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Storyline in natural science teacher education - An approach to the coherence between theory and practice

Anne Bonnevie Lund, Jardar Cyvin*

Department of Teacher Education, Norwegian University of Science and Technology, Trondheim, Norway

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ABSTRACT

The development of teacher identity depends on education rooted in theory- and practice-related activities. The Storyline Approach (TSA) can help to highlight connections between theory- and practice-oriented teaching using stories, characters, places, and tasks performed through role-play variants. In this study, natural science[1] teacher education students at a Norwegian university developed and implemented Storyline projects within the areas of biology, environmental education, and technology. This study suggests that Storyline promotes theory- and practice-oriented knowledge and discusses this in relation to the Aristotelian knowledge forms. Through practical tasks, the students in this study reflected on connections between pedagogical and didactic theories, the need for theoretical and practical knowledge, and their future work as schoolteachers. Through this case study, we have determined that Storyline is fruitful for promoting coherence between practical and theoretical knowledge in science teacher education and for the development of professional practice as future teachers.

1. Introduction

Teacher education in Europe is regularly subject to changes and revisions. Additionally, to meet expectations for future pupils, teacher education has undergone continuous reform since the *Bologna Declaration* in 1999 (Reinalda, 2008), with the aim of making it more academically robust, uniform, and comparable across Europe as well as focusing more on research to enhance teacher quality. In Norway, like a number of other Western countries, teacher education is now conducted at the master's level (NOKUT, 2020). Nevertheless, teacher education should be considered a form of professional education in which future teachers become qualified for the teaching profession and in which action is based on knowledge and reflection related to both theoretical and practical insights (Damsgaard & Heggen, 2010; Shulman, 1986, 2004; Solstad, 2010). The goal of high-quality teacher education is to ensure that university teachers have the qualitative ability to present the subject matter in an academic fashion while also caring about student learning by taking the students' own experiences and ideas into consideration and maintaining a teaching practice that involves good connection between theory and practice (Chong, Ling, & Chuan, 2011; Darling-Hammond, 2014; Korthagen, 2004; Korthagen & Kessels, 1999).

The teaching profession is based on a combination of different types of knowledge: theoretical knowledge related to the academic subject, pedagogical knowledge, practical and theoretical didactic knowledge of the subject, and the ability to know and do what is the best in a specific situation based on ethical considerations, which is often referred to as *phronesis* knowledge, a knowledge form that includes consideration and reflection based on previous experiences (Berry, Friedrichsen, & Loughran, 2015; Eisner, 2002). The Ministry of Education in Norway (Ministry of Education, 2017, Ministry of Education 2018) has also underlined the need for student teachers to develop their ability to learn the skills and competencies needed to implement interdisciplinary teaching, collaborate, and be creative. Student activity as a teaching approach has also been highly emphasized through critical thinking, problem solving, and creativity.

However, teacher education in the Western world is often described as fragmented or excessively theory-based, and both student teachers and practicing teachers have argued that teacher education lacks school-based relevance (Lillejord & Børte, 2017). It is equally as impossible to satisfactorily educate future teachers without theoretical knowledge as it is to educate them without practice in school settings. Korthagen and Kessels (1999) argue that teacher education should largely be based on specific situations that allow students to appreciate the relevance of their education in a school context. Smeby (2008) claims that it may be challenging for students to relate theoretical and practical knowledge to knowledge used in schools as professional teachers. He uses the term "coherence" to highlight the need for correlation between the practical and theoretical knowledge used by student teachers and that

* Corresponding author.
E-mail address: jardar.cyvin@ntnu.no (J. Cyvin).

[1] This study is all about *natural science teacher students*, studying for being teachers in primary school (6-13 yr. pupils) even if we further on in this paper is writing just *science students*, or *science teacher students*.

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used in school in a professional practice. To achieve coherence, the theoretical and practical aspects of teacher education should be more closely connected, both on campus and during students' practical training in schools (Damsgaard & Heggen, 2010; Darling-Hammond, 2014). In other words, it is important that a substantial part of the education of students takes place in a context relevant to their future work as teachers. Accordingly, as much learning as possible should occur in a situated context and should include time for students to reflect on and establish connections between the theories they are taught and the training they receive in educational and didactic practice. Many aspects of situated learning that are important for the development of a teacher identity are based on collaboration, social interaction, guidance, activity, and reflection – as opposed to instruction and dissemination – as described by Dewey (1938), Lave and Wenger (1991), Vincini (2003), and Wenger et al. (2002), among others.

Because teacher education is offered at the master's level in many countries, and because the academic side of teacher education has been strengthened, it is now particularly important to be conscious of the connections between theory- and practice-based teaching and thus to increase students' awareness of their future work as teachers. The composed natural science subject in teacher education provides good opportunities for exploration. However, because many teachers are involved in the subject, and because only a few lessons are available for each teacher and each topic, it is not always easy to focus on both the academic and didactic approaches needed for future teachers.

The Storyline Approach (TSA) is an approach to teaching that has been used in primary schools for many years. It may also be a useful approach in teacher education, as it helps to highlight connections between theory- and practice-based science teaching. A Storyline often includes a narrative with characters and places, a timeline, and different types of tasks that are given by the teacher and performed by the students through role-playing or drama activities. The present article is based on four case studies – one in 2015, two in 2016, and one in 2017 – in which we used a modified version of TSA for science teacher education. In total, 55 students participated in the four case studies. TSA is used in the Norwegian compulsory school system, and we therefore decided to create lessons aimed at giving student teachers an opportunity to explore this part of a teacher's work as an experience of an interdisciplinary approach, which we think will make the connection between theory and practice more visible. The Aristotelian knowledge forms distinguish clearly between theoretical knowledge and practical actions and behaviours within professional education. Because of this, these knowledge forms have the potential to activate awareness of the need for different types of knowledge.

This study addresses the following research questions:

- How did the student teachers experience TSA to selected science themes with respect to the intersection between theory and practice?
- How did the students view Storyline as a learning approach relevant to their professional development as teachers?

Storyline: an overview

Storyline is a problem-oriented, theme-based, interdisciplinary educational approach that originated in Scotland in the late 1960s (Mitchell-Barrett, 2010; Mitchell & McNaughton, 2016). It is used in both primary and secondary schools and sometimes in high schools and universities as well (Berggren, 2019; Bolstad, 2021; Eik & Fauskanger, 2003; Karlsen et al., 2019; Omand, 2018; Romstad, 2019). Bell (2002) claims that it can be used as a method to motivate pupils. Approaches to TSA differ, but it is most often used as a framework in which participants examine a situation, do activities or explore occasions at a specific place and time, take on roles in the form of drama or role-play, and communicate tasks that enable them to actively create different physical installations or situations and make discussions, written notes, or reports. In addition, the participants must apply their theoretical knowledge to practical actions. The students typically work in groups while the teacher introduces new considerations through "key questions". This group work may also involve some individual work. The students have an active role in their learning processes and in the outcome of the narratives. The teacher may evaluate the students' group work and choose to conduct more traditional teaching appropriate for developing the participants' knowledge or skills (Eik & Fauskanger, 2003). The teacher creates the story according to their professional goals. The students, in turn, may choose how to handle the given situation and how to perform the tasks within the given framework. This means that a Storyline is controlled by both the teachers and the students. The approach opens opportunities for both inquiry-based and situated learning collaboration in which students negotiate both practical and theoretical tasks. Knowledge is made available and developed using prior theoretical knowledge, languages, and other tools or artefacts through interactions among the participants. The approach often engages the students in developing a product or activity that is both theoretical and practical and frequently crosses traditional disciplines. A Storyline may incorporate a variety of working methods, and the results can provide different types of knowledge.

1.2. The island "Hope"

To illustrate TSA, we present the introduction used in our case study set on the island "Hope", conducted in spring 2016.

We are now in the year 2050. You and 10,000 other human beings are the only survivors left on Earth after a catastrophic natural disaster. You are living on an island called "Hope" in the middle of the ocean with no means of reaching other continents or islands.

(A description of the island's nature resources and settlements follows; the students view images of the island in a PowerPoint presentation).

The natural disaster has damaged the infrastructure (electricity, mobile network, internet), and you are unable to get supplies by boat or airplane. Heavy clouds permanently hang over the island, making the solar input poor.

How will you organize your lives on the island? As experts, you will develop a plan for the future survival of the island's inhabitants.

I (the teacher) am the mayor of the island, and you will create expert groups – nature experts, landscape planners, teachers, engineers, and economists – to help me.

During the project week, new elements were introduced through different methods, such as by "jumping" forward in time (time travel). Through these new elements, such as the ability to use electric power again or the discovery and repair of a computer, the story was driven forward. These jumps with new information substituted for the key questions that characterize TSA. The aims and main goals of the student groups remained unchanged but were updated with new essential information.

Our modified version of Storyline took place within a shorter period and with a less strict structure than is typically advised for this approach to teaching. This means that we did not make a list of key questions; rather, during the story, the students periodically received new missions to stimulate development and introduce more natural science elements. We began with a story told by the teacher, in which the teacher took on a role and underlined artefacts such as hats and tools that were needed for the situation. The stories were sometimes interrupted with theoretical information provided through PowerPoints as well as some discussions. The students were then asked to begin their practical work through an inquiry-based approach in "expert groups", first making plans and then testing the plans in a "general assembly" for their "village". Through this process, the students were forced to test their plans and conclusions and to discuss them with other student groups in an attempt to understand how and why their models could or could not work in both a theoretical and practical sense. This was done as a training method to connect theoretical content knowledge and practical skills. The final task was to make a wall-paper as a dissemination of their results. At the end, the teacher evaluated the students 'products.

2. Theoretical background

2.1. Research on Storyline as an approach to teaching and learning

Over the years, Storyline has developed via teacher networks with a practical aim of improving and developing the approach (Mitchell-Barrett, 2010), and research studies on Storyline have mainly focused on primary and secondary schools. Many of these studies underlie TSA to teaching and learning as a tool for more flexible approaches that emphasize problem solving, critical thinking, different forms of communication (Nuttall, 2016), creativity, and real-life cooperation in group work (Ahlquist, 2019, 2021). A study by Demir (2012) showed that instruction conducted through TSA in a science and technology course was effective in increasing the achievement level of the students in a primary school. Possibilities for using creativity and esthetic approaches to make learning meaningful have also been highlighted in previous studies (Østern & Kalanje, 2012).

There are less studies on the use of TSA in teacher education than on its use in primary and secondary schools. A review article about the use of Storyline in different fields of education (Karlsen & Lockart-Pedersen, 2020) found that, between 1967 and 2019, only a small amount of international research offered general approaches to Storyline in education. The contexts for these studies included pre-service teacher education and came from the US and certain European countries, with Norway being among the countries to produce the most peer-reviewed articles in the field. Studies from teacher education often claim that Storyline provides a way to bridge the gap between theory and practice and the possibility for student teachers to reflect on real-life practical situations to support their professional growth (Karlsen et al., 2019; Murray, 2016).

A few recent studies have investigated the use of Storyline in science teacher education. Reiser et al. (2021) underline that it is important for student teachers to experience science as a meaningful practice and that this will also have implications for their role in classroom work. Reiser et al. (2021) claim that knowledge-building practices in a Storyline are motivated by shared goals and methods of making progress and entail epistemic agency. The students collaborate and have an active role in their work and may build explanations, models, and designs together. Reiser et al. (2021) underline that TSA involves instructional routines and norms that provide these strategies. A Storyline may help students to not only understand the epistemic part of a subject matter connected to “a real world” but also involve their emotions and curiosity in their learning processes. (Schepens et al., 2009) claim that Storyline functions as a useful approach for teaching physical aspects of climate change because using Storylines might affect students’ emotions and thus their ability to make decisions because they may combine climate change information with other relevant factors.

Although there is little research on teacher education concerning TSA in science, we have found studies concerning TSA in different subjects and education levels which may be relevant to science teaching. Karlsen & Häggström, 2020 created an anthology wherein researchers from different countries addressed the use of TSA in teacher education in different subjects and with different approaches to learning and teaching. Karlsen and Häggström, 2020 underline that a learning situation which involves collaborative learning situations through the use of TSA is of great value because the situation highlights interdependence between participants in a group. The perception and value of in-depth learning, emotional binding, and responsibility between learners are made clear for the students. However, the authors also underline that these processes need time to be fulfilled and that an effective Storyline approach might therefore be time consuming (Karlsen et al., 2020a).

Teachers in school need different approaches to learning and teaching, including theoretical, practical, and esthetical approaches. Häggström and Dahlbäck (2020) claim that students’ critical reflections are a prerequisite for their learning processes in cases where transformative learning is used to build their identities as teachers. When using TSA in these situations, Häggström and Dahlbäck (2020) found that TSA was experienced as both nerve-racking and challenging; students felt stronger, more self-confident, and more prepared to use aesthetics as future teachers after working with this approach.

The national strategies for Norwegian primary and secondary schools call for teachers to obtain skills and competencies that facilitate cross-curricular collaboration together with critical thinking, problem solving, creativity, and innovation while also engaging learners in real-world problems (Ministry of Education, 2020). The use of TSA as a cross-curricular approach to teaching and learning and as a relevant and unique approach for upcoming teachers has been highlighted in multiple studies (Emo, Emo, Penrod, Venhuizen & Ekstrand, 2020; Karlsen & Häggström, 2020; Karlsen et al., 2019; Karlsen, Berggren, Ludviksen and Næsje (2020b)). However, according to Karlsen & Häggström, 2020, fundamental elements such as cooperative learning and group work still require research attention. According to Karlsen et al. (2020b), student teachers have also experienced the use of TSA in primary school as having the potential to facilitate explorative learning experiences for pupils. Emo et al. (2020) found that using TSA enhanced the instructional affective environment, student enjoyment, and student engagement with their curriculum work. According to these researchers, TSA adds personal meaningfulness not only to students but also to the work of instructors and can, in turn, contribute to a positive professional identity for all participants. Using TSA in teacher education may increase students‘ understanding and ownership, and provide tasks in which they will be able to explore, reflect, collaborate, and experience rather than taking on a passive role (Reiser et al., 2021; Schepens et al., 2009; Karlsen & Häggström, 2020; Karlsen et al., 2019, 2020a; Murray, 2016). TSA also has an important impact on the link between theory and practice (Häggström et al., 2020).

2.2. Forms of knowledge

Within didactics, it is common to classify knowledge as purely theoretical in relation to each academic subject. Schulman (1986) describes this type of knowledge as content knowledge (CK). It is quite common to classify the knowledge forms needed by teachers as a combination of theoretical knowledge related to the subject, pedagogical knowledge, and practical and theoretical didactic knowledge of the subject, also known as Pedagogical Content Knowledge (PCK) (Schulman,1986; 2004). These knowledge forms deal with everything from professional knowledge to knowledge of the best ways for students to learn a subject, the purpose of the subject, and general pedagogical approaches to the teaching situation. In recent years, there have been discussions about how to interpret PCK, challenges in PCK research, and PKC’s implications for didactic theories and practice (Hume et al., 2020). These discussions have concluded that an understanding of PCK includes different types of knowledge in addition to skills and enactments, the combination of which is referred to as *teacher professional knowledge and skill* (Berry et al., 2015).

Theoretical knowledge and concepts are crucial both for critical thinking and for professional practice (Taylor, 2008). However, the possession of theoretical knowledge alone does not make someone a good teacher. A good teacher also needs practical and didactical knowledge along with the ability to see possibilities and limitations in educational situations and to determine the right moments for action. Van Manen (1991) describes this form of knowledge as pedagogical tact or ability and claims that students and teachers can acquire it through practice. Pedagogical tact has an affinity to Aristotle’s knowledge form *phronesis* (Aristotle, 1953), which is often described as practical wisdom. In recent years, *phronesis,* together with Aristotle’s other knowledge forms, *episteme* and *techne,* has received renewed interest in professional education programs (Birmingham, 2004; Eisner, 2002; Hovdenak, 2016; Mathisen, 2007; Nussbaum, 1998; Wiese & Hovdenak, 2017), particularly in areas of education that include both practical work and theoretical understanding. *Teacher professional knowledge and skill*

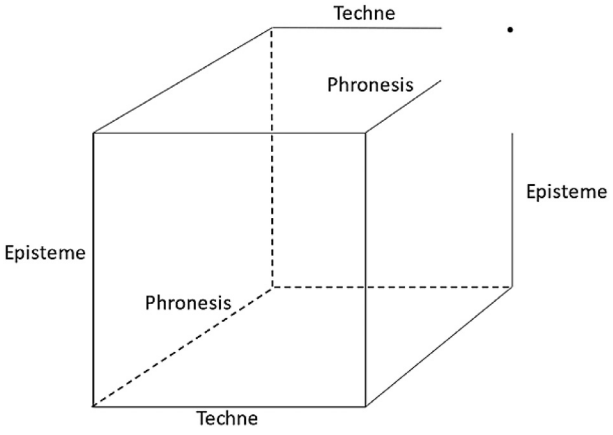

Fig. 1. Knowledge in 3D. Redrawn from Järnerot and Veelo (2020).

(Berry et al., 2015) might include *episteme, techne,* and *phronesis* (Ellebæk & Nielsen, 2016), but the Aristotelian knowledge forms distinguish even more clearly between theoretical knowledge and practical actions and behaviours within professional education. In this article, we have therefore decided to give the Aristotelian knowledge forms attention.

Aristotle categorizes all forms of theoretical knowledge as *episteme*. Within teacher education, *episteme* includes theories related to the pedagogical, didactic, and content knowledge pertaining to each academic subject. Epistemic knowledge can be communicated by teaching in a theoretical manner (Saugstad, 2002). Many would argue that in Western society, this form of knowledge has traditionally received the most trust and is regarded as superior to practical knowledge (Wiese & Hovdenak, 2017). However, increasing pluralism – and thus an increasing recognition that there is often more than one truth – has diminished belief in one true, objective form of knowledge (Eisner, 2002).

Techne refers to the practical and methodological aspects of different subjects. It encompasses the practical or technical performance of specific tasks, often connected to handicrafts or practical subjects, and is linked to skills and creative activities that have a practical result as an objective (Wiese & Hovdenak, 2017). *Techne* includes the ability to both carry out a procedure and explain the reasons for taking a particular action (Saugstad, 2002). In the context of our Storyline project, it applies to the ability to organize specific practical situations within a class or a group to achieve practical goals (Birmingham, 2004).

In Aristotle's philosophy, *phronesis* refers to practical wisdom that enables people to choose the best course of action in a specific situation based on ethical reflection (Aristotle, 1953; Gustavsson, 2000). This form of knowledge changes constantly and can be applied to social interactions and ethical actions. *Phronesis* is inseparable from but not superior to practice. However, *phronesis* also assumes the use of theoretical knowledge as well as practical skills (Mathisen, 2007). It is linked to tactful and effective practices, and it requires consideration and reflection based on previous experiences. Eisner (2002, p. 381) describes *phronesis* as "a kind of morally pervaded practical wisdom". *Phronesis* demands responsiveness, openness, and sensitivity to the moment (Hovdenak, 2016). Underlying *phronesis* is the epistemic knowledge that makes it possible to link theory and practice in a meaningful whole. This form of knowledge evolves and changes depending on the situation as well as how and with whom a person works. Therefore, *phronesis* is not learned by attending lectures but rather by training, having experiences, and participating in social life during the performance of activities (Saugstad, 2002).

According to Järnerot and Veelo (2020), knowledge is not hierarchically structured (Fig. 1). Knowledge development assumes an interaction between the different knowledge forms, which may lead to an increase in these forms. It is impossible for someone to be fully educated, as learning is a constant process. This is symbolized by the infinity sign or open end in Järnerot and Veelo's model, where each of the three dimensions or directions symbolize the three Aristotelian knowledge forms.

The Aristotelian distinction between knowledge forms implies that theoretical knowledge (*episteme*) and the practical forms of knowledge (*techne* and *phronesis*) possess different characters (Saugstad, 2002). *Episteme* pertains to general, abstract aspects of life which we cannot change, while *techne* and *phronesis* define different possibilities for actions and behaviours and are to be judged according to specific situations. Birmingham (2004) draws a comparison between *phronesis* and Schön's work (1983) on reflection, which he describes as "knowing-in-action", "reflection-in-action", and "conversation with the situation". Both *techne* and *phronesis* are therefore considered practical actions. However, while *techne* has a more instrumental character, *phronesis* builds on reflections, previous knowledge, and experiences related to both *episteme* and *techne* through ethical and moral considerations in practical contexts. In the field of professional education, this practical reflexive ability is essential for combining the theoretical, practical, and professional aspects of teaching. A conscious application of this approach to professional education could help to make education more coherent (Smeby, 2008). Wiese and Hovdenak (2017) argue for the use of and interaction between different forms of knowledge in professional education because different forms of knowledge represent different aspects of teaching practice.

2.3. Professional development towards being a teacher

Teacher identity is created and changed in light of interactions within professional contexts (Olsen, 2008) and can have an impact on self-esteem, motivation, and satisfaction. The personal side of the development of teacher identity is essential (Timostsuk & Ugaste, 2010). Identity development takes place over time and through various meetings and processes and is also coloured by previous experiences. In addition, meeting with subject teachers and the topic on campus is significant (Izadinia, 2013).

Being a teacher includes the ability to facilitate good learning situations for the pupils in school through professional skills and the ability to be the leader of effective classroom management (Dahl et al., 2016, pp. 29–30). Knowledge-based and reflective work processes with a focus on professional practice may be activated through theoretical approaches towards various academic and didactic topics. Personal experiences and attitudes should also be considered. The development of professional skills largely depends on presented challenges and opportunities as well as the visions the students have or are presented with for working as a teacher. These can affect the students' relationship to new knowledge, how they perform according to a practical or theoretical task, and the ways in which they choose to present themselves (Izadinia, 2013).

Raising awareness for and developing values and visions are also important in the development of student teachers (Izadinia, 2013; Stenberg et al., 2014) because ideas and opinions form the framework through which a teacher student filters new information and thus decide how they use attitudes and views as a backdrop for further identity development (Stenberg et al., 2014). According to Korthagen (2004), it is important that a student's education takes their concerns and worries into consideration.

Kostiainen and Pöysä-Tarhonen (2019) underline the need for student teachers to experience an education they find meaningful through an emphasis on the course design and the provision of opportunities to gain strong experiences. According to Kostiainen and Pöysä-Tarhonen (2019), the development of future teachers is also dependent on a teacher education that fosters pedagogical and critical-thinking skills and the provision of opportunities to express both positive and negative emotions.

Table 1
Overview of the material, including the courses in which the project was carried out, the content of each case, the number of students involved in the case, and the number of students who participated in the survey and interviews. The students were in the 3rd or 4th year of their four-year teacher education and were not studying for a master's degree.

Semester	Student level / subject	Case	# students participating in TSA	# students participating in survey / interview
Spring-2015	4th year / Integrated science	Case 1: Evolution and the Environment: The island "Hope".Main task: How would you organize life on the island? You are the experts, and you will make a plan for how the inhabitants should survive in the future.	10	8
Spring-2016	3rd year / Integrated science	Case 2: Sustainable Development: The island "Hope". Main task: How would you organize life on the island? You are the experts, and you will make a plan for how the inhabitants should survive in the future.	17	13/13
Autumn-2016	4th year / Integrated science	Case 3: Technology and Design (TD): A journey through the history of technology from the Stone Age to 1900 Main task: Building a stone age residence and developing it by some steps against modern time	11	6
Autumn-2017	4th year/ Integrated science	Case 4: TD: A journey through the history of technology from Leonardo da Vinci to 1900 Main task: Building a medieval residence, including the use of wheels and the introduction of electricity (1900)	17	17

3. Materials and method

This project includes four cases (see Table 1). The four Storyline cases were completed in spring 2015, spring and autumn 2016, and autumn 2017. Four different student groups which included a total of 55 students in science teacher education, participated in the study. Of these students, 44 responded to the open survey, and 13 participated in three focus group interviews (4 + 4 + 5). Table 1 provides a short description of the aim of each case regarding the natural scientific themes covered in the student teacher projects.

The participants were student teachers in their third and fourth years of teacher education who were training to teach pupils in school between six and 13 years old. We have adopted an eclectic approach, including strategies to gather and store data considered to be useful and applicable to the situation at any time (see Cohen et al., 2011, p. 23). To assist our analysis, we collected teacher logs, pictures, and small video clips of student activities and their products, but these were only used to support the researchers' memories. Our main data came from an anonymous voluntary survey in the form of open questions that students could answer via a learning platform (LMS) at the end of every case. In addition, we interviewed 13 students (three focus groups) after completing the spring 2016 case (TD). The teaching platform used at the time of teaching is currently closed, and the stored results are 100% anonymous with no connection to participant names or IP addresses (according to GDPR). The tape recordings are stored offline, the transcripts are anonymous, and the tape recordings will be deleted when the project is finished.

In the survey and interviews, we asked students nearly the same questions: whether they liked TSA as an approach to teaching the given scientific theme, how relevant they considered the case for their future work as teachers, whether they thought they had enough knowledge to attain positive results in the tasks, what they found challenging during TSA work, and why they thought we used this approach as a part of their education in science. In the interviews, we also asked if they could reflect on pedagogical theories related to the use of TSA for teaching and learning. However, this last part of the study is not given any attention in this article. The purpose of the focus group interviews was to gain a deeper understanding of the participants' experiences and perceptions of TSA than what we gathered in the survey and to obtain better insight into whether and how the students found the approach useful for their understanding of the intersection between theory and practice as well as their understanding of the types of knowledge that TSA enables and its usefulness in preparing students for their future profession. We would have liked to place the student teachers' experiences into an interpretive context and conduct interviews with all participating students (Postholm & Jacobsen, 2018), but the framework of the study did not allow us to conduct more than four focus group interviews.

Charmaz and Thornberg (2014) underline the consideration that what researchers may see in the data may be affected by the researchers' prior perspectives. The science researcher designed this project, carried out the teaching, and collected data through the survey, while the focus group interviews were done by the pedagogue. We are aware that the process of analysis may involve a somewhat one-sided interpretation of the material based on the researchers' understandings and closeness to the teaching situation. In analysing the data, it has therefore been an advantage that we are two researchers with different professional backgrounds (pedagogy and natural science and technology) and with different responsibilities in the project. The focus group interviews and the answers from the survey woded and categorized overall after thorough reading and discussions between the researchers.

The inductive coding and analyses were inspired by an approach to content analyses (Cohen et al., 2018), beginning with a determination of coding categories through an open and axial coding process for both the survey and the interviews (Cohen et al., 2018; Postholm & Jacobsen, 2018; Strauss & Corbin, 2015). Students' responses to the survey questions and the results of the transcribed group interviews provided a rich body of material which presented opportunities for different approaches. The coding therefore occurred in several iterative stages: we went back and forth in the data material, considered it from different perspectives, and used the research questions as a guide. An example from the process is shown in Fig. 2. The purpose of the study was to obtain a closer look at how the student teachers experienced TSA to selected science themes with respect to the intersection between theory and practice and how relevant the student teachers found TSA as a learning approach for their professional development as teachers.

During the analysis process, two main issues were revealed. First, very few students stated that they had learned science theory during these Storylines, and many reported that they experienced a lack of theoretical scientific knowledge. The first category therefore addresses *the students' recognized need for better theoretical knowledge in various science fields*. Second, many students claimed that they wanted to use TSA as a learning method in their future profession as teachers. The second category therefore concerns *how students' experiences of TSA resemble real teaching situations and how TSA helps students to develop professional competence*, also referred to as *TSA as preparation for professional competence as teachers.*

Category 1: Students' recognized need for better theoretical knowledge in various science fields.	Did not know, wanted to have known, want to learn more about, did not train on  Knowledge or lack of knowledge	Have to do it ourselves, challenging, try it out, takes time, creative, fun  Like or dislike the approach	Decision-making together, discussions, solve problems, dependent on each other, making plans, exploratory work  Group processes	Need knowledge to make things, make installations, real world  Theoretical and practical work
Category 2: TSA as preparation for professional competence as teachers	Have to cooperate, story and clear goal - a visual result, practical and adapted learning, practical work motivates better learning, science knowledge in practical situations, relevant  Theory and practical work in school		Challenge pupils, adapted learning, interdisciplinarity, highly relevant to school practice, used on different levels, engaging and motivating, varied and practical, organisations and good plans  Didactic: if and how to use Storyline in school	

Fig. 2. Part of the analysis process: codes included in the two categories.

We have labelled the students' statements with a number representing each of the four cases. Additionally, to clarify which of the cases the statements concerns, we have used *S* to represent spring and *A* to represent autumn and have labelled the year the Storyline project was carried out. For example, "Student 6, S-16, Hope or TD" is student 6, spring 2016, in the case Hope or TD.

4. Results, analysis, and discussions

In the following section, we analyze, elaborate on, and discuss the two categories as results of the coding process: *the students' recognized need for better theoretical knowledge in various scientific fields* and *how TSA may help students to develop professional competence as teachers*.

4.1. The need for better theoretical knowledge

Theoretical knowledge implies the understanding of concepts as well as the application of concepts and theories in different contexts. Therefore, it is expected that concepts and theories can be justified, explained, and used within a variety of relevant contexts. In this project, many students explained that they liked the methodology of TSA and working in a group to solve a practical and theoretical issue, but very few could explain concepts or theoretical issues they had learned during the process of TSA. Nevertheless, several students expressed what they did not know as well as issues or theoretical approaches to different subjects that they would have liked to know or to know more about. Student 6 (A-16, TD), for example, wrote, "We should have been better in using the different names of the concepts. For me, I did not use the name of the materials and tools while working. Therefore, I did not train on this as much as I needed." The analysis revealed that during practical activities, many students expressed awareness of their own theoretical deficiencies and wanted to acquire deeper theoretical knowledge of various themes. "Day 2 with electricity, on the other hand, was very challenging when I had really no knowledge of it", wrote Student 3 (A-16, TD). The lack of theoretical reference was felt in situations in which students required theoretical knowledge to discuss and engage with the problems presented in TSA and to create products. Student 11(S-16, Hope) wrote, "Population issues and ecology, we need more theory about this…" As a result of their lack of knowledge, some students claimed that their group had to solve problems on their own, such as by searching on the internet: " ....We checked a bit on YouTube ourselves…" (Student 10, A-16, TD).

In the subject of TD, the knowledge of materials and tools as well as practical skills are as important as a theoretical background. The analysis of the survey and focus group interviews showed that the students who worked with TD felt that the experience revealed shortcomings in their knowledge of different materials. One of the students reported that, while participating in the TSA project, they had learned difficult techniques with which to build stable buildings. Students also discovered that better planning and drawing in advance could have a

significant positive impact on the results: “The drawings should be better prepared and the whole process should have been thought through before starting the construction” (Student 17, A-17, TD).

Tasks presented in cases 3 and 4 included the construction of houses or vehicles and the switching of power circuits to produce electricity. Although many students observed that electricity connection, installation, and the application of induction principles required theoretical knowledge they did not possess, they found the work interesting. During the TSA project "Hope" (cases 1 and 2), the students lacked knowledge relevant to the themes of evolution, biodiversity, energy, the environment, sustainability, and health. However, during the work, some students also found new issues which they wanted to know more about. Student 8 (S-16, Hope) wanted to learn more about genetics and population issues, while student 9 in the same case asked for more information about populations and their consequences on their surroundings.

The students‘ relations to new knowledge were affected by their personal experiences, challenges during their education, and their approaches to performing in accordance with practical or theoretical tasks (Izadinia, 2013). Reiser et al. (2021) underline the importance of student teachers experiencing subjects (in this case, science) as a meaningful practice. According to the researchers, this may be achieved through sharing goals and making progress together. The students in our TSA collaborated and had an active role in their work. In both the “Hope” cases and the two TD cases, the students were required to closely cooperate through discussions and the formation of plans rooted in theoretical knowledge and to collaboratively construct their models. All of the groups claimed that they cooperated well. However, through TSA, several of the students recognized a lack of both theoretical and practical knowledge, and it seems that these students received a “wake up call” about the need for more theoretical knowledge (*episteme*). It also seems that the approaches made the students more conscious about how the epistemic part of a subject matter is connected to “the real world”. Using TSA entails an acknowledgement of the need for both theoretical and practical knowledge (*episteme* and *techne*) to solve challenges. This sheds light on the connection between *episteme* and *techne* as equals rather than as hierarchically structured forms of knowledges (Järnerot & Veelo, 2020).

According to Reiser et al. (2021), the cooperation process in TSA entails epistemic agency. We found that performing practical activities in different disciplines raised the students’ awareness of their lack of a theoretical foundation while also clarifying the need for and relevance of new knowledge. As Student 28 (A-16, TD) wrote, "I think it was very nice to work this way and I got really challenged on things I did not know very well. Even though I did not know how to deal with the situation in the beginning, it was exciting to try to find a way that worked and then try it out and test it. Very good we did not get any recipe and had to find out ourselves.” In our study, the lack of knowledges made some students frustrated, but many viewed TSA as a funny, interesting, and creative approach to teaching and learning in which they felt motivated. Both Reiser et al. (2021) and Shepherd et al. (2018) claim that TSA may help students involve their emotions and curiosity in the learning process. This seems to correlate with the students’ experiences in our study.

By dealing with different challenges, the students focused on making good decisions to solve problems and reflected on what they did not know and how to deal with the situation. Karlsen et al. (2020a) underline that the perceptions of deep learning, emotional binding, and responsibility are made clear for students through TSA. They also underline that this may be time consuming. Some of the students in our study did mention in the survey that the approach is time consuming. Our TSA cases were completed during a short period, and this made it extra clear for the students that learning takes time.

4.2. TSA as preparation for professional competence as teachers

Many students also reflected on how to use TSA in school. For example, student 22 (A-17, TD) stated, “This may challenge pupils in very many ways, and it can be adapted to individual in a fairly simple way. You have to use theory in practice, you have to cooperate and think for yourself as there is no final decision on the problem or a way to solve it”. The student continued to reflect on the learning process: “The pupils are challenged, but the teacher is involved and guides along the way to take them a little further than they can on their own”. In Aristotelian thought, *phronesis* refers to practical wisdom that manifests in social interactions along with ethical actions and assumptions and that requires the use of both theoretical knowledge and practical skills (Aristotle, 1953; Gustavsson, 2000; Hovdenak, 2016; Mathisen, 2007). In our study, we found that the students reflected on and considered how to act correctly in different didactic situations. We claim that students who use TSA to learn and teach in science acquire experiences that will serve as an important basis for the ability to make tactful decisions and good practices. The students in this study have experienced the approach themselves and have shown the ability to consider and reflect based on previous experiences.

The analysis of the survey revealed that many students believed that TSA fits their program well because it involves “variation, creativity and inquiry-based learning” (Student 6 (A-17, TD) while also implying a great degree of interdisciplinarity. Student 9 (S-15, Hope) claimed, “TSA first of all seems like a method which promote interdisciplinarity, and it really capture and stimulates curiosity”. Student 11 (A-17, TD) claimed that TSA is “a nice way for teachers to get the interdisciplinarity in”. These reflections all coincide with other studies on TSA in different subjects and levels (Ahlquist, 2019; Karlsen et al., 2020a, 2019; Karlsen & Häggström, 2020; Karlsen & Lockart-Pedersen, 2020; Emo et al., 2020).

Many students considered the work to be highly relevant to school practice: “[It is] easier to engage [pupils in school] when you have a story and a very clear goal which make a visual result. And everybody working together makes motivation” (Student 10, S-16, TD). Student 8 (S-15, Hope) stated that the Hope project is a very creative activity and underlined it as a valuable approach that could be used in schools. Students saw the benefits of TSA as a practical approach that provides a variety of possibilities for adapted learning situations and the possibility to adapt learning to individual needs in a school setting. “The methodology – to work in groups, close to the real world as a project – is a very good approach related to interdisciplinarity which may easily be adopted to abilities and level of knowledge” (Student 23, A-17, TD). The feeling of having a learning process that is close to the real world during TSA is highlighted by Karlsen et al. (2019). Additionally, Reiser et al. (2021) claim that student collaboration by taking an active role in groups may help students understand both the epistemic part of a subject connected to “a real world” and involve emotions and curiosity in their learning processes. Karlsen et al. (2020a) claim that collaborative work in groups is of great value because the participants will experience the need for an interdependence between participants in the group. Many students in our study highlighted the value of dealing with a practical and theoretical issue in a group. Making students aware of the link between theory and practice, (f.ex. Häggström et al., 2020) is claimed by many researchers to be a challenge for teacher education (Chong et al., 2011; Darling-Hammond, 2014; Korthagen, 2004; Korthagen & Kessels, 1999), and we find that TSA is a possible answer to this challenge.

When it is necessary to situate themes in broader contexts, the student teachers observed that practical work can be motivation for better learning. Student 9 (A-17, TD) wrote, “You learn more when you implement the theories in practical work”. Many students found TSA to be relevant for their future work: “Like we have worked today shows how relevant much of what we learn in school is, I mean that we actually need it, for example when it comes to materials, strengths / weaknesses and mathematics” (Student 7, A-17, TD). This same student also continued by saying, “In addition, it is a form of work that is very practical, and then you get to use more knowledge and senses, you get creative, engaged, inspired and it is fun”. Student 13 (S-16, Hope) claimed that

this approach is an effective one to use in a school class, particularly if the teacher is engaged and manages to involve the pupils in the project. Student 11 (S-16, Hope) found the approach to be a motivating way to work because the participants can contribute to and be motivated to work towards a solution.

A few students were concerned about the workload and implementation of TSA. They thought it might be difficult to control a group during a Storyline because there are many technical and practical challenges that must be solved. Therefore, they believed that TSA requires more than one teacher in a classroom: "I think there must be a clear framework for this work in the primary school. The methods can be good on different levels, but especially in primary school, there must be much help, so the pupils can go on with the work without the teacher running between the groups" (Student 18, A-17, TD). At the same time, students generally agreed that using TSA is feasible as long as potential challenges are considered and solved during the planning period.

The analysis shows that the students used pedagogical and didactic theories to justify their working methods. Student 14 (S-15 Hope) explained how TSA can engage and involve student teachers and potentially students in school as well: "I think the teaching method is brilliant. Really catches the attention and engages. Especially fun that you [the teacher] 'dressed up' to give us a feeling of really being part of the story. Fun that we got into different roles. This made us feel like being part of the story and I felt we were taking the problems seriously and trying the best way to familiarize ourselves with the situation and to do a good job."

The students appreciated the opportunity to engage in exploratory work within a group striving to achieve a common goal. Many also responded positively to the varied and practical activities of TSA, which they viewed as encouraging, as involving different forms of knowledge, and as an exercise in creativity. Student 13 (A-17, TD) expressed these benefits as follows: "You really learn something necessary. In addition, it is a very practical method. You use different types of knowledges and senses. You have the possibility to be creative, involved, and inspired while having fun". Some students emphasized the additional bonus of being able to take advantage of each other's skills and knowledge while participating in TSA. In addition, students commented on the use of science language, and several claimed that TSA gave them ideas that they could develop and adapt as future teachers. One of the students in a focus group described the experience as very realistic and as a nice way to motivate all students. The student also underlined that the use of TSA in teaching and learning provides the opportunity to build or make something, which the student found very engaging. Student 13 (A-17, TD) claimed that TSA is a method that uses science knowledge in practical situations, which gives the subject and the content relevance and, as the students wrote, "in turn makes it feel like something useful to learn". All but one student wanted to use TSA as a future teacher.

Teacher education, particularly in science as a composed subject (including the scientific disciplines of chemistry, physics, biology, geology, TD, and science didactics), often involves many science teachers, which can result in teachers spending little time on each discipline and subject. Teaching can move swiftly from one theme to another, and students may consequently feel that the subject matter is insufficiently covered or that the themes are disconnected. The study of science education may therefore appear both superficial and fragmentary. At the same time, science teacher education has a dualistic focus. The Norwegian National Framework Plan (NRLU, 2016) combines scientific knowledge and skills (within scientific disciplines such as biology, physics, chemistry, geology, and TD) with didactic skills. When students request more in-depth discussion and more focus on didactics, it is challenging to provide this because the total framework for the subject is limited to 30 or 60 credits (ECTS). In this project, students applied epistemic theories and knowledge concerning educational and didactic theory on (among other topics) adapted learning, motivation, and how to learn. Using TSA, the students also found that theoretical knowledge (*episteme*) concerning the subject matter was an indispensable part of their education and realised that their knowledge in this area was insufficient. TSA highlights challenging conditions in education, which can affect how students learn both scientific knowledge and science didactics, as well as the challenges of teaching a composed and, to some degree, fragmented science subject.

As mentioned previously, an education which qualifies students for the teaching profession should offer a teaching and learning environment based on knowledge and reflections related to both theoretical and practical insights (Damsgaard & Heggen, 2010; Shulman, 1986, 2004; Solstad, 2010). The students' own experiences and ideas must be taken into consideration, and qualification for a teaching profession requires coherence between theory and practice (Chong et al., 2011; Darling-Hammond, 2014; Korthagen, 2004; Korthagen & Kessels, 1999). We find that TSA may fulfill these challenges.

5. Conclusions

In this project, students applied epistemic theories and knowledge concerning educational and didactic theory on (among other topics) adapted learning, motivation, and how to learn. Using TSA, the students also found that theoretical knowledge (*episteme*) concerning the subject matter was an indispensable part of their education and realised that their knowledge in this area was insufficient.

To promote students' awareness of and identification with their future professional roles, teacher education must be rooted in theory- and practice-related activities as well as knowledge and skills, and the relationships between these should also be emphasised (Chong et al., 2011; Darling-Hammond, 2014; Korthagen, 2004; Korthagen & Kessels, 1999). In our study, TSA effectively illustrated how students could use non-traditional methods as a point of entry into science and scientific didactic work. At the same time, the study shows that, through the performance of a practical task, students were able to reflect on connections between pedagogical and didactic theories, the necessity of both theoretical and practical knowledge, and their future work as teachers in school (Damsgaard & Heggen, 2010; Shulman, 1986, 2004; Solstad, 2010). In addition, students perceived TSA assignments – in which they were required to develop, explore, and accomplish practical and situated projects (see Mitchell-Barrett, 2010) in biology, environmental education, or TD – as suitable, meaningful, and motivational in the context of science education. Through the course of their work with TSA, the students became aware of gaps in their professional skills and asked to be taught more theory. The students considered their experience with TSA to be relevant to their future profession as teachers. It appears that the students successfully related the theoretical and practical knowledge acquired during TSA cases to classroom knowledge and professional practice as teachers.

We conclude that using TSA in teacher education might help to create coherence between practical and theoretical knowledge and between classroom teaching and professional practice. The project also revealed a need to spend more time on each case, as this would likely have enabled the students to devote more attention to remedying their lack of theoretical knowledge.

Based on the findings presented in this article and in accordance with those of Karlsen et al. (2019), we believe that there is great potential in further exploring the use of TSA and conducting follow-up research related to students' needs for more practice-related teaching. In doing so, it is possible to highlight the connection between theory and practice as well as the use of TSA to motivate the acquisition of new theoretical knowledge.

Declaration of competing interest

Regarding the paper "Storyline in science teacher education: Which forms of knowledge does it enable, and how is it relevant for the professional development of future science teachers? "- we see no conflict

of interest. The work is done as university employees, and we have received no extra funding.

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