) = -2.125$, $p = .044$), CK ($t(25) = -2.507$, $p = .019$), PCK ($t(25) = -3.469$, $p = .002$), TCK ($t(25) = -2.416$, $p = .023$), and TPACK ($t(24) = -2.268$, $p = .033$), as shown in Figure 3.

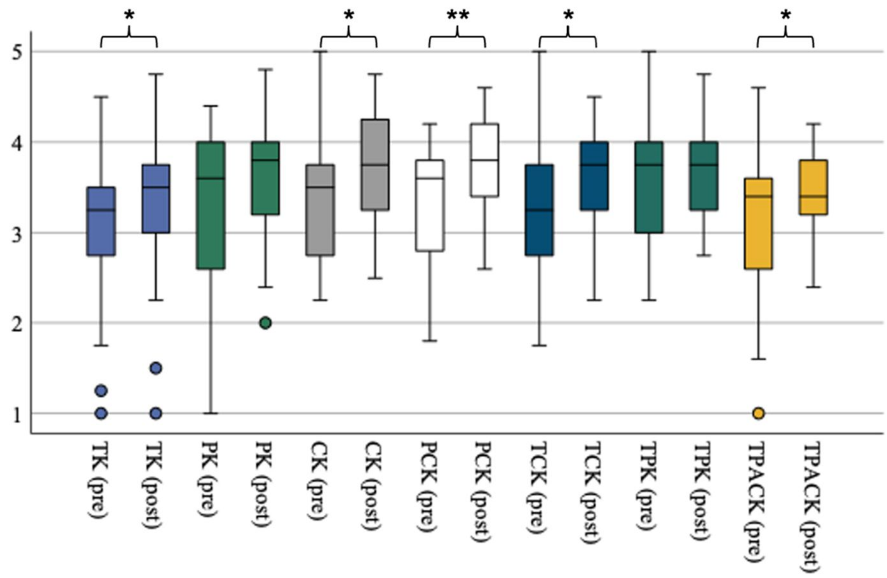

Figure 3. Box-plots of professional knowledge before and after attending the course. Significant differences are marked with an asterisk.

Quantity and Quality of Technology Exploitation

Overall pre-service teachers described the use of 75 different digital media applications in their lesson plans. They mainly included science learning apps, online available explanatory videos, video creation applications, and interactive presentation hardware such as smartboards. The quality of pre-service teachers' technology exploitation ranges from augmentation (45 %) over modification (40 %) to redefinition (13 %) classified according to Puentedura's SAMR-Model (2006). Therefore, digital media are used by pre-service teachers as a direct substitute with functional improvement (augmentation) or to allow for significant task redesign (modification/redefinition).

DISCUSSION

The designed course has a (significantly) positive influence on pre-service teachers' behavioural intentions and professional knowledge regarding the use of digital media in science education. Participants highlighted the practical approach of the course, which combines fundamental science education topics with digital media applications for teaching and learning science. After attending the course, pre-service teachers are able to design first multimedia enriched learning situations that go beyond the mere substitution of 'classical' media, as evident from lesson plans. Whereby ICT is used for functional improvement (augmentation) and/or the redesign of the teaching and learning activities (modification/redefinition). However, the gathered data reflects pre-service teachers' self-perceptions and theoretical lessons, an objective analysis concerning their actions in classroom practice can only be done by lesson observations.

CONCLUSION AND OUTLOOK

The results show that the chosen course design – integration of digital media approaches alongside science education topics – can be assessed as positive in retrospect. Digital media should not be taught additionally, but systematically be integrated into existing study programs. By doing so, pre-service teachers learn how to implement digital media applications purpose-oriented in science education. Thus, the presented course design can serve as a successful example for curriculum designers to redesign courses at their universities in a similar way.

However, the gathered data reflects pre-service teachers' self-perceptions and theoretical lessons, an objective analysis concerning their actions in practice will be investigated in the upcoming semester. Pre-service teachers will design and teach digital media enhanced science lessons in groups of three to four. Related lesson plans are analysed by qualitative content analysis in terms of quantity and quality of technology exploitation (Backfisch et al., 2020). The quality is rated based on conceptualizations by Puentedura (2006) for the level of technology integration (SAMR: Substitution, Augmentation, Modification, Redefinition) and by Chi and Wylie (2014) for the cognitive engagement of students (ICAP: Interactive, Constructive, Active, Passive). In addition, the development of pre-service teachers' behavioural intentions and professional knowledge will be recorded a third time at the end of the upcoming semester. In this way, it is possible to gain a more detailed understanding of the relationship between knowledge on and in action, behavioural intentions, and how their development can be supported by study programmes.

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PRE-SERVICE SCIENCE TEACHERS' BELIEFS ON DIGITAL TECHNOLOGY– BEFORE AND DURING THE COVID-19-PANDEMIC

Julian Küsel[1] *and Silvija Markic*[1]

[1]Ludwigsburg University of Education

The COVID-19-pandemic influenced the digitisation in Higher Education all over the world enormously. The summer semester of 2020 was the first complete digital semester in the history of German Universities. In this transformation process, it is essential to examine students' beliefs regarding digital technologies in higher education for successfully implementing online teaching and learning with digital technology. This study explores pre-service science teachers' beliefs regarding current mostly used digital technologies. On the one side, the research focuses on the pre-service teachers' beliefs about their learning with digital technologies. On the other side, the study investigates the pre-service teachers' beliefs about their future teaching with digital technologies in school. Besides, the interest for further education and suitable formats are evaluated as well. 146 science pre-service teachers used the quantitative Digital Technologies Survey. The study distinguishes between pre-service science teachers from the winter semester 2019/2020 before the COVID-19-pandemic and those from the digital semester of summer 2020. The results show that overall pre-service science teachers' beliefs regarding digital technology in learning and teaching are on a moderate level. However, differences in the evaluation of own learning and future teaching with digital technology were identified. The pre-service science teachers who participated in the digital semester rate digital technology slightly higher than those who participated in the semester before the COVID-19-pandemic. Highly significant differences were seen only in the intensively used technology of the digital semester. Results will be discussed concerning the digital prerequisites of participants and modifications concerning teacher training.

Keywords: ICT Enhanced Teaching and Learning, Higher Education, Technology in Education and Training

THEORETICAL BACKGROUND

Since March 2020, the COVID-19-pandemic has resulted in enormous teaching and learning changes in general and in higher education in particular. With the enforced modifications, most tertiary education in Germany needed to turn to digital in the summer semester of 2020, starting in April 2020. This change was challenging, while before the COVID-19-pandemic, higher education's digitisation has been realised only inadequately and selectively in Germany (Dittler & Kreidl, 2018).

Before the COVID-19-Pandemic, educational policies in Germany demands learning with digital technology in schools and higher education (KMK, 2017, 2019). Thus, teachers and pre-service teachers need to use digital technology in their (future) teaching. In order to do so, teachers are supposed to have general media knowledge and digital literacy in their individual subjects. In addition, they should have competencies in media didactics, media ethics, media education, and media-related school development (e.g., KMK, 2017 for Germany).

To reach a successful implementation of new methods and media, students` and teachers` beliefs need to be taken seriously in the process (Czerniak & Lumpe, 1996). In line with

Bandura (1986), personal beliefs are the best indicator of why a person behaves, acts, and makes decisions in a particular way. Studies argue that teachers' or pre-service teachers' beliefs strongly affect their behaviours in the classroom (Nespor, 1987; Pajares, 1992) and influence their teaching and learning strategies (Markic & Eilks 2012; Hewson & Kerby, 1993; Pajares, 1992). These beliefs consist of various internal variables, are very broad and multidimensional, and influence all interactions between teachers and students in educational contexts (Koballa, Graves, Coleman, & Kemp, 2000; Lent, Brown, & Hackett, 2002). (Pre-service) teachers' beliefs are based on their experience as learners in class (Keys, 2007; Richardson, 2003) and change over time during further education and personal and professional development (Prestridge, 2017). However, studies have shown that teachers' beliefs are relatively constant and cannot be easily changed (Prestridge, 2017). Thus, beliefs are one crucial factor that positively influences teachers' motivation to integrate digital media in their classes (Ertmer & Ottenbreit-Leftwich, 2010). Therefore, it is essential to examine pre-service teachers' beliefs regarding digital technologies in higher education.

RESEARCH QUESTION

In research (e.g., Admiraal et al., 2017; Hatlevik, 2017), studies have been conducted on specific technologies or general beliefs of pre-service teachers, but few have compared the adoption of various digital technologies by pre-service teachers. Noticing this lack, the present study focuses on pre-service teachers' beliefs towards various digital technologies in higher education. A distinction in the evaluation is made between learning during studies and future teaching in class. Second, the interest in further training and suitable formats of courses are evaluated. Thirdly, due to the COVID-19-pandemic, lecturers and students needed to work with digital technology in summer 2020 more intensively and exclusively. Thus, the differences in beliefs of pre-service teachers comparing both semesters were evaluated. In summary, three main research questions are raised for the evaluation:

RQ1 How do pre-service science teachers evaluate digital technology concerning their (a) own learning and (b) future teaching in school?

RQ2 For which digital technologies do pre-service science teachers wish to receive further information and education during their studies? How should this training be structured?

RQ3 Are there any differences in pre-service science teachers` beliefs on digital technology in the digital semester and the semester before COVID-19? If yes, how are these differences characterised?

METHOD AND SAMPLE

For answering the named research questions, the authors adapted the quantitative *Digital Technologies Survey* by Martin, Polly, Shanna, & Wang (2020). The adaptation, analogue to Martin et al. (2020), built on the existing readiness framework (Rollnick, Mason, & Butler, 2010). A framework with three components was created: (i) importance, (ii) helpfulness, and (iii) competence. These components are considered essential in the evaluation of beliefs regarding current digital technologies. It is distinguished between pre-service science teachers' learning in their studies and future teaching with digital technologies. Questions on the desired type of further education on digital technology in science teaching are added. As in the original questionnaire, a 4-point Likert scale on five different categories and in relation to different digital technologies is used. This sums up to 86 items. In the next section, digital technologies and categories are listed and explained.

Digital technologies

Collaboration Tools, Learning Management System, Online Meeting Tools, Online repositories for lesson plans or activities, Social Media, Classroom Response Systems, Supplemental Video, Creation tools, Video creation/editing, Podcasts, Interactive Whiteboard, Instructional Games and Simulation, Adaptive Technology, Mobile Apps.

Categories and questionnaire scales

- *Importance*: Asked about the importance of the above-named digital technologies for participants' own learning and future teaching – not important (1), somewhat important (2), moderately important (3), very important (4).
- *Helpfulness*: Asked about the helpfulness of the above-named digital technologies for participants' own learning and future teaching – not helpful (1), somewhat helpful (2), moderately helpful (3), very helpful (4).
- *Competence*: Asked about the participants' self-assessed competence in learning and teaching with the named digital technologies – not competent (1), somewhat competent (2), moderately competent (3), very competent (4).
- *Interest in receiving training*: Rating of participants' interest in receiving information and training about the named digital technologies – not interested (1), somewhat interested (2), moderately interested (3), very interested (4).
- *Formats of professional development support*: Rating of participants favors regarding various formats of professional development – not desirable (1), somewhat desirable (2), moderately desirable (3), very desirable (4). The questionnaire uses current training formats, like professional development workshops/training, instructional videos, or other documentation (manual), web resources or tutorials, product demonstrations, faculty/peer mentoring, and one-on-one consultation with an instructional technologist.

Altogether, 146 pre-service science teachers completed the quantitative questionnaire. They were aged 19 - 53 ($M = 23.06$). 84.9 % were female, which is typical for the study program of primary science teachers in Germany. The study distinguishes between two groups: (i) 70 pre-service science teachers from the winter semester 2019/2020 before the COVID-19-pandemic (pre-semester) and (ii) 76 pre-service science teachers from the digital summer semester 2020 during the COVID-19-pandemic. Demographics show substantially more attendance at online courses for the second group.

RESULTS

RQ1: Evaluation concerning pre-service teachers' learning and future teaching

Table 1. Results for importance, helpfulness, competence, and interest.

	Importance		Helpfulness		Competence		Interest
	Learning	future Teaching	Learning	future Teaching	Learning	future Teaching	
M	2.49	2.65	2.32	2.63	2.45	2.51	3.02
SD	0.49	0.48	0.46	0.50	0.44	0.50	0.50

Overall, the participants rate digital technology for their learning little to moderately important with a value of $M_{\text{Importance-Learning}} = 2.49$ (see Table 1). The participants rate learning management systems, online repositories for lesson plans or activities, supplementary videos, and collaboration tools as moderately important for their own learning. Video creation/editing, podcasts, and adaptive technology are not very important. For their future teaching, the pre-service science teachers rate digital technology overall also little to moderately important, with a value of $\text{M}_{\text{Importance-Teaching}} = 2.65$. For their future teaching, creation tools (publishing online content, digital storytelling, websites), online repositories, digital games and simulations, supplementary videos were rated important. Social media and podcasts were rated not very important. Thus, the participants evaluate digital technology as slightly more important for their future teaching as for their own learning. Some unique digital technologies (like learning management systems or online-meeting-tools) are rated more important for their learning. In contrast, the rest of the named technologies (like an interactive whiteboard, collaborative tools, or digital games) are rated more important for the own future teaching by all the participants.

Considering the helpfulness of digital media for their own learning and future teaching, the participants rate digital technology for their learning little to moderately helpful with a value of $M_{\text{Helpfulness-Learning}} = 2.32$. Concerning their learning at the university, some similarities to the rating of importance can be seen. Learning management systems, supplemental videos, collaboration tools, and online repositories for lesson plans or activities are at a high level of helpfulness. On the other hand, video creation/editing, podcasts, and adaptive technology were not helpful in their learning. For their future teaching, the pre-service science teachers rate digital technology overall also little to moderately helpful with a value of $M_{\text{Helpfulness-Teaching}} = 2.63$. Here, the participants rated the helpfulness of digital media in their future teaching similarly to the rating in the category importance: creation tools, supplementary videos, online repositories, and instructional games and simulations were rated as moderately helpful in their teaching. Social media and podcasts were rated as less helpful. Thus, the participants evaluate digital technology as slightly more helpful for their future teaching as for their own learning. Some unique digital technology (like learning-management-systems, collaboration tools, and online-meeting-tools) are rated more helpful for own learning.

The category competence shows a different picture. Here, the participants were asked to rate their self-assessed competence in using digital technology for learning and teaching. The self-accessed pre-service science teachers' competence in using digital technology for learning and future teaching is rated little to moderately confident in learning and future teaching with values around 2.50. In contrast to the categories of importance and helpfulness, there are only minor differences in the self-assessed competence in learning and teaching with these media. Students feel moderately competent in using learning management systems, supplementary videos, social media, and collaborative tools. They rate their competence in video creation/editing and adaptive technology between not competent and somewhat competent. For the remaining different media, they feel somewhat competent.

RQ2: Interest and Support

In the category of interest in training, participants were asked to rate their interest in receiving training in the respective digital technology. The results show that the participants are moderately interested in digital technology training with a value of $M_{Interest} = 3.02$. Participants are more than somewhat interested in all digital media with no score below $M_{Interest} = 2.0$. They rate creation tools, instructional games and simulations, and adaptive technology as moderately to very desirable. The other media are also moderately interesting for them, with values around $M_{Interest} = 2.90$. Social media and podcasts were rated as not very interesting.

In the category formats of support, participants were asked to rate preferred training formats in learning digital technologies for learning and teaching. All of the named training formats seem moderately desirable for the participants with an average $M_{Formats} = 3.02$. Continuing professional development workshops or training, instructional videos or other documentation, web resources or tutorials, and product demonstrations were rated the highest. Personal guidance from an instructional technologist was rated lowest.

RQ3: Differences between before and during the Covid-19 pandemic

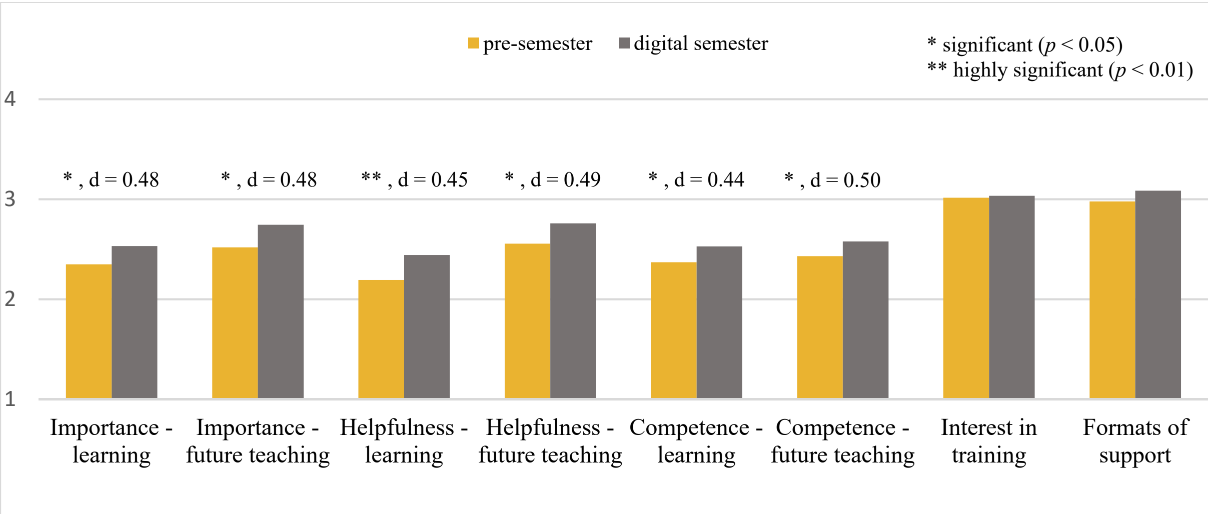

Figure 1. Students' beliefs in the digital semester and the semester before COVID-19.

Overall, the pre-service science teachers participating in the digital semester rated the named technologies in importance, helpfulness, and competence slightly higher than the pre-service science teachers in the semester before the pandemic (see figure 1). This difference is statistically significant with medium effect sizes. Regarding the students' rating of interest in training and support formats, both groups rate these on a similar level.

The scores of the unique digital technologies show that only a few were rated significantly more important and helpful. Interactive whiteboards ($\Delta M_{\text{Importance}} = 0.42$, $p = .008$, $d = 0.44$; $\Delta M_{\text{Helpfulness}} = 0.41$, $p = .008$, $d = 0.25$) and online meeting tools ($\Delta M_{\text{Importance}} = 1.85$, $p < .001$, $d = 1.56$; $\Delta M_{\text{Helpfulness}} = 2.09$, $p < .001$, $d = 1.01$) were significantly more important and helpful for learning in higher education for pre-service teachers in the digital semester. Regarding the pre-service teachers' future teaching, the biggest differences were stated at online-meeting tools ($\Delta M_{\text{Imporance}} = 1.02$, $p < .001$, $d = 0.95$; $\Delta M_{\text{Helpfulness}} = 1.24$, $p < .001$, $d = 1.12$) and learning-management-systems ($\Delta M_{\text{Importance}} = 0.46$, $p = .008$, $d = 0.44$; ($\Delta M_{\text{Helpfulness}} = 0.49$, $p = .003$, $d = 0.49$). Regarding the self-assessed competence to learn and teach with digital technology, pre-service science teachers participating in the study during the first online semester in Sommer 2020 rate significantly higher compared to those of the pre-semester. Again, this is based on a highly significant different evaluation of only one learning technology, the online meeting tools ($\Delta M_{\text{Importance}} = 1.62$, $p < .001$, $d = 1.34$; $\Delta M_{\text{Helpfulness}} = 1.42$, $p < .001$, $d = 1.37$).

Interest in training was rated by both groups similar, but pre-service science teachers from the digital semester rated their interest in online-meeting-tools significantly higher ($\Delta M_{\text{Interest}} = 0.36$, $p < .001$, $d = 0.72$). Regarding the desired formats webinars ($\Delta M_{\text{Formats}} = 0.53$, $p = .001$, $d = 0.54$), online help-desk or support ($\Delta M_{\text{Formats}} = 0.30$, $p < .031$, $d = 0.36$) and product demonstrations ($\Delta M = 0.28$, $p = .05$, $d = 0.32$) were rated significantly more desirable by pre-service science teachers in the digital semester.

DISCUSSION

Based on this study's results, pre-service science teachers' beliefs regarding digital technology in learning and teaching are on an average level. Only a few of the various digital technology was rated on a high level. The slight differences between learning and future teaching evaluation can be explained by the lack of usage of digital technology in higher education until the pandemic but also less till no usage of digital technology in secondary education for the participants. When there is no use of digital technology by lecturers in higher education, the reflection about the importance and helpfulness of these is missing and thus, not seen. Is seems as if the evaluation of participants' learning reflects their education. Nevertheless, they can imagine that some digital technology could be important or helpful in their future teaching. Starting from the innovation in teaching based on digital media, the question should be raised if pre-service teachers in this study, who have traditional beliefs regarding their future teaching (which means limited usage of digital media), would successfully follow the innovation and integrate digital media in their teaching.

There is a significant difference in pre-service teachers' beliefs between pre- and online-semester. Due to the study design, we cannot detect a change in the participants' beliefs. However, demographics show remarkable similarities between both groups. Based on the lack of other reasons and indications, we assume that the detected differences in beliefs can be justified mainly with the digital semester. This influence is supported by the result that the only technologies that the pre-service science teachers used intensively during the digital semester, like learning-management-systems and online-meeting-tools, are rated significantly higher.

Thus, it is inferred that the difference in pre-service teachers' beliefs between pre- and online-semester is based on their digital semester experience.

Further, only selective technologies seem more important and helpful in learning and future teaching for the pre-service teachers. The same applies to their self-assessed competence in learning and teaching with this technology. The beliefs regarding the other technologies do not differ between the two groups. In conclusion, the digital semester influences pre-service teachers' beliefs regarding single digital technology but does not influence their general beliefs regarding learning and teaching with digital technology. This confirms already known research results, that beliefs are relatively constant and cannot be easily changed (Prestridge, 2017), and that long-term learning processes are recommended (Huberman, 1993; Reusser & Tremp, 2008).

Starting from the results of the present study, for the teacher training, this implicates that it could be insufficient to teach only exemplary digital technology and hope that (pre-service) teachers will transform the gained experience to other teaching aspects with digital technology. Therefore, a systematic approach in teacher training could be promising in order to fulfil the demands of the educational policy.

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HOW TO TEACH SCIENCE DIGITALLY!? DIKOLAN – A FRAMEWORK FOR PRE-SERVICE TEACHER EDUCATION

Alexander Finger[1], Lars-Jochen Thoms[2,3], Lena von Kotzebue[4], Monique Meier[5], Johannes Huwer[2,3], Till Bruckermann[6], Erik Kremser[2,7], Sebastian Becker[8] and Christoph Thyssen[9]

[1]Leipzig University, Leipzig, Germany

[2]University of Konstanz, Konstanz, Germany

[3]Thurgau University of Education, Kreuzlingen, Switzerland

[4]University of Salzburg, Salzburg, Austria

[5]University of Heidelberg, Heidelberg, Germany

[6]Leibniz University Hannover, Hannover, Germany

[7]University of Darmstadt, Darmstadt, Germany

[8]University of Cologne, Köln, Germany

[9]University of Kaiserslautern, Kaiserslautern, Germany

Introducing prospective science teachers systematically to subject-specific competencies for the integration of digital elements into future teaching needs a suitable curriculum. According to the analysis presented in this paper, the competency frameworks published so far lack the subject-specificity that is required for successful integration of digital media and technologies into science education. Therefore, by deducing seven central digital competency areas that are compatible with skills needed for planning and running science lessons we developed a framework of digital competencies for teaching in science education (DiKoLAN - Digitale Kompetenzen für das Lehramt der Naturwissenschaften, transl. Digital Competencies for Teaching in Science Education). A detailed description of DiKoLAN and the underlying concepts was published together with presentations of 23 established teaching projects related to DiKoLAN (see https://dikolan.de*). DiKoLAN enables teacher educators to coordinate training objectives according to both cross-curricular and subject-specific learning objectives formulated specifically for science teaching subjects. The sum of all contained competency expectations describes the advisable basic level of competence that all science teachers should have reached at the end of the university training phase. In this paper, we present and discuss our concept of DiKoLAN, as a structured approach to systematically integrate digital media into teacher education. Moreover, as DiKoLAN is structured by using the TPACK model, it is compatible with existing models and therefore integrable into existing course structures.*

Keywords: ICT Enhanced Teaching and Learning, Initial Teacher Education (Pre service), Technology in Education and Training

INTRODUCTION

The COVID-19 pandemic was not the first time that the importance of digital media for the future viability of a society was recognised. As early as the 1990s, industrialised countries began attempting to use digital media in education and to describe the skills needed. These efforts have gained momentum in recent years, leading to the development of numerous corresponding educational frameworks. But so far, none of these frameworks are specific to teaching in science subjects, although research has shown that addressing content-specific teaching with digital media is of major importance for promoting teachers' technology acceptance and the ambition to implement digital tools in teaching (Vogelsang et al., 2019; Mayer & Girwidz, 2019). To tackle this problem, the teacher training (pre- and in-service) must be adapted and restructured to the new challenges due to advancing digitalisation. To successfully implement digital competencies in university teacher education, training needs to be subject-specific. Therefore, subject-specific digital competencies must be identified, formulated, structured, and categorised in a system that is suitable for curricular allocation and coordination. This is a central prerequisite for a consistent integration of these competencies into courses of science education and pedagogy. Hence, a collaboration of nine researchers from Germany, Austria, and Switzerland in the field of science education addresses the following open questions:

1. Which digital competencies are addressed in already published competence frameworks?
2. What digital competencies do science teachers need beyond general pedagogical digital competencies?
3. How can these competencies be defined, structured, and graded in a meaningful way?

METHODS

In order to answer the listed questions, a literature review was conducted first. This resulted in an overview of the current frameworks and standards in teacher education (for more details, see Kotzebue et al., 2021). One of the most influential frameworks in the international arena is the UNESCO's ICT Competency Framework for Teachers (ICT-CFT), which set an international standard at a very early stage in describing the facets of competency required for ICT teaching (UNESCO ICT-CFT, 2011). However, this framework is not so much a specific, formulated set of skills, but rather a guiding principle that helps to design digital educational concepts that are compatible with respective national goals. ICT-CFT was developed for teachers at primary and secondary level and describes desirable ICT teaching activities in consideration of six aspects (ICT, ICT in education, curriculum and assessment, pedagogy, organisation and administration, as well as teacher professional learning) and three levels (technology literacy, knowledge deepening, knowledge creation) (UNESCO ICT-CFT, 2011, p. 3). Numerous national and international frameworks used the ICT-CFT as guidance for the development of their own frameworks, such as the ICT-enhanced Teacher Standards for Africa (ICTeTSA, 2012) or the ICT Competency Framework for Teachers in Guyana (Moore, Butcher & Hoosen, 2016). In addition to the ICT-CFT, there are other frameworks that have a decisive influence on regional and national curricula. Some of these can be seen as precursors of the ICT-CFT, such as the ISTE Standards for Educators in the Anglo-American region (Crompton, 2017), or as influenced by them, such as the European Framework for the Digital Competence of Educators (DigCompEdu, Redecker, 2017). Like the ICT-CFT, they serve a similar basic function in their regions in describing general guidelines and standards for teacher education and addressing skills of teachers themselves. For the European region, DigCompEdu (Redecker, 2017) is one of the most relevant frameworks to strengthen 21st century skills (Trilling & Fadel, 2009) and thereby promote the digital transformation of the European Union.

DigCompEdu describes in five competency areas a total of 18 non-subject-specific competencies as a prerequisite for teachers to open up potentials of digital technologies in teaching-learning processes (Redecker, 2017). The development of pupils' digital competence is covered by a sixth also non-subject-specific competence area which covers a total of five competencies. For DigCompEdu, corresponding self-assessment tools are available in three variants, addressing teachers at school, at university, or in adult education (Ghomi & Redecker, 2019). Based on this structure DigCompEdu influences the development of curricula in many European countries, e.g., national frameworks in Spain (Common Digital Competence Framework for Teachers-CDCFT; INTEF, 2017) and in Norway (Professional Digital Competence Framework for Teachers; Kelentric, Helland & Arstorp, 2017). Due to the broad level of application, DigCompEDU, like other overarching frameworks, focuses more on pedagogical aspects of teachers' professional development in the context of digitalisation (Caena & Redecker, 2019; Redecker, 2017). However, subject-specific competencies that teachers need in order to implement the content requirements of the national curricula and thus to be able to apply the professional added value of digital media are missing. Therefore, the national guidelines for the integration of ICT in education as well as their specification and implementation were also analysed (Kotzebue et al., 2021; Meier et al., 2021). As an example, for this, in Germany *The Standing Conference of the Ministers of Education and Cultural Affairs* published a strategy for education in the digital world (KMK, 2016), which formulates interdisciplinary digital competencies that all pupils have to acquire until the end of compulsory education - *Kompetenzen in der digitalen Welt* (*transl.* Competencies in the Digital World). The summarised guidelines and specifications compilation represents one of the central documents for the digitalisation of schools and teaching in Germany. Competencies in the Digital World comprise a total of six overarching areas of competency pupils are supposed to develop (1. searching, processing and storing, 2. communicating and cooperating, 3. producing and presenting, 4. protecting and acting safely, 5. problem solving and acting, 6. analysing and reflecting) which are divided into 21 areas of competence and are described by a total of 61 competencies. Similar to the specifications of UNESCO and DigCompEDU, no subject-specific competencies are described here, but rather a multidisciplinary canon that pupils need for a sustainable participation in society. It is up to the federal states and ultimately the teachers to integrate these competencies into the curricula or syllabus of the individual school subjects and ultimately to address them with suitable teaching concepts. In addition, there is a lack of information on how these essential competencies for students are acquired by teachers during their pre- or in-service phase, or what they need to be able to teach these competencies. Our review of the literature revealed that none of the existing frameworks address digital competencies that future teachers need, especially for teaching the natural sciences (Kotzebue et al., 2021).

But how can competencies be meaningfully defined, structured, and graded in teacher education? One result of our analysis showed that the TPACK framework (Koehler et al., 2013) is very prominent in teacher education. TPACK describes central knowledge areas that a teacher needs for successful teaching (pedagogical knowledge, PK, content knowledge, CK, and technological knowledge, TK) as well as their intersections (Fig. 1). They form domains that can be assigned to individual components of teacher education and in their connection enable successful teaching.

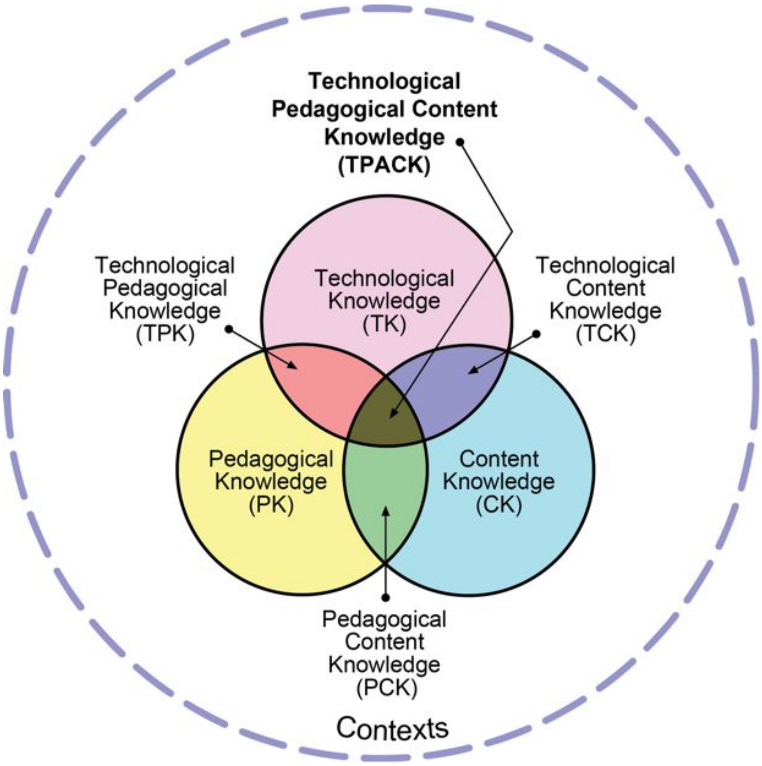

Figure 1. The TPACK framework (http://tpack.org).

Taking the educational perspective of biology, chemistry, and physics into account, it is important to reflect scientific methods used in the respective professional fields. The literature often formulates and delineates general interdisciplinary practises (e.g., search for information, and communication) or subject-specific working methods (e.g., measurement, data acquisition, logging, drawing, modeling and mathematics; Gott et al., 1999). Moreover, to adequately represent the natural sciences, teacher education needs to discuss the use of digital technology as part of scientific practices (Evagorou et al., 2015). Hence, the TPACK model is a compatible approach to also structure digital competencies with reference to manageable fields of activity or application areas of teaching as well as to elements of the science method as a central component (Thyssen et al., 2020). Since the TPACK model is widely accepted in teacher education and covers technological and content knowledge as well as pedagogical knowledge, it is an excellent blueprint for the internal structuring of individual competency areas, even if only TK and the intersections formed with it need to be taken into account for a description of digital competencies. In addition, aspects of digitality were considered according to the DPaCK model (Huwer et al., 2019).

RESULTS

As a result of the literature review as well as the structuring approach of the TPACK model, a working group of nine researchers from nine universities developed a new framework for digital competencies for pre-service teachers in the natural sciences: the structured and graded framework “Digital Competencies for Teaching in Science Education (DiKoLAN)” (Becker et al., 2020; Kotzebue et al., 2021). DiKoLAN describes seven areas of competencies (see Fig. 2).

Figure 2. The DiKoLAN framework (Digital Competencies for Teaching in Science Education) (https://dikolan.de/en/).

Thereby, the structuring of the competency areas follows an overarching structure (Kotzebue et al., 2021). Four competency areas in the upper row in Fig. 2 (*Documentation*, *Presentation*, *Communication/Collaboration*, as well as *Information Search and Evaluation*) are more general and interdisciplinary but still covering subject-specific contexts of teaching the natural sciences and subject-specific content and elements related to scientific research. The three additional subject-specific areas in the lower row (*Data Acquisition*, *Data Processing*, as well as *Simulation and Modelling*) are closely linked to subject-specific ways of working methods in the natural sciences and their didactics (Thyssen et al., 2020).

Professional knowledge included in the individual areas of competency is further differentiated based on the didactic function and the targeted areas of application: Teaching (TPACK), Methods/Digitality (TPK), Content-specific Context (TCK), and Special Tools (TK). Thus, the inner structure of DiKoLAN follows the technology-related competence areas described in the TPACK model (Koehler et al., 2013). Furthermore, DiKoLAN classifies the competency expectations on three levels (*Name*, *Describe*, and *Use/Apply*). In addition, the framework also considers the *Legal Framework* and *Technical Core Competencies*.

DISCUSSION

Relation to Relevant Frameworks Published by Governmental Institutions

DiKoLAN with its overarching structure is based on already existing frameworks and expands them in the sense of subject-specificity for the natural sciences. Figure 3 illustrates the relations between DigCompEdu (Redecker, 2017), the Competencies in the Digital World (KMK, 2016) and DiKoLAN.

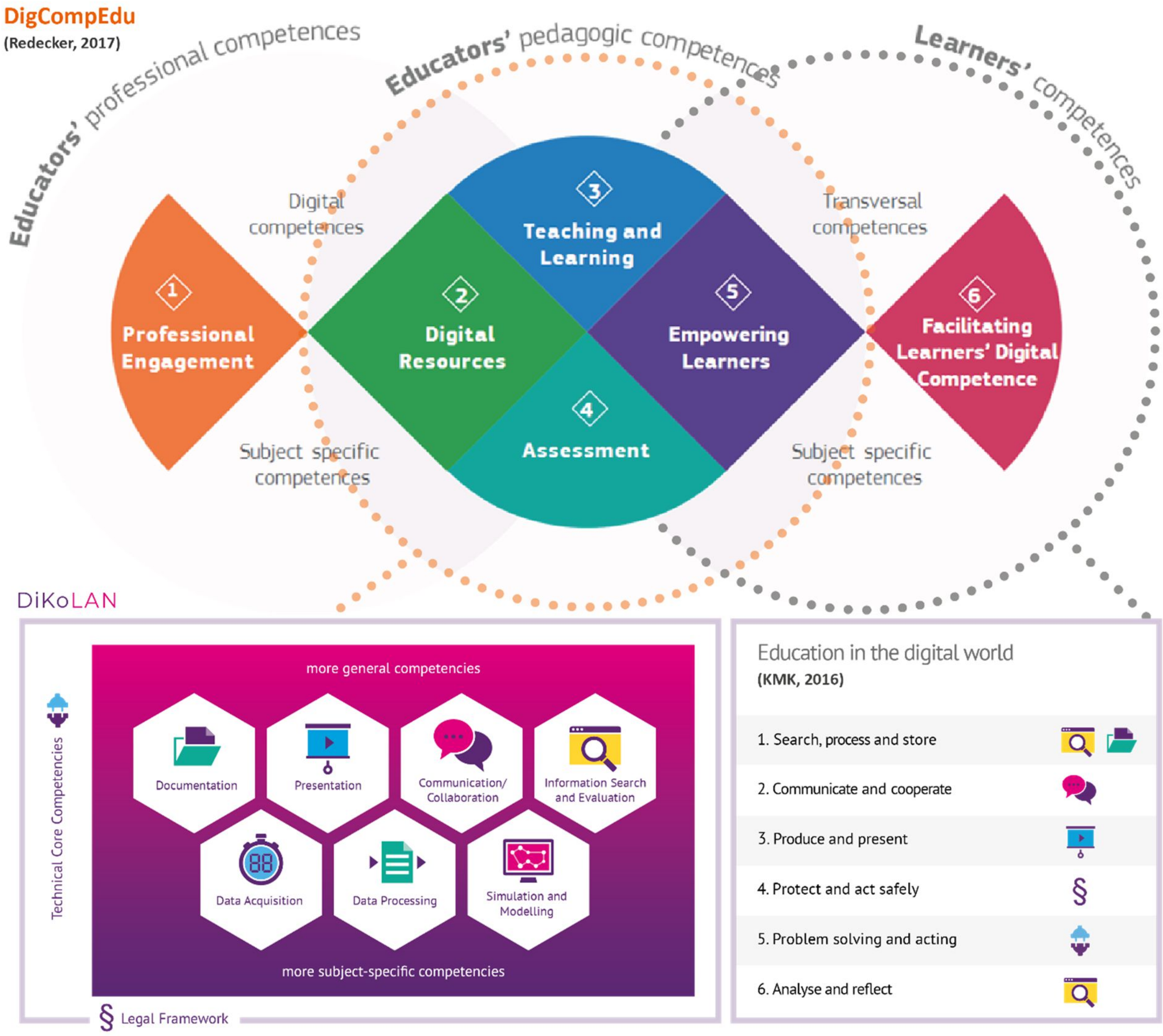

Figure 3. The DiKoLAN framework and its relation to DigCompEdu (Redecker, 2017) and the Strategy "Bildung in der digitalen Welt [Education in the Digital World]" (KMK, 2016) (transl. from Thyssen et al., 2020).

In DigCompEdu, general pedagogical and didactic competencies of teachers are taken into account with the competence areas 1 to 5. Aside from this, DigCompEdu also mentions subject-specific elements but does not further explicate them. Therefore, DiKoLAN specifies essential elements of these competency areas for the natural science subjects. Based on these competencies, the competencies of learners addressed in DigCompEdu area 6 can then be fostered in teaching, according to the Competencies in the Digital World, starting from the corresponding competencies of teachers. In this way, the subject-specific elements mentioned only marginally in DigCompEdu, but not explained in detail are specified by DiKoLAN for science teaching.

Reference to empirical findings

Eickelmann et al. (2017) analysed the use of ICT in school and identified relevant indicators for the use of digital technology in teaching and learning five typical applications: 1. working with word processing programmes, 2. designing presentations, 3. using applications for data collection and processing, 4. working with spreadsheet programmes and 5. working with simulation, experimentation, or modelling programmes. Eickelmann et al. (2017) also mention pedagogically or didactically relevant teaching activities (visualisation, research, and individual support as well as communication and cooperation) as important albeit not subject-specific indicators for teaching and learning with ICT. Figure 4 illustrates which competencies are needed on the part of teachers to support students' learning activities with ICT according to Eickelmann et al. (2017).

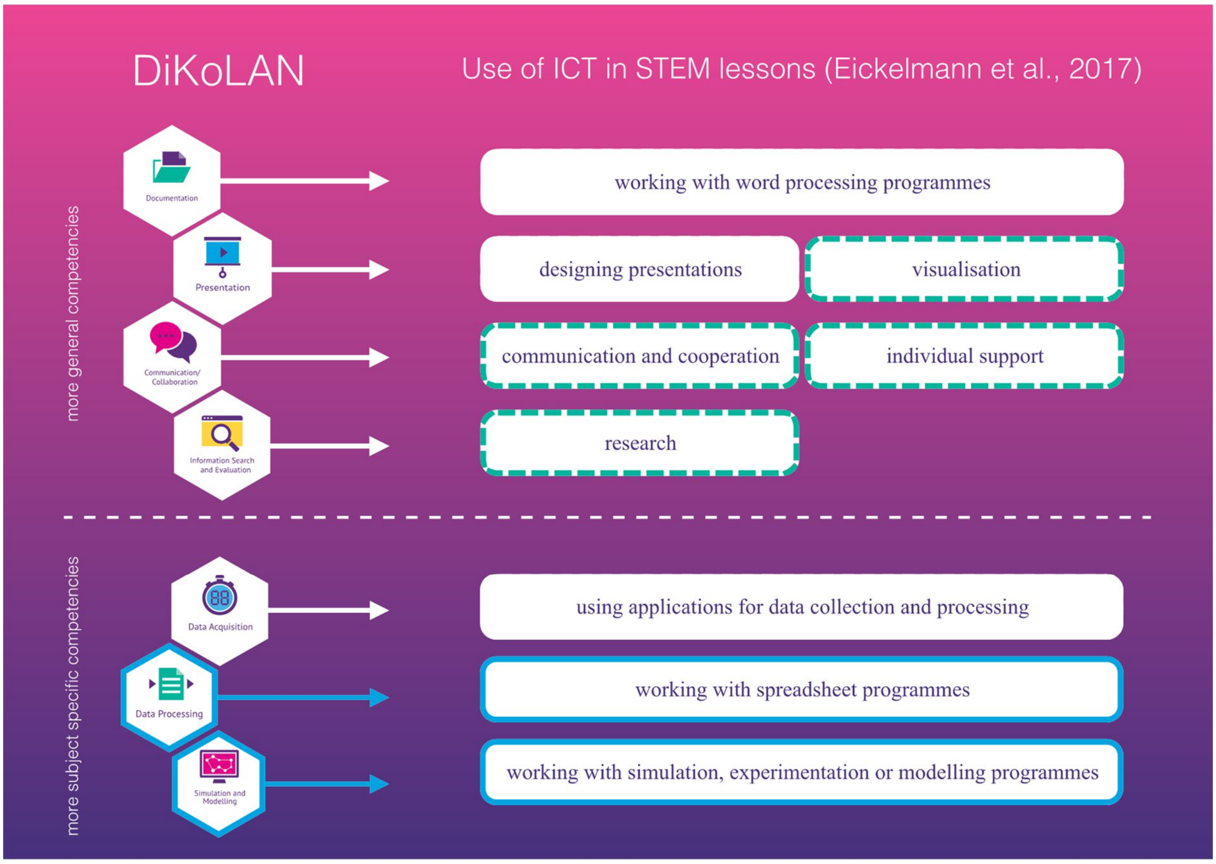

Figure 4. The DiKoLAN competency areas (left side) in assignment with the use of ICT in STEM lessons (right side): typical applications (no outline) and pedagogical functions (dashed outline). For the blue framed applications, a significantly higher use in STEM lessons was found by Eickelmann et al. (2017). Hence, the blue framed competency areas are specific to STEM teaching.

DiKoLAN covers all of the indicators for ICT use in the classroom empirically validated by Eickelmann et al. (2017). In addition, Eickelmann et al. (2017) showed that in STEM lessons compared to other subjects' digital technologies are used significantly more often to process data and students are significantly more often encouraged to use simulation, experimentation and modelling programs. Thus, the meaningfulness of the differentiation of the competency areas into more subject-specific and more general competency areas is also empirically supported. Although there is no significant difference in the frequency of use of data acquisition in the classroom, this does not mean that these competency areas do not require a subject-specific professional knowledge. Since, based on the theoretical derivations already mentioned, firstly, fundamentally different technologies are used generically in the area of data acquisition for teaching in the natural sciences than in other subjects, and secondly, DiKoLAN also pursues the didactic goal of emphasising the special importance of data acquisition in the natural sciences and science teaching, it remains justified to assign data acquisition to the more subject-specific competency areas.

CONCLUSION

The *DiKoLAN* framework provides for the first time a detailed overview of subject-specific digital competencies that prospective natural sciences teachers should acquire at the university level. Planning and implementing lessons, in which digital tools support or even enable the teaching-learning process, involves a variety of competencies. In the development of DiKoLAN, considerations of different frameworks and models have been incorporated (DigCompEDU, TPACK etc.) (Kotzebue et al., 2021). The inner structuring of DiKoLAN according to the TPACK model is coherent to the organisational structure of university teacher education. Hence, DiKoLAN can be used as a support tool in the design of university teacher training courses and for coordinating training objectives, both interdisciplinary and subject-specific, coupled with the development of corresponding curricula (Thoms et al., 2021). Additionally, DiKoLAN proved to be compatible with the interdisciplinary specifications of the *European Framework for the Digital Competence of Educators* (DigCompEdu) as well as the *Competencies in the Digital World* (KMK). However, DiKoLAN is subject to constant change due to the rapid progression in the field of digitalisation. Thus, if necessary, new competency areas can be added to the honeycomb structure as well as new competency expectations can be added within a competency area and existing ones can be changed or deleted. Therefore, the framework is subject to future research and development.

ACKNOWLEGMENTS

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TRANSFORMATION OF PRE-SERVICE SECONDARY SCIENCE TEACHERS' BELIEFS ABOUT GOOD LESSONS AND IDEAS OF PLANNING

Yukinori Utsumi[1]

[1] Gifu University, Gifu, Japan

The concept of pedagogical content knowledge (PCK) is recognized as of great importance. However, there is little consensus on what PCK entails. This study explores the transformation of pre-service science teachers' beliefs about good lessons and lesson planning in Japan. Data were collected using a descriptive survey questionnaire. The findings revealed four main points: First, pre-service science teachers in Japan believe that it is important to explore how teachers can effectively teach science and how they can help their students understand the contents of science lessons. Both pre-service science teachers' beliefs about lessons and lesson planning were strongly affected by the ministry's curriculum guideline. This led to the belief that good lessons are lessons that make students think about their learning contents. Second, the skills needed to teach science are systematically integrated into the most complex community, which shows "the learning of science related to the ministry's curriculum guideline" through classes in the university. Third, the transformation of their beliefs about lessons affects the transformation of the lesson planning process.

Keywords: Initial Teacher Education (Pre service), Pedagogical Content Knowledge, Secondary School

INTRODUCTION

The concept of pedagogical content knowledge (PCK), which was introduced by Shulman (1986), is recognized as one of the most important components of teachers' professional knowledge. PCK has been influential in research on teacher education. However, there is still little consensus on what PCK is (Stender, Brückmann & Neumann, 2017). In the model of teacher professional knowledge and skill (TPK&S), PCK is defined as both a knowledge base used in planning for and the delivery of topic-specific instruction in a very specific classroom context and a skill that is used to facilitate teaching (Gess-Newsome, 2015). Personal PCK is the knowledge of, reasoning behind, and planning for teaching a particular topic in a particular way, for a particular purpose, and to particular students to facilitate enhanced student outcomes (Gess-Newsome, 2015). Teachers' beliefs, motivation, and self-regulation have a moderating effect on the influence of topic-specific professional knowledge (TSPK). Although TSPK influences personal PCK, this influence is amplified or filtered as a teacher develops personal PCK over time (Stender, Brückmann & Neumann, 2017). Teachers' beliefs influence the manner in which they prepare their lesson plans.

RESEARCH OBJECTIVES AND RESEARCH QUESTIONS

This study aims to examine the transformation of pre-service science teachers' beliefs about lessons and preparing lesson plans in Japan. To achieve this, it uses a descriptive survey questionnaire.

The research questions are as follows:

1. What kind of transformation of pre-service secondary science teachers' beliefs about good lessons was recognized after taking classes about lessons planning?
2. What transformation about their ideas on good lesson planning was recognized?

METHODS

This study involved 31 third year pre-service science teachers studying in the Faculty of Education at the same university in Japan. The pre-service teachers took two subjects: 12 classes for Methodology of Science Education Ⅲ and 12 classes for Methodology of Science Education Ⅳ. In both classes, they learned how teachers should prepare lesson plans for secondary science lessons. Descriptive survey questionnaires were administered to the participants through an online survey platform. The questionnaires were administered during the first day of classes in May (pre-description) and during the final day of classes in August (post-description), 2020. The questionnaire had two open-ended questions questions—Q1and Q2. Both the questionnaire and the answers were written in Japanese.

Q1: What do you think makes up a good science lesson is like?

Q2: How can one teach good secondary science lessons?

To answer the research questions, an analysis was conducted using Higuchi's (2004) KH Coder, an open source program for quantitative analysis. This Coder's quantitative text analysis is defined quantitatively, and it involves arranging or analysing text-based datasets using computer applications to understand the quality of the original text material (Higuchi, 2014).

RESULT

Volume of description

Terms that are used in the ministry's curriculum guideline in Japan were regarded as one compound word, such as "perspectives and thoughts," "observation; experiment," "things; phenomenon," and "problem-solving."

Numbers of words in each of the descriptions studied are listed in Table 1.

Table 1. Number of words in each of description.

Number	Beliefs about good lessons		Ideas of good lesson planning	
	pre-description	post-description	pre-description	post-description
word	23209 (9349)	26355 (10601)	28927 (11733)	32357 (13059)
word types	1649 (1337)	1616 (1304)	1899 (1573)	1868 (1531)

Note: Numbers in parentheses indicate the number of words in the analysis.

Word Frequency

Table 2 shows top 30 words of each word frequencies in each of descriptions. The original words are Japanese in descriptions.

Co-occurrence network analysis

Co-occurrence network analysis helps identify the relationships between words in a text. This study used nouns, verbs, and adjectives from the reviews and created a co-occurrence network with highly co-occurring words to facilitate the understanding of a more complete image of the

.

a a

a a

b

b

21	aim (52)	result (56)	setting (68)	prediction (67)
22	think[b] (50)	inquiry (56)	comment (62)	think[b] (66)
23	knowledge (50)	self (55)	important (58)	time (66)
24	problem (48)	discussion (53)	self (55)	self (66)
25	MEXT (48)	observation; experiment (50)	knowledge (54)	comment (63)
26	competency[c] (46)	introduction (49)	important (50)	science lesson (63)
27	self (45)	learning (43)	prediction (50)	important (61)
28	discussion (44)	important (43)	learn (48)	school science (60)
29	competency[d] (44)	express (43)	observation (46)	have (58)

30	learning (43)	proactive (42)	question (46)	interest (53)

destination. Additionally, the network illustrates more important edges using a minimum spanning tree [Higuchi, 2014].

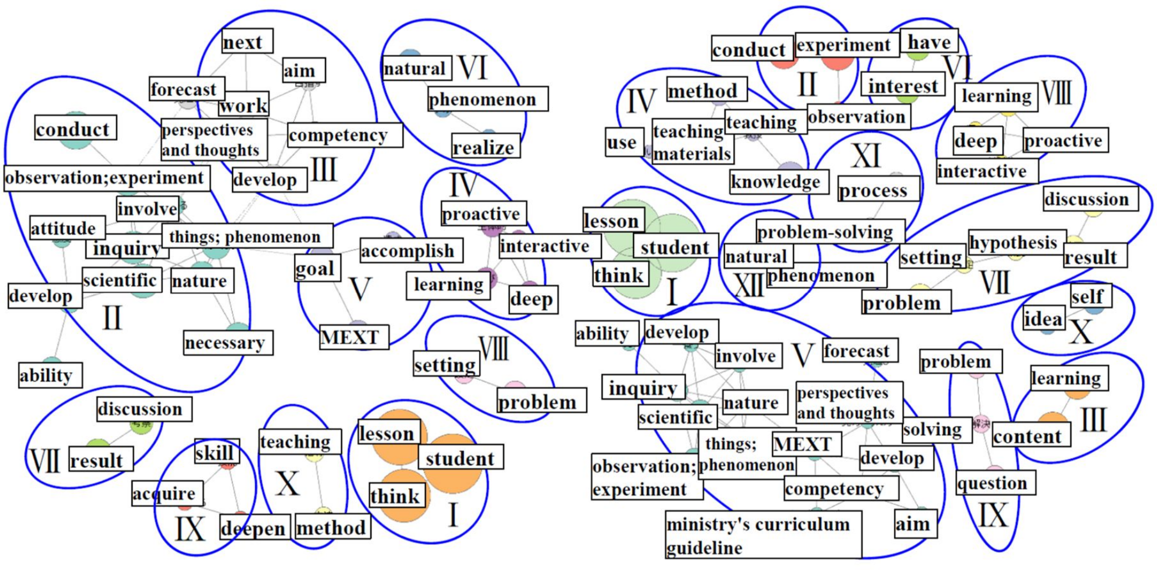
Co-occurrence network analysis of beliefs about good lessons in description

Figure l (a) illustrates the word co-occurrence network in pre-service science teachers' beliefs about good lessons in the pre-descriptions, which consists of 10 communities.

Community (I) shows "how lessons should be," including "student," "lesson," and "think," which are strongly interconnected. For example,

"I think that good lessons trigger student's thinking process (like discussions)" (Student 14).

Community (II), the most complex community, shows "learning of science related to the ministry's curriculum guidelines," such as "scientific," "observation; experiment," and "things; phenomenon." Community (III) shows the main content of the ministry's curriculum guidelines, which takes into account "competency" and "perspectives and thoughts." For example,



(a) pre-descriptions **(b) post-descriptions**

Figure 1. The word co-occurrence network in pre-service science teachers' beliefs about good lessons

Note: MEXT is short for 'the Ministry of Education, Culture, Sports, Science and Technology' in Japan.

"By having a relationship with things and phenomenon in the nature, working perspectives and thoughts, and observing or conducting experiments, students are able to develop competency to enquire about things and phenomenon scientifically (MEXT, 2018)"(Student 1).

Community (Ⅳ) illustrates the "proactive, interactive, and deep learning" required by the ministry's curriculum guidelines. For example,

"Students are required to acquire competency through 'proactive, interactive, and deep learning' activities outlined in the ministry's curriculum guidelines" (Student 16).

Community (Ⅴ) shows "the aim of the ministry's curriculum guidelines." For example,

"The competency to inquiry about things and phenomenon in nature scientifically should be nurtured through students' proactive activity (MEXT, 2018)" (Student 31).

Community (Ⅵ) illustrates "the recognition of natural events," including "nature," "events," and "recognize." Community (Ⅶ) highlights "the results and discussion," while community (Ⅷ) shows "problem and setting." Out of these three communities (i.e., communities (Ⅵ), (Ⅶ), and (Ⅷ)), "the processes of learning, such as recognition of things and phenomenon in nature, setting of problem, setting of hypotheses, verification planning, conducting of the observation and experiment, handling of results, discussion and reasoning, and expression and communication are presented" (Student 12).

Community (Ⅸ) shows "getting the skills" such as "get" and "skill." For example,

"Regular lessons in which students are interested need to be developed to facilitate the understanding of things and phenomenon in nature and to acquire skills of the observation and experiment" (Student 25).

Community (Ⅹ) shows "the teaching methods." For example,

"Teachers are required to understand the contents of units and determine which teaching method is best suited for specific units" (Student 4).

Figure 1 (b) shows the word co-occurrence network in pre-service science teachers' beliefs about good lessons in the post-descriptions, which consist of 12 communities.

Community (Ⅰ) shows "how lessons should be," including "student," "lesson," and "think," which are interconnected. For example,

"If teachers are already aware of what their students know and what they don't know, they should not create lessons that allow students to make their own conclusions" (Student 5).

Community (Ⅱ) shows "the experiment and observation." For example,

"The skills to enquire scientifically include being able to analyse and discuss the results and draw a conclusion by carrying out activities such as making observations and conducting experiment with an aim of achieving particular objectives" (Student 20).

Community (Ⅲ) shows "the learning contents." For example,

"Good science lessons are ones that allow students to easily understand the contents of lessons in which they are interceded in and with which they can relate other events" (Student 3).

Community (Ⅳ) shows "the knowledge of teaching," including "teaching," "resources," and "methods." For example,

"The three sets of mixed teacher knowledge are 'teacher knowledge concerning subject matter', 'teacher knowledge concerning pedagogy', and 'teacher knowledge concerning students'" (Student 4).

Community (Ⅴ) shows "proactive, interactive, and deep learning," which is a prerequisite provided for by the ministry's curriculum guidelines. For example,

"Students are required to acquire competency through 'proactive, interactive, and deep learning' activities, as outlined in the ministry's curriculum guidelines" (Student 16).

Community (Ⅵ) shows "the interest." For example,

"I think that ideal lessons are the ones that draw students' interest to the contents of the lessons, with questions emerging naturally and, in addition to that, students can take lessons proactively with a perspective that they can answer the questions" (Student 7).

Community (Ⅶ) shows "the process of problem-solving," which includes the "problem," "hypothesis," "results," and "discussion." For example,

"The process of inquiry means 'setting of the problem', 'hypothesis', 'observation and experiment', 'result', and 'discussion.'" (Student 8).

Community (Ⅷ) shows "proactive, interactive, and deep learning," which are a prerequisite of the ministry's curriculum guidelines. For example,

"Students are required to acquire competency through 'proactive, interactive, and deep learning' in the ministry's curriculum guidelines" (Student 16).

Community (Ⅸ) illustrates "problem-solving," which includes "question," "problem," and "solving." For example,

"Science lessons are developed along the process of problem-solving; i.e., recognition of things and phenomenon in nature, setting of problem, setting of hypotheses, verification planning, conducting of the observation and experiment, handling of results, discussion and reasoning, and expression and communication (MEXT, 2018). Teachers are required to guide students to solve problems adaptively by following this process" (Student 12).

Community (Ⅹ) shows "lessons that allow students to think." For example,

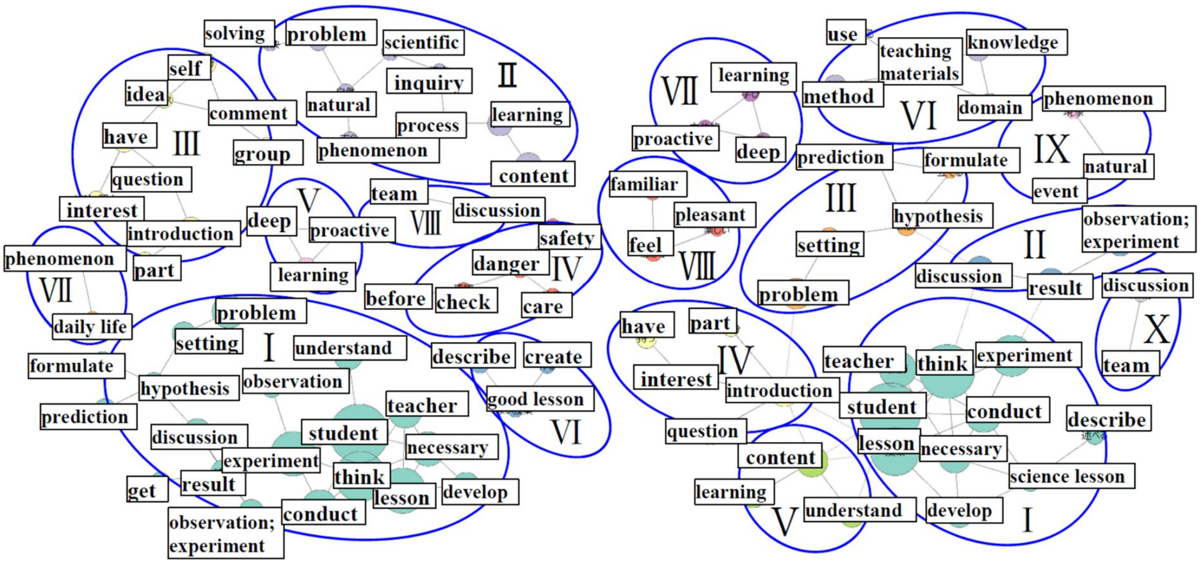
"I think that good lessons are ones that allow students to air out their opinions and deepen their knowledge through discussions with their peers" (Student 20).

Community (Ⅺ) shows another "process of problem-solving." Community (Ⅻ) shows "the phenomenon in nature." For example, for these two communities, "Science lessons are developed along the process of problem-solving; i.e., recognition of things and phenomenon in nature, setting of a problem, setting of hypotheses, verification planning, conducting observations and experiments, handling the results, engaging in discussions and reasoning activities, and allowing expression and communication (MEXT, 2018)" (Student 4).

Co-occurrence network analysis of ideas of good lessons planning in descriptions

Figure2 (a) illustrates the word co-occurrence network in pre-service science teachers' ideas of good lesson planning in pre-descriptions, which consist of eight communities.

Community (Ⅰ), the most complex community, shows "how lessons should be," including "student," "lesson," and "think," which are interconnected and associated with the process of



(a) pre-descriptions **(b) post-descriptions**

Figure2 . The word co-occurrence network in pre-service science teachers' ideas of good lessons

problem-solving, such as "problem," "hypothesis," "results," and "discussion." For example,

"Students can understand the contents of lessons and discuss and think about the experiment methods they can employ" (Student 21).

Further, "students can collect the results, discuss them, talk about them, and compare their opinions (Student 31).

Community (Ⅱ) shows "the learning content of science lessons" such as "content," "learning," "inquiry," "nature," and "science." For example,

"It is important for students to think about things related to real problems in society as this deepens their understanding about nature and sharpens their scientific inquiry skills" (Student 25).

Community (Ⅲ) shows "the track of science lessons," which includes "introduction," "questions," "ideas," and "comments." For example,

"In the introduction, teachers draw students' interest to certain things by asking questions related to familiar parts of the objects in question" (Student 16).

Community (Ⅳ) shows "the safety in experiment," which includes "safety," "danger," and "beware." For example,

"Teachers should check what is dangerous, conduct experiments to facilitate preparation, describe the impeding danger, and conduct exercises to promote consciousness and ensure safety in a lesson plan" (Student 26).

Community (Ⅴ) illustrates the "proactive, interactive, and deep learning" required by the ministry's curriculum guidelines. For example,

"Students are required to achieve 'proactive, interactive, and deep learning' to develop their competency in relation to the contents of a unit and time to teach in the ministry's curriculum guideline (MEXT, 2018)" (Student 6).

Community (Ⅵ) shows "the good lessons." For example,

"It is important that a teacher devises way of teaching and creating good lessons" (Student 19).

Community (Ⅶ) shows "the phenomenon in daily life." For example,

"Teachers should clarify a domain using lessons that are related to the kind of phenomenon that students interact with in their daily lives" (Student 1).

Community (Ⅷ) shows "group discussions." For example,

"It is good that students interact with members of their group and share their views on the most appropriate answer to a specific question" (Student 31).

Figure 2 (b) shows the word co-occurrence network in pre-service science teachers' ideas of good lesson planning in the post-descriptions that consist unities.

Community (Ⅰ), the most complex community, shows "how lessons should be," and it includes "students," "think," "lessons," "experiments," "conduct," and "teachers," which are strongly interconnected. For example,

"I think that students need enough time to make observations and this about the experiments" (Student 1).

Community (Ⅱ) illustrates "the results and discussions in inquiry." Community (Ⅲ) shows "the problem and hypothesis in inquiry." For example, out of these two communities (i.e., Community (Ⅱ) and (Ⅲ)), "MEXT (2018) presents a specific process that involves introduction, setting of problem, setting of hypotheses, verification planning, conducting observations and experiments, handling the results, discussions and reasoning, and expression and communication" (Student 20).

Community (Ⅳ) shows "the introduction," which includes "question" and "interest." For example,

"Setting the problem in the introduction phase allows the students to identify the problem by themselves, and this leads to proactive learning because the problem arises from the students' questions" (Student 16).

Community (Ⅴ) shows "the understanding of learning content in science lessons." For example,

"I think that lessons that incorporate a lot of observations and experiments are effective in facilitating students' understanding of learning content" (Student 25).

Community (Ⅵ) shows "the resources," which include "resources," "methods," and "knowledge." For example,

"There are four types of mixed teacher knowledge: 'teacher knowledge concerning subject matter and pedagogy,' 'teacher knowledge concerning subject matter and pedagogy,' 'teacher knowledge concerning pedagogy and students,' and 'teacher knowledge concerning subject matter, pedagogy, and students'" (Student 26).

Community (Ⅶ) highlights the "proactive, interactive, and deep learning" required by the ministry's curriculum guidelines. For example,

"Lessons whose quality is improved by realizing 'proactive, interactive, and deep learning' are ideal" (Student 1).

Community (Ⅷ) illustrates the feeling, which includes "interesting" and "relevant." For example,

"I think students feel that it is interesting to use resources related to things and phenomenon in nature because they are more familiar with them and hence easily imaginable" (Student 20).

Community (Ⅸ) shows "the things, phenomenon in nature." For example,

"According to MEXT (2018), the process is developed in science lessons as follows: introduction, setting of problem, setting of hypotheses, verification planning, conducting observations and experiments, handling results, discussions and reasoning, and expression and communication" (Student 3).

Community (Ⅹ) shows "group discussions." For example,

"When students predict the answer to a specific question, they should be allowed to discuss their predictions in a group" (Student 31).

DISCUSSION

Transformation of pre-service science teachers' beliefs about good lessons

The common characteristics of the communities in both Figure l(a) and Figure1(b) were analysed quantitatively. Community (Ⅰ) in both Figure 1(a) and Figure l(b) illustrate how lessons should be and the terms used are strongly interconnected. The word “think” implies that the participants think of how teachers should teach science and that they think that it is important to make students think about the learning contents in science lessons. Community (Ⅳ) in Figure l(a) and Community (Ⅷ) in Figure l(b) illustrate the “proactive, interactive, and deep learning” required by the ministry’s curriculum guidelines. This implies that the participants recognize the ministry’s prerequisites as the key components of teaching. Community (Ⅵ) in Figure l(a) and Community (Ⅻ) in Figure l(b) show the unique phenomenon in nature. This implies that the participants recognize that students learn the phenomenon in nature through science lessons.

The unique characteristics illustrated by the communities in both Figure l(a) and Figure l(b) were analysed quantitatively. Communities (Ⅱ), (Ⅲ), and (Ⅴ) in Figure l(a) were found to be weakly connected. These three communities show that the learning of science has to be related to the ministry’s curriculum guidelines. These three communities are integrated into one community—Community (Ⅴ) in Figure l(b). Communities (Ⅶ) and (Ⅷ) in Figure l(a) are separated to illustrate the process of problem-solving. These two communities are integrated into one community—Community (Ⅶ) in Figure l(b). This implies that the participants recognize problem-solving as a set of the process. Taken together, these findings reveal that the knowledge needed to teach science is integrated systematically through two lessons: Methodology of Science Education Ⅲ and Ⅳ. Communities similar to Communities (Ⅺ) and (Ⅻ) in Figure l(b) were not found in Figure l(a); however, these two communities were found in Figure l(b). This means that the participants recognize these two communities as of utmost importance.

Transformation of pre-service science teachers’ ideas about good lessons

The common characteristics of the communities in Figure 2(a) and Figure 2(b) were analysed quantitatively. Both Community (Ⅰ) in both Figure 2(a) and Figure 2(b) show “how lessons should be,” and these words are strongly connected. The word “think” means that the participants think of how teachers can effectively teach science and that they think it is important to allow students to think about the learning content of science lessons. Community (Ⅴ) in Figure 2(a) and Community (Ⅶ) in Figure 2(b), which are found in beliefs about good lessons in Community (Ⅳ) in Figure 1(a) and Community (Ⅷ) in Figure 1(b), illustrate the “proactive, interactive, and deep learning” required by the ministry’s curriculum guidelines. This implies that the participants recognize that it is important for the teaching techniques adopted to adhere to the ministry’s curriculum guidelines and plan their lessons accordingly. Community (Ⅷ) in Figure 2(a) and Community (Ⅹ) in Figure 2(b) illustrate the importance of “group discussions.” This implies that the participants recognize the importance of discussions in creating good lessons.

The unique characteristics exhibited by the communities in both of Figure 2 (a) and Figure 2(b) were analysed quantitatively. Community (Ⅰ) in Figure 2(a) was divided into two communities, which are similar to Communities (Ⅰ), (Ⅱ), and (Ⅲ) in Figure 2(b). Community (Ⅰ) relates to Communities (Ⅱ) and (Ⅲ), which are annularly connected to Communities (Ⅳ) and (Ⅴ). This implies that the participants considered ways through which they can teach the lessons effectively in relation to each of the communities; i.e., Communities (Ⅰ), (Ⅱ), (Ⅲ), (Ⅳ), and (Ⅴ) in Figure 2(b). These communities, which are similar to Communities (Ⅵ) and (Ⅷ) in Figure 2(b), are not found in Figure 2(a). This implies that the participants recognize that these two communities, which are related to resources and the feelings of "interesting" and "relevant," form part of the important elements in teaching science. This suggests that their idea of lessons is transformed closely through two classes; Methodology of Science Education Ⅲ and Ⅳ.

CONCLUSION

Pre-service science teachers in Japan believe that it is important to transform how science is taught in schools and ensure that students are allowed the opportunity to reflect on the learning content of science lessons. This leads to the teachers' beliefs that good lessons are the ones that make students think about the learning content in science lessons. In addition, both pre-service science teachers' beliefs about lessons and lesson planning are affected strongly by the ministry's curriculum guidelines, which emphasize the need for "proactive, interactive, and deep learning."

The skills needed to teach school science are integrated systematically into the most complex community, which illustrates how "the learning of science is related to the ministry's curriculum guidelines." This is affected through two lessons offered by the university, which guide teachers on how to plan secondary science lessons, including making lesson plans. Taken together, the transformation of the participants' beliefs about science lessons affects the transformation of their lesson planning techniques.

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ANALYSIS OF THE CURRICULAR EMPHASIS PREFERENCES OF PRESERVICE SCIENCE TEACHERS IN CHILE AND SPAIN

Sylvia Moraga-Toledo[1y3], Cristina García-Ruiz[2] and Teresa Lupión-Cobos[2]

[1] Faculty of science education, Playa Ancha University, Valparaíso, Chile

[2]Science Education, University of Málaga, Spain

In context-based science education, the concept of curricular emphasis exhibits a particular interest to teachers, as it helps to identify what they consider science education to be. Therefore, in this work, we present a quantitative study on the curricular emphasis preferences from two educational context, Chile and Spain. Using a Likert-type questionnaire as a research instrument, we comparatively analyze the choices of 40 pre-service science teachers from Physics and Chemistry, identifying similarities and differences between both countries. The results show a clear preference for the emphasis on Science, Technology and Society, even though the contrasts of the two educational systems and the profile of the pre-service teachers.

Keywords: context-based learning, initial teacher education (pre-service), inquiry-based teaching

INTRODUCTION

A common trend that has been registered in recent years in science education consists of adopting a context-based approach (Pilot & Bulte, 2006), to promote students' interest in science, providing coherence and necessary cohesion to the contents addressed in the curricula.

In this sense, its combination with the practice of inquiry, in which students adopt a positive attitude towards science, participating actively linked to the educational transposition of scientific research and more independent in the learning process. Therefore, it is associated with a change in the perspective of teaching, applying the context as a starting point for the development of scientific ideas, and not the other way around, as is usual in more traditional methodologies (Bennett et al., 2007; Lupión-Cobos et al., 2017).

However, this conceptual change requires the inclusion of new teaching strategies and approaches related to the development of both personal and professional skills, which allow students to acquire an adequate understanding of the Science, Technology and Society relationships (STS), which applies to everyday situations and contributes to their personal development and active integration in society, as scientifically and technologically literate citizens (Boerwinkel et al., 2017; European Commission, 2014).

In this educational framework, teachers not only require a solid knowledge of the content, but they also need to be involved in the design and practice of the teaching process, which is associated with numerous responsibilities (Slavit et al., 2016). From their guiding role, they are expected to help their students develop critical thinking, problem-solving, and decision-making or use ICT tools, thus enhancing responsible citizenship skills.

Thus, teachers' sense-making processes are involved in a social setting of teachers' understanding and perceptions of new aspects related to teaching innovative curricula compared to teaching conventional curricula (Spillane et al., 2002).

It is important to identify the teachers' points of departure on their attitudes towards the introduction of a context-based approach (Coenders et al., 2010) since their beliefs and their evolution are different depending on personal factors in which teachers face to do it (Avraamidou, 2014).In addition, the challenges of features of the schools where the teachers work, the structures of their science departments, and the institutional policies in the workplace (Pedretti, et al., 2008; Avraamidou, 2014).

In fact, new strategies are being studied for adequate professional development in teaching context-based science curricula, as an exemplar of curriculum innovations in which teachers are confronted with new pedagogy and new content simultaneously. Dolfing et al. (2020) have analysed the strategies to support teachers' professional development regarding from the perspective of teachers' sense-making relate to teachers' accommodation of the new aspects in content and pedagogy of teaching context-based science curricula guiding the design of activities. They described the framework in three new aspects: setting a context in class, performing a new teaching role, and teaching new content.

Professional competences for context-based education: the importance of the curricular emphasis

These changes in teacher cognition and practice directly affect teachers' professional competence to apply these didactic approaches, with an inherent complexity associated with the difficulty of transferring real problems to the classroom and a whole series of limitations that condition it (de Putter-Smits, 2012). For example, teachers have difficulties in selecting and prioritizing content, and that the use of contexts should not be reduced only as a motivating introduction, an anecdote between lectures or a final mention of the technological application of what has been taught (Marchán-Carvajal & Sanmartí, 2015a; Moraga-Toledo & Palomera-Rojas, 2022).

Therefore, from pre-service teaching, it is essential to address the development of the teaching skills and competencies necessary to face context- and inquiry-based science teaching successfully. In this sense, it is important to train initial teacher trainees to develop, implement and evaluate the results of their own proposals as it is a good way to provide them with practical experience of these approaches and to transfer the knowledge to the classroom (Lupión-Cobos, et al., 2017). Distinguishing mainly among "use of context", "regulation" and "emphasis". Although the first two can be associated with the familiarity with which the teacher adopts the context, and their ability to regulate student learning through specific activities, respectively, the "emphasis" presents greater complexity, referring to the messages and objectives that provide an answer to the why of learning (Roberts, 1982). And as also inquiry is inherently linked to context, and context-based teaching requires extra-situational knowledge of the context and not just declarative knowledge of science (Jaana et al, 2019)

Given the relevance of the preferences about the curricular emphasis for the inquiry and context-based science education and considering the diversity on its application regarding distinct curricular systems, this study aims to compare pre-service teachers' initial perceptions in Chile and Spain on the matter.

METHODOLOGY

Participants in this study were 40 pre-service science teachers (PSST) from the Chilean Physics Pedagogy Degree (25) and the Spanish Master's degree in Secondary Teacher Education (15). For data collection, we used the questionnaire developed by de Putter-Smits (2012), which consists of an extension of van Driel et al. (2005). The five-points Likert-type questionnaire (1: totally disagree; 2: disagree; 3: neither agree nor disagree; 4: agree, and 5: completely agree), was translated into Spanish from its English version, has a total of 54 questions (38 about science education in general, and another 16 specific to Physics and Chemistry), and includes three curricular emphasis: fundamental science (FS), science, technology and society (STS) and knowledge development in science (KDS). While FC considers that theoretical notions and scientific knowledge should be taught first, since they provide a basis for understanding the natural world and are necessary for students' future education, STS implies the relevant role of communication and decision-making in matters involving scientific issues. Finally, KDS, related to the nature of science, connects with the idea that students should learn how scientific knowledge develops in socio-cultural contexts, understanding science as a constant development system.

Table 1 classifies according to the three curricular emphases, the 38 items on science teaching in general and table 2 classifies according to the three curricular emphases, the 16 items specific to Physics and Chemistry.

Table 1. Classification of the 38 items about science education in general.

	Fundamental Science (FS, n=12)	**Science, Technology and Society (STS, n=8)**	**Knowledge Development in Science (KDS, n=9)**
Items	1, 6, 7, 13, 18, 21, 23, 29, 30, 32, 35, 37.	3, 5, 9, 15, 17, 20, 22, 25, 26, 28, 31, 34, 38.	4, 8, 11, 12, 14, 16, 19, 24, 27, 33, 36.

Table 2. Classification of the 16 items specifics for Physics and Chemistry.

Fundamental Science (FS, n=5)		**Science, Technology and Society (STS, n=0)**	**Knowledge Development in Science (KDS, n=3)**
Items for Physics	40, 42, 43, 44, 46.	---------	39, 41, 45
Items for Chemistry	40, 42, 43, 44, 46.	---------	39, 41, 45

For both countries, we collected the data prior to implementing an inquiry and context-based teaching proposal, located at an equivalent learning moment (6th semester in Chile and 2nd quarter in Spain). Given that within the 54 initial questions de Putter-Smits (2012) identifies the items with the highest correlation, we calculated the frequency distribution, mean scores and standard deviation for the set of items associated with the different emphasis.

RESULTS

We present the main findings concerning each of the curricular emphasis and educational contexts. Regarding STS items (I1-I12) results, we observe a similarity in the preferences (figure 1). The value means for the Spanish PSST in this emphasis is 4.04, which is lower than the Chilean PSST (4.34), expressing a marked predilection for the use of Science-Technology and Society contexts for the last ones. Thus the Spanish students scored considerably lower in items I2, I10 and I11, related to the importance given to the discussion of current social topics in the science subject, to whether the exit qualifications should be based on an analysis of social situations where science plays an important part, or to the preference on the use of societal context to show what the importance of science is, respectively.

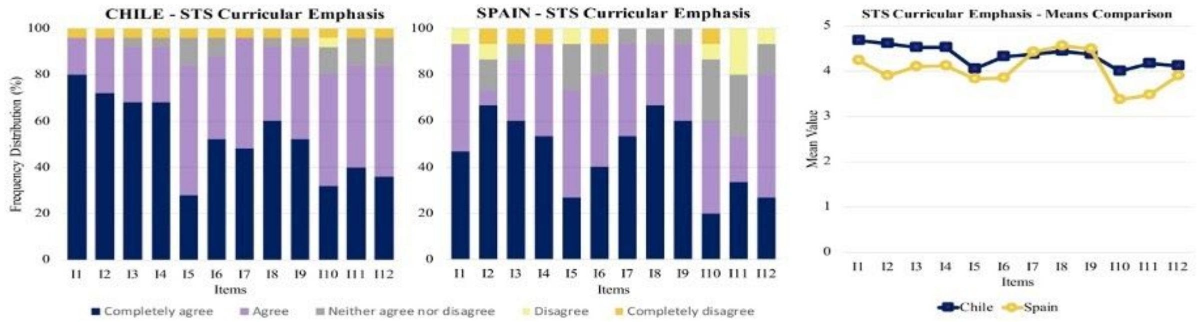

Figure 1. Frequency distribution (Chile and Spain) and means comparison for the STS curricular emphasis.

About the KDS curricular emphasis items (I13-I19/I20) (figure 2), although the total means value still differs a little (4.25 for Chile and 3.89 for Spain), the profile depicted by both Chilean and Spanish PSST is even closer. There are just two considerably differences concerning I13 (about the important task of science education to acquire insight into the socio-historic development of scientific knowledge) and I19 (about the relevance of treating the historical background of radioactivity). Hence, for both items, Spanish PSST scored lower than Chilean. Here we would also like to remark that the absence of Chilean data for I20 is due to the specificity of this item for Chemistry PSST, and therefore, only Spanish students scored it.

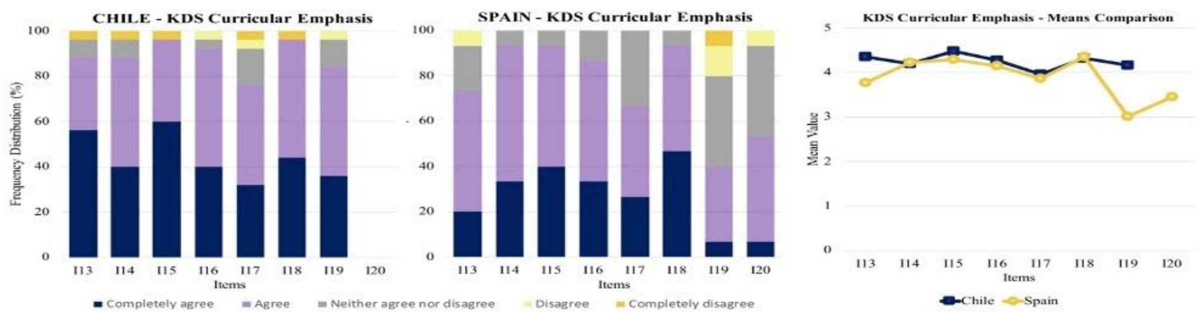

Figure 2. Frequency distribution (Chile and Spain) and means comparison for the KDS curricular emphasis.

Finally, although the results on the FS curricular emphasis items (I21-I28/I29) (figure 3) are practically identical for both countries, and so are the total mean values (2.85 for Chile and 2.87 for Spain). We want to highlight the scores on I24, related to whether students should acquire basic scientific skills before working on applications. For FS emphasis, this item obtained the highest scores both in Chile and Spain, even though all the others did not score greater than 3.5. As it happens before, the absence of Chilean data for I28 is due to the specificity of this item for Chemistry PSST, and therefore, only Spanish students scored it.

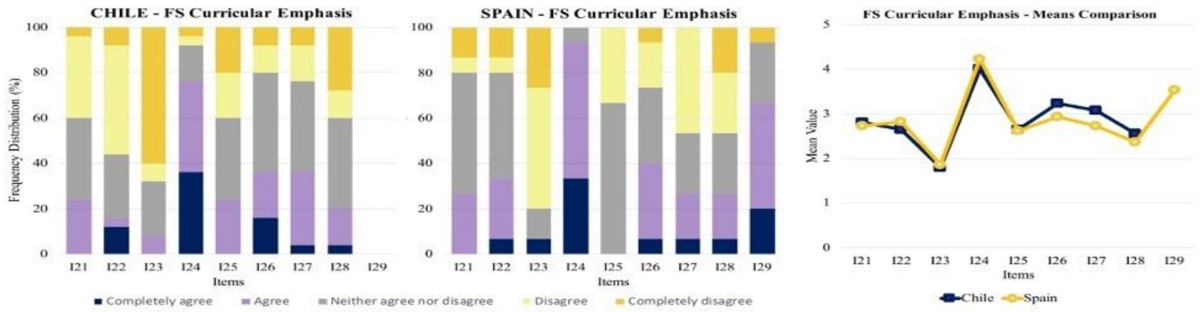

Figure 3. Frequency distribution (Chile and Spain) and means comparison for the FS curricular emphasis.

CONCLUSIONS

Since international studies usually highlight the disparities between educational systems, even more considering the differences when approaching inquiry and context-based science education, we gratefully have established a small-scale comparison about Chilean and Spanish PSST's curricular emphasis preferences. For both, we observe an apparent positive inclination towards the use of STS and KDS emphasis, a trend that, according to van Driel et al. (2005), would represent an approach to more active teaching strategies. This tendency is more marked for Chilean PSST, mainly due to the curricular structure and duration of the Physics Pedagogy degree and the Chemistry Pedagogy degree, as well as to the differences in the scientific background with respect to the Spanish ones. Although these finding may not be generalisable and apply to a small number of participants, the satisfying results obtained encourage us to continue promoting this type of didactic approaches, highlighting the relevance of teaching in context and providing tools for its proper implementation within the two countries.

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PRIORITY MATTERS TO BE RESEARCHED ACCORDING TO TRAINEE PRIMARY EDUCATION TEACHERS

Sandra Laso Salvador[1]; Mercedes Ruiz Pastrana[1]; M Antonia López-Luengo[1]; José Remo Fernández Carro[2]; Angel Ezquerra[3]

[1]Universidad de Valladolid, Valladolid, Spain
[2]Universidad de Castilla la Mancha, Cuenca, Spain

[3]Universidad Complutense de Madrid, Madrid, Spain

It is important to train scientifically literate citizens. In this, formal education plays a relevant role. In the present work, a questionnaire was administered which was prepared ad hoc for a convenience sample comprised of 367 primary education teachers undergoing initial training, from 5 Spanish universities. The questionnaire sought to detect how teachers are able to identify science in society and what matters are considered most priority. The results of the analysis show that Health and the Environment, but not others, are the subjects consider most important by future primary teachers. The awareness of scientific issues forgotten needs to be included among the teacher education course activities. The analysis according to sex, age and academic year variables have shown statistically significant differences regarding the sex variable. Comparative analysis with the results of questionnaires addressed to the population at large, both European and Spanish, have found some differences in order of priority of scientific issues.

Keywords: Initial Teacher Training, Scientific Literacy, Socio scientific Issues

INTRODUCTION

The scientific literacy of all citizens is increasingly necessary in today's world (Aikenhead, 2006; Ezquerra and Magaña, 2017) in the face of the evident crisis of confidence in science as indicated rise of anti-vaccine movements, terraplanists, Climate Change deniers or advocates of homeopathy… (Achterberg et al., 2017; Saltelli and Funtowicz, 2017). The pursuit of scientific literacy for participatory democracy is a goal claimed within the movement socio-scientific issues (ISS) and advocated in science education reforms internationally, which is necessarily linked to the development of critical thinking or the ability to search for and evaluate information (Acar, Turkmen y Roychoudhury, 2010; Sadler, Romine and Topçu, 2016). That concern mobilises institutions in different countries who seek to know the situation of the population and its evolution (DeBoer, 2011; DeBoer, 2014; Roberts & Bybee, 2014; Cortassa, 2016) in order to improve the scientific training of their citizens. This diagnosis in Spain has been carried out through surveys by the Spanish Foundation for Science and Technology (FECYT according to the acronym in Spanish) every 2 years from 2002 and at European level through the Eurobarometer study on Public Perceptions of Science (Directorate-General for Communication, 2014).

Due to the important role formal education has in scientific training of citizens, different countries have enshrined in their legislation the intention to train their population scientifically. In the case of Spain, it is included in the current educational law (LOMCE, 2013): "Preparation for the exercise of citizenship and for active participation in economic, social and cultural life, with a critical and responsible attitude and with the ability to adapt to the changing situations of the knowledge society". However, legislating is not enough, more research efforts are needed both to document the potentialities or constraints of scientific literacy and citizenship education through science curricula and to evaluate what training and viewpoint teachers have. Especially relevant is improving of teachers training of the first stages of education. More so since, research has showed the public domain of science of the trainee Primary Education teachers affects the kind of thinking they develop, and their teaching plans (Spiliotopoulou and Papantoniou, 2011). For this it would be necessary to consider factors and skills such as decision making, problem solving, identification of science in the environment, sustainable development, etc. (Hodson, 2003). Nevertheless, scare work has been carried out on this group to detect its capacity to identify science in society and its transfer to the classroom. Prior studies show that Primary Education teachers in initial training do not show differences compared with other citizens of the same age (Fuertes-Prieto et al., 2020). Moreover, they have difficulties in adequately including science in the learning process (Ezquerra, Rodríguez & Hamed, 2014; Rivero et al., 2017).

Due to all this, it is of interest to diagnose capacity to identify the presence of science in society among this group of teachers. Therefore, the aim of this work was to analyse what subjects are considered important to be researched by science in a sample of students of the Degree in Primary Education.

METHOD

Participants

A convenience sample was drawn, it was composed for 367 students of Primary Education Degree, belonging to five Spanish universities (Granada University, Valladolid University, Complutense University of Madrid, Castilla-La Mancha University and CEU Cardenal Spinola, Sevilla). Most of the participants of the group (72,75%) were women. This is a similar percentage to that of the Spanish active teaching staff. As expected, the majority were young people between 19 and 24 years old. None of the students were in their first year.

Coding of data procedure

The method used to carry out this work is described below. In order to achieve the objectives, the research has had three stages (Figure 1). The first was putting into circulation the next question: *"please tell us which topics you consider to be the most important for science to investigate. If you can, please tell us up to five topics"*. The question was on-line administered in the context of a science education course during the first semester of academic year 2019-2020.

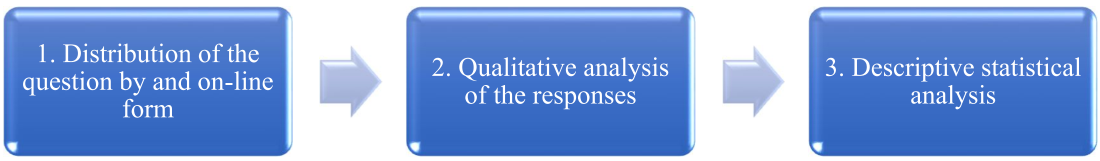

Figure 1. Stage of research.

Once the responses were received, next stage was to implement a qualitative analysis of the responses (content analysed by adopting an emergent coding approach) to detect the recurring themes. Initially, three coders independently inspected the answers what were encoded and assigned to categories. Next, emergent categories identified by the independent coders were compared and differences were reconciled, resulting in a common list. In the different refining phases until to find the consensus, the research team grouped the categories to generate a system of macro-categories. These major categories are comparable to those already used in similar studies such as the FECYT surveys administered to citizens in Spain and Eurobarometer in Europe. Thus, expressions such as "Alzheimer" or "Rare diseases" were encoded in the emergent category "Diseases" that, along with other emergent categories such as "Treatments" or "Vaccines", configured the macro-category "Health". Subsequently, a descriptive statistical analysis was carried out of the citations to allow the relative frequency of each macro-category to be obtained in the set of responses.

RESULTS AND DISCUSSION

The overall results obtained are shown in Table 1. It gives a brief description of the macro categories detected in alphabetical order and their relative frequencies. According to our sample, the topics that Spanish trainee teachers consider a priority to be investigated by science could be grouped into seven macro categories.

Table 1. Short description of the macro- categories and their relative frequencies (RF).

MACRO-CATEGORIES	DESCRIPTION	RF
Basic and applied science	Groups the mention of basic scientific disciplines and their applications in society.	11.1%
Education	Compiles aspects related to scientific literacy and teaching.	5.9%
Environment	Records codes that refer to climate change, energy sources, pollution, conservation of the environment, etc.	21.1%
Food	Records content related to types of food, nutritional characteristics and properties, diets, etc.	3,2%
Health	Covers references to diseases, medical treatments, medicines, etc.	37.8%
Pseudo-science	Compiles mentions of non-scientific practices.	0.3%
Society	Covers items linked to wellbeing, consumption, culture, sports, the economy, politics, and population.	9%
Technology	Covers codes related to telecommunications, means of transport, robotics, and new materials.	11.4%

The data indicate that students show interest in two topics: Health (37.8%) and Environment (21.1%); while Technology (11.4%) and Basic and Applied Science (11.1%) occupy the third and fourth place, respectively. The themes Society (9%), Education (5.9%) and Food (3.2%) are presented as a lower priority. It is important to point out that responses were also gathered on practices that are not considered scientific, for example "Astrology". These affirmations are grouped in an eighth category, Pseudoscience (0.3%). Although it could be considered as anecdotal for, they amount to a low percentage, in our opinion it is a type of declaration that should not arise among future teachers. Their presence among preservice teachers should be a source of reflection, since these may be part of the hidden curriculum that they will transmit to their students (Fuertes-Prieto et al., 2020).

In order to obtain greater detail of the distribution of priorities that future Primary Teachers have, the relation between the macro-categories established and three distinctive variables was studied: sex, age and academic year. We point out that there are no statistically significant differences for the age and academic year variables. Nevertheless, our data shows, with significant differences ($p<0.05$) that women are more likely than men to mention Health (39,66% vs. 33,09%), Environment (23,11% vs. 16,18%), Education (6,99% vs. 3,31%) and Food (3,28% vs. 2,94%). However, men prioritize topics related to Basic and Applied Sciences (16,54% vs. 8,99%), Technology (15,81% vs. 9,70%), Society (11,76% vs. 7,99%), and Pseudoscience (0,37% vs. 0,29%) (see Figure 2). These results differ from the findings of Revuelta and Corchero (2016) who identify women as one of the social groups that most believe in pseudoscience.

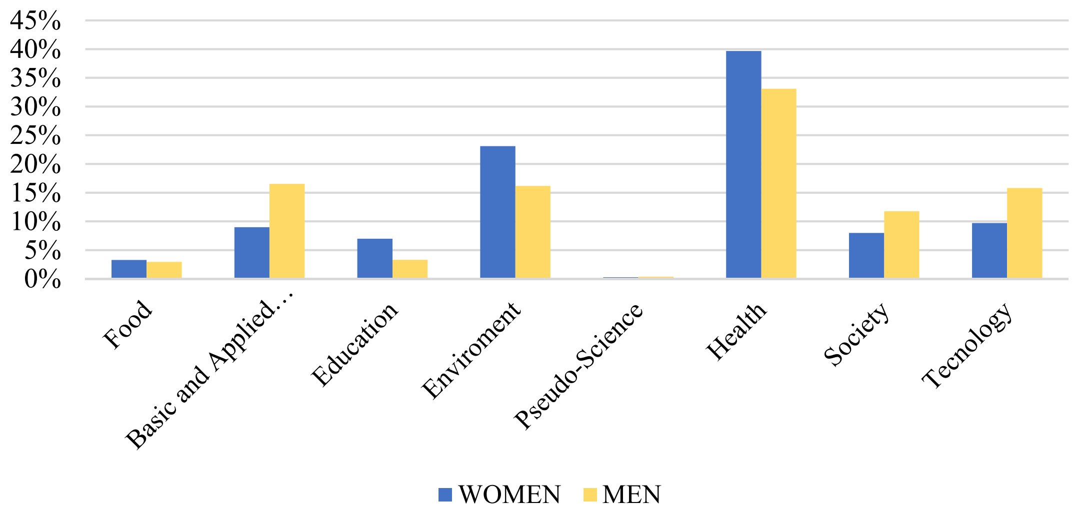

Figure 2. Comparative study between sex variables.

Comparative study between teacher-students and citizens

Although the question was not exactly the same, a comparative study has been carried out for the discussion in this study between our data and the results (1) of the Eurobarometer (2014) and (2) the Social Perception of Science Survey (FECYT, 2019) among Spanish citizens. The preliminary study carried out compares the position that each subject occupies according to the importance the different samples are assigned. Figure 3 shows the results obtained in this study, Figure 4 shows the results of the social perception of science in Spain and Figure 5 shows the results for European citizenship.

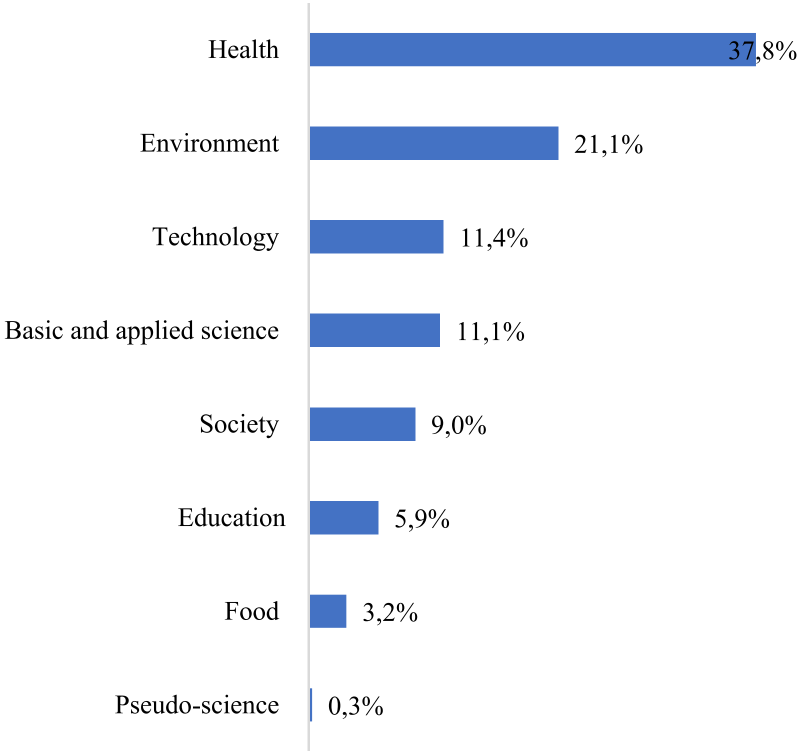

Figure 3. Results of teachers training obtained in this research.

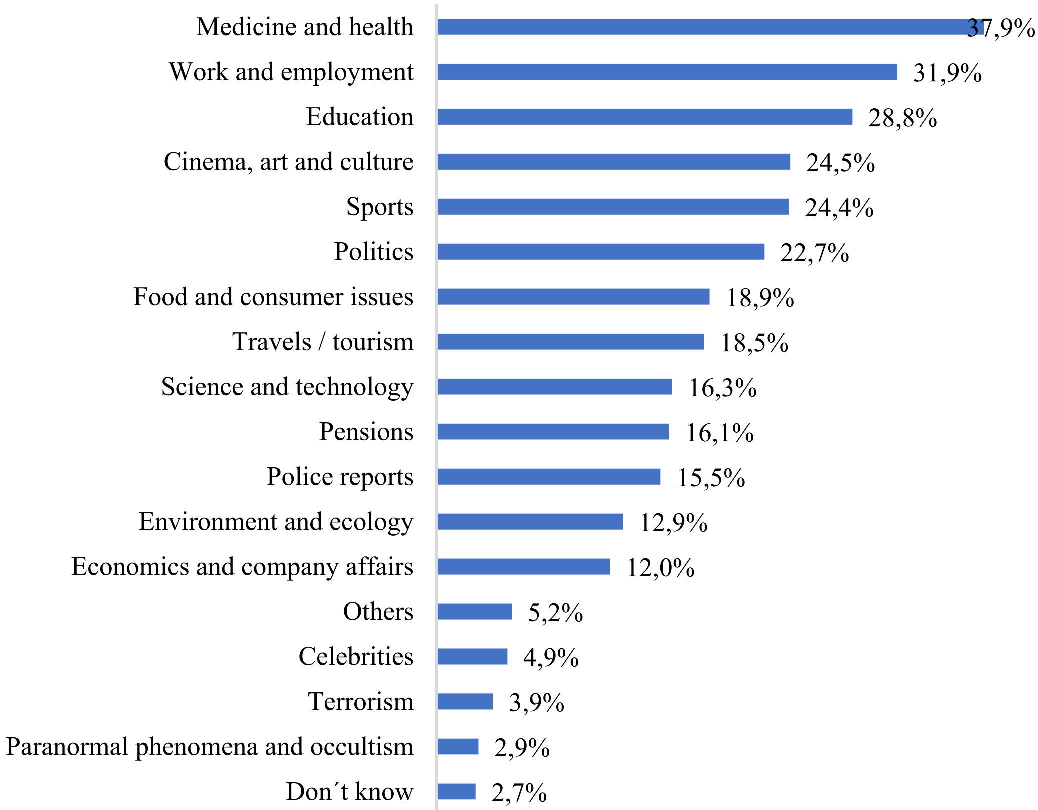

Figure 4. Results of Social perception of science and technology survey (Spanish Foundation for Science and Technology -FECYT-). Source: FECYT (2019). Percepción social de la ciencia y la tecnología 2018.

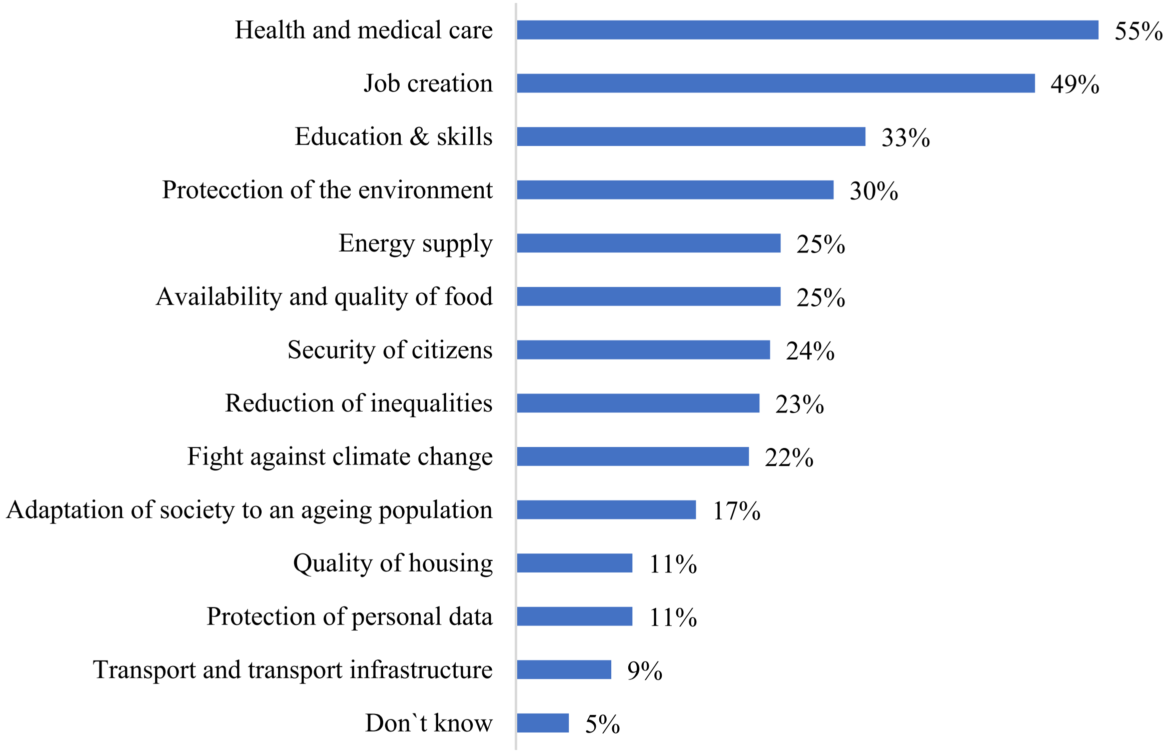

Figure 5. Result of Eurobarometer. Source: Directorate-General for Communication (Coord.) (2014). Special Eurobarometer 419.

Health is in a high position, regarding the European population (55%), the Spanish citizens (37,9 %), and the trainee Primary Education teachers (37,8 %). But if the Environment macro-category is considered to include protection of the environment, climate change and sources of energy as it is in the present research, the European population put this macro-category above Health (the sum of percentages is 77%). However, that is not the case for Spanish citizens. In regard of Environment, the Spanish general population consider in a lower position (12,9 %) than the university students of this research (21,1 %), and the European population.

About Education, Spaniards (28,8 %) match European citizens (33 %) when, in both cases, they grant greater importance to that matter than the sample in our study (5,9 %), which are preservice teachers. It is surprising that future teachers place Education in such a low position compared with other matters and that this order is less ambitious than that gathered from citizens at large, especially for the Spanish citizens.

We found concerning the emergence of pseudo-sciences (0,3%) among the answers to our study but the relative frequency in the sample is low than that from Spanish citizens (2,9%). The emergence of uncritical pseudo-scientific proposals in our society has been a matter of concern for years but has recently become more pronounced in Spain (Cano-Orón 2019; Cortiñas-Rovira et al. 2015; Fuertes-Prieto et al., 2020). These results confirm the need to improve the training of future teachers in this aspect, since it would affect in the citizens of the future.

CONCLUSIONS AND LIMITS OF THE STUDY

Findings showed that, according to our sample, Spanish student-teachers priority issues to be investigate by science could be group in seven macro-categories. Health and Environment were the main. Considering the responses provided in each of the identified macro categories, it can be seen how future teachers value the role of science in society through a utilitarian approach to science to achieve individual or collective good. Results showed no significant difference between students' age or academic year. Statistically significant differences were found in sex.

What the students mention as the more important matters to be researched differs from the Spanish and European population. Their awareness of scientific issues of daily life needs further development and evidence suggests that there is a need for more specific guidance to be included in the teacher education course activities. This study has allowed us to identify a wide range on which to work on Science in Society in the classroom. In this way, an education that responds to the needs of students would be achieved, improving their quality of life and promoting educational inclusion.

This preliminary study requires more deep analysis and that cannot be covered in the limited length of this text. Our research group infer the relationship between the priority issues than science must research for the trainee Primary Education teachers and the Nature of Science conception. This inference comes from the low position for social issues, especially Education, and is now in process of study.

Lastly, it is necessary to point out that the results shown here reflect a pre Covid-19 vision, that would foreseeably change if the data gathering had taken place late.

ACKNOWLEDGEMENTS

The authors would like to thank all the students who participated by answering the question for their generosity and time. This work has been funded by Project: “Identification of scientific contexts in society. Tools for teachers and citizens (SCIxSOC)" (RTI2018-094303-A-I00) of the Ministry of Science, Innovation, and Universities –Spain– in the framework of the National R&D&I Program Oriented to the Challenges of Society – State Plan for Scientific and Technical Research and Innovation 2019-21.

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TEACHER, TEACHING AND SCHOOL FROM THE PERSPECTIVE OF PRE-SERVICE CLASSROOM TEACHERS

Aslı SAYLAN KIRMIZIGÜL[1], Esra KIZILAY[1] and Nagihan TANIK ÖNAL[2]

[1]Erciyes University, Kayseri, TURKEY

[2]Niğde Ömer Halisdemir University, Niğde, TURKEY

Pre-service teachers' views, expectations and the factors that affect their choice of profession affect their career success. Starting from this point of view, this research aims to investigate the thoughts of the pre-service classroom teachers on teaching profession, school, and expectations from the faculty of education. The phenomenology design was conducted with the participation of the 18 pre-service classroom teachers. Data were collected through the open-ended interview form. Data were analyzed with content analysis. According to the results, most of the participants stated that teacher is a guide, informant and compassionate, and they thought the professional duties and responsibilities, and raising individuals with universal values are the most important duties of the teacher. The participants' reasons for choosing the teaching profession were mostly internal factors. Most of the participants stated that schools are anywhere where learning takes place, and that school should provide students with knowledge, and universal values. The findings revealed that the expectation that most of the participants had when starting education faculty was to become equipped with professional knowledge and skills. Lastly, only seven participants stated that their expectations were met by the faculty.

Keywords: Pre-service classroom teachers, perspective, expectation

INTRODUCTION

Teaching is a profession that has a long history, from being a preferred career with high social status to being regarded as a career selected by individuals, based on the extent that teaching is judged to be useful (Moosa, 2020). It is known that pre-service teachers' views on the concept of teacher, their expectations from teaching and the factors that affect their choice of profession affect their career success (Tataroğlu, Özgen, & Alkan, 2011). For this reason, it is very important to determine the opinions, expectations and preferences of pre-service teachers.

It was found that pre-service teachers generally describe teaching as a profession that requires responsibility and sacrifice (Ozbek, Kahyaoglu, & Ozgen, 2007; Watt & Richardson, 2008). In the studies, it was determined that pre-service teachers had expectations from the program and teaching staff such as to become equipped with professional knowledge and skills, none rote learning, to take applied courses, and learning through discussion (Cakir & Akkaya, 2017; Tataroglu et al., 2011). Various studies were conducted on the reasons for pre-service teachers to choose teaching programs (Cakir & Akkaya, 2017; Ekinci, 2017; Tataroglu et al., 2011; Watt & Richardson, 2008; Yurdakal, 2019). In these studies, it was determined that many internal and external factors such as the fact that teaching is a respected profession, getting insufficient score in the university exam, enjoying the teaching, and loving children were effective under the profession choices of pre-service teachers.

Above mentioned studies conducted with pre-service teachers are generally quantitative. In this context, there is a need for qualitative studies in which the opinions, reasons for career choice, and expectations of pre-service teachers about the teaching profession are investigated comprehensively. Moreover, no study investigating the perceptions of pre-service classroom teachers on school was found in the literature. Within this context, this qualitative research aims to investigate the thoughts of the pre-service classroom teachers on teaching profession, school, their choice of profession, and expectations from the faculty of education.

METHOD

Research Design

Phenomenological design was used in the research. In phenomenological studies, the researcher focuses on a phenomenon, collect data through in-depth interviews and interpret the participants' perceptions (Fraenkel, Wallen, & Hyun, 2012). The present research was carried out with phenomenological design since it was aimed to investigate, understand and explain pre-service teachers' experiences related to teacher, teaching and school.

Participants

The participants of the study consisted of 18 fourth-year pre-service classroom teachers studying in a university in Central Anatolia, Turkey during the spring semester of the 2019-2020 academic year. Participants were determined by criterion-based sampling. The main criteria are that participants have teaching practice experience and are willing to participate in the research.

Data Collection Tool

In phenomenological research, data can be collected through in-depth interviews or interview forms consisting of open-ended questions (Creswell, 2007). In this context, data were collected through an interview form consisting of four open-ended questions:

(i) Who is a teacher? What are the most important duties and responsibilities of the teacher?

(ii) Why did you choose to be a teacher?

(iii) Where is the school? What should the school contribute to a student?

(iv) What were your expectations when starting the education faculty? Have they been met?

Before the open-ended written interview form was applied to the participants, two field experts were informed about whether these questions were suitable for the purpose of the study. Then, in the classroom environment, data were collected.

Data Analysis

Content analysis, which is used to formulate themes and categories in order to organize and make sense out of large amounts of descriptive information (Fraenkel et al., 2012), was used in the research. The collected data were analysed separately by two researchers, and the agreement level between them was checked for consistency. While analysing the data, the codes were firstly determined, and similar codes were taken together to create the categories.

As a result of the analyses, the average percentage of the agreement between experts regarding the codes were measured as 0.90. The percentage value above 70% is considered reliable (Miles & Huberman, 1994).

RESULTS

Pre-service Teachers' Views on Teacher

The pre-service classroom teachers stated the characteristics of the teacher as guide, informant, compassionate, role model, the one who enlightens the mind, warm-hearted and patient, respectively (Table 1).

Table 1. Pre-service teachers' thoughts on who teacher is.

Categories	f
Guide	8
informant	7
compassionate	6
role model	5
enlightens the mind	4
warm-hearted	3
patient	2

Majority of the participants thought that the most important duties and responsibilities of the teacher were professional duties and responsibilities, and raising individuals with universal/ human values (Table 2). In addition, the participants mentioned the responsibilities such as raising students with national values, preparing them for the future, dealing with their problems, guiding them, and following the latest developments.

Table 2. Pre-service teachers' thoughts on duties and responsibilities of the teacher.

Categories	f
Professional duties and responsibilities	11
Raising individuals with universal/ human values	11
Raising individuals with national values	7
Preparing individuals for the future	6
Dealing with students' problems	4
Guiding the student	3
Following the latest developments	2

Pre-service Teachers' Views on the Reasons for Choosing the Teaching Profession

In the study, pre-service teachers' reasons for choosing the teaching profession were grouped under two themes (external and internal factors) and 10 categories. As it is seen in Table 3, internal factors outnumbered external factors, and number of participants emphasizing internal factors is also higher.

Table 3. Pre-service teachers' reasons to choose the teaching profession.

Theme	Categories	f	Sample answer
Internal factors	Enjoying teaching	14	*"I chose this profession because I love both teaching and children."* [P2]
	Liking of children	10	
	Making the world a better place	7	*"Teaching is the most enjoyable and effective way to change world."* [P10]
	Childhood dream	3	*"Becoming teacher was my childhood dream."* [P9]
	Enjoying self-improvement	2	*"I found this profession suitable for me as I love to improve myself."* [P1]
	Being interested in psychology	1	*"I love to think about psychology and talk about people's problems."* [P11]
External factors	Being inspired by teacher	4	*"One reason to choose teaching is my first grade teacher, whom I love so much. Also it is a respected profession."* [P17]
	Being a respected profession	2	
	Family influence	1	*"I chose this profession with guidance of my uncle who was a teacher."* [P3]
	Inadequate score	1	*"Since my score was inadequate for my dream job I chose this job."* [P3]

Pre-service Teachers' Views on School

As it is seen in Table 4, most of the pre-service classroom teachers stated that schools are anywhere where learning takes place. Some participants defined school as an institution, while some saw it as a home.

Table 4. Pre-service teachers' thoughts on where the school is.

Categories	f
Any place where learning happens	11
Official institution	5
Home	4
The place where training activities are carried out in a systematic and planned manner	3

Pre-service teachers generally stated that school should provide students with knowledge, and universal values such as honesty, respect, love, fairness (Table 5).

Table 5. Pre-service teachers' thoughts on the school's contributions to the students.

Categories	f
Knowledge	11
Universal/ human values	11
Skills	8
Socialization	6
Discovering interests and talents	6
Experience	3

Pre-service Teachers' Expectations from the Faculty

According to the findings, the expectation that most of the pre-service teachers had when starting education faculty was to become equipped with professional knowledge and skills (Table 6). Moreover, six participants stated that they expected to take applied courses rather than theoretical ones. Seven participants stated that their expectations were met, whereas six participants stated that their expectations were partially met, and four participants stated that their expectations were not met by the faculty.

Table 6. Pre-service teachers' thoughts on expectations from the faculty of education.

Categories	f
Becoming equipped with professional knowledge and skills	11
Taking applied courses rather than theoretical courses	6
Providing ways to exchange ideas	2

DISCUSSION OF FINDINGS AND IMPLICATIONS

The results revealed that most of the pre-service classroom teachers thought teacher was a guide, informant and compassionate. Thinking that behaviourism is centered around transmission of knowledge from the instructor to the students (teacher is the informant) whereas constructivism is focused on the construction of knowledge by the students (teacher is a guide), this finding is interesting. Moreover, majority of the pre-service teachers stated that teacher's most important duties and responsibilities were professional duties and responsibilities, and raising individuals with universal/ human values such as honesty, justice, compassion and tolerance.

According to the findings, pre-service classroom teachers' reasons for choosing the teaching profession were mostly internal factors such as enjoying teaching and liking of children. These findings are in line with many other studies in the literature (e.g., Buldur & Bursal, 2015; Tataroglu et al., 2011). The extrinsically motivated teacher focuses on the benefits of teaching such as salary, lengthy holidays and status. On the other hand, intrinsic values are the highest motive for choosing teaching. The pre-service teachers who are motivated by internal factors tend to be more committed to the teaching profession (Moosa, 2020; Roness, 2011).

Most of the pre-service classroom teachers stated that schools are anywhere where learning takes place. Some participants defined school as an institution, while some saw it as a home. Pre-service teachers generally stated that school should provide students with knowledge, and universal values such as honesty, respect, love, fairness. In parallel with these findings, Dilekçi, Limon and Sezgin Nartgün (2021) investigated pre-service teachers' metaphorical images of school, and found that the most common metaphor was family/home. Additionally, the participants stated that schools are the sources of information.

According to the results, most of the pre-service teachers expected to become equipped with professional knowledge and skills. Some of them also stated that they expected to take applied courses. Similarly, Tataroglu et al. (2011) stated that pre-service mathematics teachers had expectations from the program to become equipped with professional knowledge and skills, to take applied courses, and to learn through discussion. It is remarkable that no pre-service teacher focused on pedagogical knowledge. In their study Frågåt, Henriksen and Tellefsen (2021) investigated first and final-year pre-service science teachers and in-service physics teachers to describe the knowledge and skills needed to be a good teacher. The results of their study revealed first-year pre-service teachers put more emphasis on pedagogical skills and personality traits, whereas final-year pre-service teachers and in-service teachers focused more on teacher content knowledge and skills. However, teacher knowledge comprises more than subject-matter knowledge, thus teacher education should focus on integrating content knowledge and pedagogical knowledge.

This study is limited to the selected participants. In the research, a cross-sectional study was carried out and the fourth-year pre-service teachers were studied. It can be suggested to conduct longitudinal studies designed to cover all grade levels of pre-service teachers from different departments. By this way, the findings of the present study would be validated by incorporating a larger sample size and different grade groups. Within this context, it is suggested to examine the future professional expectations of pre-service teachers by adding new questions to the interview form.

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