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Engaging Students in Scientific Practices in a Remote Setting

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Abstract: The goal of science education has shifted from teaching scientific concepts to facilitating students' active role in making sense of phenomena through engaging in scientific practices (SPs). While engaging in scientific practices, students use and develop core ideas. The COVID-19 pandemic forced a shift towards online education, stressing the need to explore how SPs are used in a remote setting. This study aimed to investigate upper secondary students' use of SPs during collaborative work in a remote setting. The study was conducted in two stages. In Stage 1, the researcher designed collaborative assignments according to the SP approach. In Stage 2, students (N = 16) worked on the designed assignments in small groups. Students' actions on the computer were recorded with screen-recording software and investigated from three perspectives: use of digital resources, use of SPs, and collaboration. Interviews were conducted to understand students' perceptions and engagement and were analysed by content analysis means. The results indicated that the collaboration actions were intertwined with SPs use and use of digital resources. The challenges faced by students varied by SPs, with developing models and constructing scientific explanations causing the most challenges. We discuss possible strategies to engage students in SPs in online settings.

Keywords: online learning; collaborative learning; technology-enhanced learning; COVID-19

1. Introduction

Scientific practices (SPs) reflect the multiple ways in which scientists explore and understand the world and are similar to expert performance in science. Such scientific practices are being promoted globally in science education [1,2] and recognised in science curricula [3,4]. In the Finnish curriculum, using and learning scientific practices are seen as the core aims for science education [5]. While many competencies can be categorised as scientific, and various practices can be used in science lessons [6], we focused on the following scientific practices, which are common and emphasised in the Finnish curriculum and in many other curricula, such as in the Next Generation Science Standards (NGSS): asking questions, developing and using models, planning and conducting an investigation, analysing and interpreting data, applying mathematics, constructing an explanation, and obtaining information [7]. According to the literature, the use of SPs in a classroom setting can support the development of student engagement [8–10]. In this study, situational engagement is conceptualised as situations in which students experienced a specific task as cognitively challenging and, at the same time, evaluated their interest in and the skills for the task as high [11]. We follow the assumption that when students are situationally engaged in scientific practices, they will seek similar activities in the future, encouraging them to learn science [12]. The focus on engagement in the SP approach, along with the use of inquiry-based learning, emphasises the connection between doing and learning [7]. "Doing science" is quite often considered to be only conducting experiments in the laboratory, but science education requires a far wider context.

In 2020, teaching processes around the globe were affected by the COVID-19 pandemic, which forced a shift towards learning in a remote setting. Teaching, learning, and students' well-being in Finland during the COVID-19 pandemic have been analysed and discussed

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in several papers and books [13]. The preconditions, such as teachers' and students' digital competences and the digital infrastructure necessary to switch to distance teaching and learning, have been recognised to be at an appropriate level [14]. However, students', teachers', and principals' engagement and well-being have been shown to have been decreased during the pandemic. Due to the supportive pre-conditions, the switch to distance teaching and learning was organised effectively, but the remote learning period weakened the equality of teaching and the conditions that encouraged learning and well-being [15]. Consequently, the science teaching processes were affected by the COVID-19 pandemic. According to recent studies, during remote learning, students were doing considerably less practical work and collaboration [16], which meant less opportunities for students to develop key scientific practices [17] and conceptual understanding [18]. In online settings, virtual laboratories and simulations such as PhET interactive online simulations are often used to address experimental work. While there have been multiple prior studies on virtual laboratories and simulations, most of them investigated concrete solutions or tasks [19]. The SP approach, on the other hand, stresses that SPs are not independent but necessarily interrelated, and, when transferred to the online setting, the same deep connection and interrelation between SPs should be kept.

In addition, a sociological perspective on scientific practices has not yet been pursued in the literature [20]. The COVID-19 pandemic has limited opportunities for student collaboration and interaction and created the need for more meaningful learning and collaboration and ways to support students' engagement [16,21–24]. This is why investigation of the use of SPs within remote collaboration situations is of particular interest. As most studies on SPs cover classroom settings [1,7,8], there is limited knowledge of the SP approach in online settings [25]. The purpose of this study was to investigate first-year upper secondary students' collaborative work in a remote setting, focusing on three perspectives: use of scientific practices, collaboration, and use of digital resources and tools. This study was guided by the following research questions:

1. What are the patterns of use of SPs during collaborative work in a remote setting?
2. What were the students' challenges when using SPs in collaborative online assignments? How were these challenges overcome?
3. How was the use of SPs in collaborative online assignments perceived by the students?

In this study, we use the terms "remote" and "online" interchangeably to refer to a setting without the physical presence of teachers and students in the classroom, and in which learning is accomplished using a multitude of digital resources and tools.

2. Materials and Methods

This exploratory study consisted of two stages. In Stage 1, we designed collaborative online physics assignments in cooperation with the physics teachers involved in the study. In Stage 2, the assignments were implemented in Helsinki secondary schools through online learning.

2.1. Assignment Design

In the design phase, we collaborated with the teachers and chose the topics for the assignments, related core ideas, and concepts, ensuring they were in line with the current teaching. For each topic, two assignments were developed. The context of the first assignment was similar to the contexts in which this topic is usually presented in the learning materials. The second assignment could be imbedded in a context possibly unfamiliar to students, yet it still fell under the same topic and represented the same core ideas and concepts. In this way, it is possible to explore the use of SPs in different contexts, both familiar and unfamiliar.

In each assignment, there were several tasks addressing different scientific practices so that the set of two assignments would address all the scientific practices that were at the core of this study. The first task in the assignment did not require deep prior knowledge, e.g., making observations based on the given video or virtual simulation, thus easing the "entrance" for the student. The subsequent tasks required students to work with prior and new knowledge and to use scientific practices. The practices concerning experiments utilised PhET interactive online simulations. The investigations were not set in stone, and it was possible to choose different investigation questions within one experimental setting or to explore different models. The assignments included links to several online resources, but students were encouraged to search for additional information and to use additional resources and materials. One example of the assignments is presented below (see Figure 1). In this example, students investigated liquid flow, and the highlighted SPs were constructing scientific explanations and using and developing models. Though the SPs related to conducting experiments were not the focus of this assignment, the PhET simulation was used to support visualisation of the context. In addition, using the simulation made some of system's the parameters visible, which might support students when developing models. Students could investigate conservation of mass or conservation of energy in this assignment, depending on their level. Developing models included developing visual models and mathematical models in the form of equations, leading to a continuity equation or Bernoulli's principle. In the presented task, the conservation of mass was chosen by the teacher and researcher. Additional videos and other possible resources were used to support students in finalising their conclusions and connecting their observations and models.

Assignment 2

(1) Open the digital lab "flow" (link). Investigate the phenomena by changing parameters. What have you observed? Write 2–3 observations.
(2) Choose one of the observations. For this observation: What could be possible further investigation? Formulate an investigation question.
(3) Imagine a mass of liquid moving along the flow in the tube with different cross-sectional areas. What would you observe when this mass flows from one part of a tube to another one with a different cross-sectional area? You can support your explanation with drawings.
(4) If, every second, 5 grams of liquid enters the tube, how many grams per second leave the tube on the other side? Explain your answer.
(5) In what way could we write the conservation of mass? Develop a model.
(6) Watch the video (link) or watch/read any other source on the topic.
(7) Explain the model given in the video/another source. Make conclusions about your model and the model presented.
(8) Does the presented model provide a background for any of your observations and/or investigation questions? Explain.

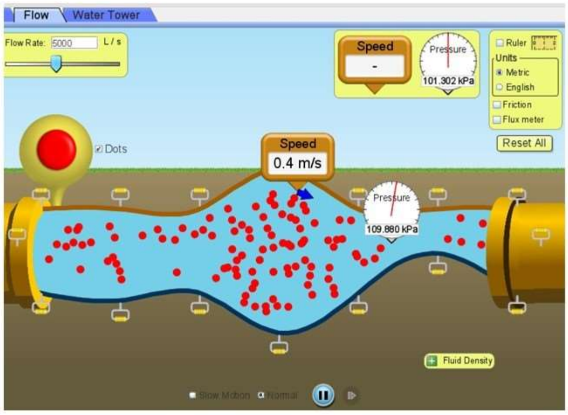

Figure 1. Example assignment with a screenshot from a PhET simulation.

2.2. Implementation of Assignments

In Stage 2, the assignments, designed in Stage 1, were implemented in two schools in Helsinki. This subsection describes our research context, data collection, and data analysis.

2.2.1. Research Context

The purpose of this study was to explore first-year upper secondary students' collaborative work in a remote setting, focusing on three perspectives: use of SPs, collaboration, and use of digital resources and tools. The assignments designed in Stage 1 were implemented in two schools in the metropolitan area of Helsinki in the autumn of 2020 in a remote learning setting.

We worked with two teachers from two different schools. The teachers implemented the assignments as part of their teaching for their first-year upper secondary class in a remote setting. Participation in the study was voluntary. Four students from one school and 12 students from another school volunteered to participate and recorded their screens while working on the assignments. Altogether, 16 upper secondary first-year students participated in the study.

Students worked collaboratively on the assignments in small groups, with 2–4 students per group. For each assignment, students had two 2 h online synchronous sessions. During each session, students worked together on a shared document (e.g., using Google Doc or Teams) and communicated via online chats. They used PhET interactive online simulations and a variety of digital tools and resources of their own choice. The teacher was not in the same synchronous session; however, students were allowed and encouraged to contact the teacher with any questions or problems. After both assignments were completed, participants perceived experiences were collected via semi-structured interviews.

2.2.2. Data Collection and Analysis: Screen Recordings

In order to explore the use of SPs in online settings, data collection for this study included screen recordings created with screen-recording software (APowerSoft or any similar software of the student's choice). This collection method has been used in previous studies [26,27]. Recording of a screen is a rather invasive method of data collection that can make it difficult to find willing participants [28,29]. In this context, informing participants of the details of the study was an important step towards allaying hesitation [28]. We thoroughly informed potential participants about the data collection and analysis process in our study. The software recorded participants' exact actions on their computers, allowing us to see the process from the inside: the interaction with other students in the chats or shared documents, the ways of accessing and using digital resources, the ways in which scientific practices were used, and the surrounding context. Overall, the screen-recording data consisted of screen-recording videos of 16 students, about 60 h altogether. The collected screen-recording data were rich and dense, revealing the "hidden moments" of the learning process. To analyse the macro-level patterns of the collaborative work in a remote setting, we developed a method that enabled visualisation of the complex screen-recording data of the students' work processes. The analysis involved two stages: (1) systematic coding of the screen-recording data; and (2) conversion of this data into a pictorial form, which enabled visualization of data and perception of the patterns of the processes as a whole.

For systematic coding, observable elements of activities and actions were coded using Atlas.ti, following three perspectives: access and use of digital resources, SPs use, and collaboration. The coding scheme was developed based on a literature review [30–32] and through an examination of the data. The main categories and some examples of the codes are presented in Table 1. As students were collaborating via online chats and/or shared documents, the collaboration perspective was analysed by coding students' messages.

Table 1. Examples of codes.

Category	Subcategory	Examples of Codes
Access and use of digital resources	Using digital resources	Experimenting/playing with the simulations In-depth reading or watching content resource Using computational software (e.g., GeoGebra)
SPs use	Analysing data	Transforming data in the form of graph/chart
	Building a scientific explanation	Presenting evidence and data Formulating a reasoning
Collaboration	Conversation	Coordinating group process Confirming/accepting
	Active learning	Elaborating
	Creative conflict	Doubting Offering an alternative

In a remote setting, in which an individual on the micro level may asynchronously navigate within digital resources and tools individually, it is important to analyse the observable actions of that individual. However, as we wanted to explore the macro-level patterns of collaborative work in a remote setting, we also needed a way to visualise the macro-level view of the collaborative process. For this macro-level view, each category was visualised with a colour: green for SPs use codes, orange for the use of digital resources codes, and pink for collaboration codes. The visualised table (see Table 2) presents the observable actions of all students working on the assignment in the group at the same time. Each dot represents a code of observable actions belonging to one of the categories. Each row signifies a three-minute episode of group work, and, in each row, we can observe what happened on both the individual and group levels. Several dots of the same colour mean that student applied several different actions from one category. Thus, we can see from Table 2 that all three students were mostly accessing and using digital tools and resources during the first three minutes. Afterwards, Student 1 was active in the discussion, and, by minutes six to nine, the students were all using scientific practices and engaging in discussions. Based on our initial explorations and previous research on collaborative processes [33,34], data are presented in three-minute segments. The resolution is sufficient for revealing activities but not too detailed for the macro-level view. In addition, this macro-level visualisation allows us to follow the chronological aspects of overall processes and imparts the ability to zoom in on targeted events for a more detailed intermediate level of analysis.

Table 2. Visualised data of the first 15 min of work by one of the groups. The dot colour represents that the observed action belongs to one of the following categories: 🟠 Access and use of digital resources; 🟣 Collaboration; 🟢 SPs use.

Group 1, Assignment 2			
Time Period, min	**Student 1**	**Student 2**	**Student 3**
0–3	🟠🟠🟠🟠	🟠🟠🟠	🟠🟠🟠🟠🟠🟣
3–6	🟣🟣🟣🟣🟣	🟠🟠	🟣
6–9	🟣🟢🟣	🟣🟢🟢🟢	🟢🟠🟢🟠🟢🟣🟣
9–12	🟣🟣🟣🟣	🟣🟣🟣	🟢🟢🟢🟢🟢
12–15	🟣🟣🟢🟢🟠	🟣🟣🟢	🟠🟠🟢🟣

To investigate students' challenges in more detail, we implemented an intermediate level of analysis. We utilised results from the macro-level analysis, following the episodes in which SPs were used and the episodes in which students were collaborating actively in the chat. We zoomed out from these episodes to larger parts of the surrounding context related to the episode, including relevant discussion in the chat. This material was further coded inductively, focusing on how SPs were used. This analysis facilitated the identification of challenges related to each SP.

2.2.3. Data Collection and Analysis: Interviews

Altogether, eight first-year upper secondary students were interviewed to obtain information about their experiences and perceptions of collaborative work in a remote setting. The semi-structured interview focused on students' perceptions in terms of skills, interest, and challenges within each of the main three perspectives, namely, use of SPs, collaboration, and use of digital resources. The interviews were conducted remotely using Zoom, Google Meet, or Teams, based on the student's preference. Each interview took between 20 and 40 min.

In the analyses of the interviews, we combined deductive and inductive approaches. The main categories were chosen to be in line with the overall study design and included such categories as "use of SPs", "use of digital "resources", "collaboration", "perceptions", and "general comments". According to the literature, situational engagement theory is described through interest, skill, and challenge [11]; thus, such subcategories were added to the "perceptions" category. Furthermore, we maintained an unconstrained matrix on the subcategories level, allowing different subcategories to emerge within the category's bounds and following the principles of inductive content analysis.

3. Results

The results of this exploratory study are reported in three subsections: (1) macro-level view and patterns of the processes during the collaborative work on the designed assignments in a remote setting; (2) students' challenges; and (3) students' experiences and perceptions of collaborative work in a remote setting.

3.1. Overview of the Processes during the Collaborative Work in a Remote Setting: Macro-Level View of the Processes

The data analysis revealed that the use of SPs was intertwined with the use of multiple resources and active collaboration (See Table 3). The findings show that the use of SPs was preceded by using digital resources and collaborative actions. SPs use and collaboration progressed iteratively, supported and amplified by using digital resources and tools. In Table 3, we can also observe the "asynchronous" aspect of the learning process in the online setting, where students shift between collaborative, digital, and cognitive (related to SPs) dimensions. Thus, in Table 3, Student 1 from Group 2 is actively using digital resources, while Students 2 and 3 are involved in the discussion. This use of digital resources resulted in engaging scientific practice and further discussion within the group. The students whose action sequences included rare SPs that used actions (green dots) demonstrated rich collaboration. According to the literature, an individual's engagement in the social processes in collaborative learning positively predicts an individual learning gain: actively becoming aware of and arguing about each other's ideas enhances one's own understanding of the domain's content [35,36].

Table 3. Visualised data of the first 21 min of work of two groups. The dot colour represents that the observed action belongs to one of the following categories: 🟠 Access and use of digital resources; 🟣 Collaboration; 🟢 SPs use.

Table 3. *Cont.*

	Group 1, Assignment 2			Group 2, Assignment 2		
Time Period, min	**Student 1**	**Student 2**	**Student 3**	**Student 1**	**Student 2**	**Student 3**
0–3	🟠🟠🟠🟠	🟠🟠🟠	🟠🟠🟠🟠🟠🟣	🟣🟠🟠🟠🟣	🟣🟣🟣🟣	🟠🟠🟠🟠🟣
3–6	🟣🟣🟣🟣🟣	🟠🟠	🟣	🟠🟠🟠🟠🟠	🟣🟠🟠	🟠🟣
6–9	🟣🟢🟣	🟣🟢🟢🟢	🟢🟠🟢🟠🟢🟣🟣	🟠🟠🟠	🟣🟣🟣	🟣🟣🟣
9–12	🟣🟣🟣🟣	🟣🟣🟣	🟢🟢🟢🟢🟢	🟢🟢🟠🟣	🟠🟠🟣	🟠🟠🟣
12–15	🟣🟣🟢🟢🟠	🟣🟣🟢	🟠🟠🟢🟣	🟠🟠🟣	🟠🟠🟠🟢🟢	🟣🟣🟣
15–18	🟣🟢🟣🟢	🟠🟣	🟢🟢🟢	🟢🟠🟣	🟠🟣🟣🟢🟢	🟠🟠🟣
18–21	🟢🟣	🟢🟢🟠🟠	🟢	🟠🟣🟢	🟢🟢🟢🟢🟢	🟢

Following the episodes of use of SPs as well as episodes of rich collaboration, we further zoomed in on the students' challenges and the ways they were overcome.

3.2. Students' Challenges When Using SPs in an Online Setting

In this section, we will present the findings regarding students' challenges when using SPs in an online setting. We will present the results of the intermediate-level analysis of the screen recordings, as well as findings from the interview analysis, with a focus on challenges related to the use of SPs, collaboration, and use of digital resources. Finally, we will present the results of the interview analysis concerning the ways in which the experienced challenges were overcome by students.

3.2.1. Screen-Recording Data

In the intermediate level of analysis of the screen-recording data, we examined the experienced challenges related to SPs use. The findings reveal that most challenges were related to such scientific practices as developing models and constructing scientific explanations (see Table 4). The task "develop a model" spurred discussions concerning the task objective. The design of the assignments allowed various ways to model several phenomena from various perspectives; however, student discussions revealed a common belief in one and only one correct model. Obtaining information did not cause challenges and students demonstrated confidence browsing, accessing, and evaluating a variety of resources. However, synthesising information from several sources required additional team effort, especially when constructing scientific explanations, and was accomplished in an iterative manner.

Table 4. Examples of actions and chat discussion excerpts that represented challenges in SPs use from the analysis of screen-recording data.

Scientific Practice	Observed Actions/Excerpt of Discussions
Planning and carrying out investigations	Changing the controlled variable in a virtual experiment
	Writing the experiment plan after the experiment
	A: (after an internet search) "Oil density is 800, and we got 910. Did we calculate it correctly?"
Developing scientific explanations	J: "I don't know if it is understandable, but here is what I think . . . " L: "Ok, I did something. Now can someone explain to me in a smart way what I am doing?"
Developing models	L: "Well, this is done, now some model. Whatever it means." K: "Yes. Doesn't it just mean like some "theory" that fits?"
	M: "Well, so we did the totally wrong thing." N: "Yes, our model was wrong."

Scientific explanations were, in most cases, first developed in chats. The communication regarding scientific argumentation in the chat messenger developed iteratively on a personal level: students often rephrased their contributions, editing their messages several times or adding additional logical connections before sending them to the chat. Most of the constructed scientific explanations consisted of the claim and grounds, with evidence and facts that helped to support their claims. However, linking the grounds to the claim caused challenges and was even missing in several cases.

The findings concerning the practice of planning an experiment presented a particular interest. None of the groups could come up with a plan for the experiment until they had spent a significant amount of time trying out the simulations, and the plans were written after the experiments were conducted. Though this "inverse" way of experimenting, representing learning-by-doing, we want to stress the following points: (1) the plan for the experiment was formulated in a coherent scientific way only by groups that also read the texts on the topic before/after they conducted an experiment, thus connecting their experiences with the existing models of phenomena; (2) collaboration played a significant role in the iterative process of conducting an experiment; and (3) the "inverse" method might lead to wasting time and resources in a real experiment.

3.2.2. Interview Data

In addition to the challenges observed in the screen-recording data, we analysed the students' interviews and their perceptions of experienced challenges. Under the SPs use category, the practice of developing models was perceived by most of the students as a challenging scientific practice. However, the articulated reasons for that differed in nature. Most of the students stated reasons of a cognitive nature, while others claimed that developing models required a lot of communication.

An unexpected challenge category mentioned in the interviews was the use of chat messengers. Nearly all the students perceived using chat messengers as a challenge.

However, as the corresponding interview excerpts in Table 5 indicate, in most cases, the challenge of using the chat messenger was related more to communication in general and to scientific communication in particular. Additionally, students felt that they could have progressed faster if they had talked instead of using chat messengers.

Table 5. Interview excerpts representing challenges in SPs use.

Challenge Category	Subcategory	Excerpts from the Interviews
Collaboration	Using a chat messenger	"It is hard to write so that others understand you." "It was difficult to develop your ideas so they can be written clearly." "It was difficult to understand others because we had to write."
	Working in a group	"We had to ask others if it is OK." "It took a lot of time to share all the ideas."
SP use	Developing models	"Developing models was difficult because it required a lot of communication." "It was difficult to develop models and make explanations." "To develop the model and to analyse it, that was difficult." "Developing models was difficult because it required a lot of communication."

The perceived challenge of using the chat messenger instead of talking when constructing scientific explanations might be explained from the perspective of iterative explanation construction in a collaborative situation. We assume that when discussing ideas in a group in a classroom setting, students might focus less on the detailed and precise formulation of their thought as a whole. These communicated oral messages might more so resemble pieces of ideas, as incomplete "drafts", to be extended and rephrased further in the discussion process, especially in the case of active collaboration, when several people talk almost at the same time. A written message, however, might be perceived more as a "complete" unit of information, and any lack of logic or information in the message can be seen and recognised by the student before sharing it with others. As we observed in the screen-recording data, students tended to edit and rephrase their messages with explanations several times before sending them to the chat. In such a case, the iterative manner of constructing an explanation first took place on an individual level and required more cognitive effort in the first iteration. Thus, it was perceived as more challenging.

The ways that the students overcame these challenges incorporated both social and technical aspects (Table 4). The participants mentioned the importance of working as a team and the iterative nature of the collaborative process, as well as the rich use of digital resources.

An additional interesting point concerns the involvement of the teacher. The students were allowed to contact the teacher for support and hints, but none of the groups used this resource. Even when facing challenges and feeling "stuck", they attempted to overcome the issues on their own. It is possible that contacting a teacher in this study setting required more effort from the students than in a classroom setting, where the teacher is always nearby, making it easy to ask for hints whenever one faces challenges. In the designed setting, students preferred to take a moment to think more and discuss in their teams. This issue, however, should be tackled in the design phase, and the overall learning design should provide students with easy ways to communicate with the teacher.

3.3. Students' Perceptions

Students' perceptions were analysed with a special focus on interest, skill, and challenge. The interviewees expressed that they still felt the need for further practice, even though they had the appropriate level of skills to complete the assignments. Most reported that the most challenging, interesting, and successful part of the assignment was related to the same SP (see Table 6). Even when other parts of the assignment were completed successfully, many interviewees highlighted the part, where they used the, reportedly, most challenging SP, as the part where they achieved the most success.

Table 6. Examples of students' perceptions regarding the assignments in terms of skill, interest, and challenge.

Student's Level of Skills to Complete the Assignments	Most Challenging SP	Most Interesting SP	Most Successful SP
J: "It was enough, but on the border"	Develop models, construct scientific explanations	Ask questions, develop models	Plan an experiment, use and develop models
L: "It was just enough"	Ask questions, develop models	Ask questions, develop models	Ask questions, develop models

Considering that reported interest with appropriate skill and challenge levels related to a particular practice [8,11], we can assume that students were situationally engaged in scientific practices when working collaboratively in the online setting. The findings also aligned with the study conducted by Marks [37], suggesting that students who were situationally engaged were more likely to experience learning as rewarding and to seek similar activities in the future.

4. Discussion

In this section, we will first discuss the results and findings of the study and then reflect on the study limitations and further research directions.

In this exploratory study, we attempted to bring scientific practices to the online remote setting and explore students' work on collaborative online assignments designed according to the SP approach. The data revealed that the use of SPs was tightly intertwined with collaborative situations and the use of various digital resources. Moreover, both the use of digital resources and collaboration aspects helped students to overcome challenges and to move past the "stuck" moments, which meant that these components were crucial when transferring the SP approach to online settings. Online assignments should incorporate and support these aspects to enhance engagement in SP in an online setting.

The developing models SP and the building scientific explanations SP caused challenges of different natures. The same SPs have been reported in the literature to be challenging in non-digital environments, and a large number of studies have investigated ways to support students in using these SPs in a classroom setting [8,38,39]. In our context, interactive simulations could promote forward thinking of model limitations and rebuttals, e.g., friction on/off buttons could indicate that friction plays a significant role and alters the behaviour of a system. Although the participants did not reflect on this in the current study, this possibility can be taken into consideration in future assignment designs and used to introduce the concept of model limitations and rebuttals in argumentation. Models also play an important role when coming up with ways to find an unknown value in the experimental setting—i.e., when planning an experiment. While planning an experiment requires working with models and meta-knowledge [38], planning the experiment after the experiment, as observed in our study, was closer to an iterative description process. Thus, challenges related to developing models could lead to an "inverse" method of experimentation, which might waste time and resources, especially in a non-digital setting. Our findings supported the idea that SPs are not independent but necessarily interrelated [39].

Another interesting finding concerned the teacher's involvement. None of the groups used this resource even when facing challenges and feeling "stuck". Instead, they pursued their attempts to overcome the challenges on their own. The role of the teacher in similar activities and how remote learning encourages or discourages independence, and collaboration should be further investigated.

The students generally perceived the designed assignments and related scientific practice learning positively and reported interest and an appropriate level of challenge and skills, which allows us to assume that situational engagement took place. They further stated their wish to practice similar activities in the future.

There are some limitations in this exploratory study, and further research is thus required. First, we can consider the implementation phase of this study as short (two months). It might be beneficial to investigate SPs use in online settings in the long run in longitudinal studies. Moreover, further studies might take objective measures to examine its effect on student achievement. Another limitation is the number of study participants. Though this study was explorative in nature, and the current number of participants allowed for a deep exploration of processes in an online setting using varied methods of data collection, it was not possible to make generalisations. In addition, since participation in the study was voluntary, there was a risk that mostly high achieving students volunteered. However, we believe that because data were collected during online groupwork, which was a part of usual remote learning activities, participation in the study was not perceived by students as a high-level physics activity for only highly achieving students and that students of different levels of achievement have participated in the study. In further studies, a higher number of participants, both teachers and students, is recommended.

5. Conclusions

This study explored the use of SPs in collaborative online settings and students' engagement in SPs. Students encountered challenges of different nature; however, most challenges were using and developing models and constructing scientific explanations. The design of the assignments should support students when dealing with the SPs related to models and scientific explanations. Additionally, the assignments designed for online learning should be collaborative and require the use of variety of digital tools and resources, as these aspects helped students to overcome challenges. Joining the discussion of the weakened collaboration and SPs use in remote settings [16,21], our study has explored students' challenges when using SPs and demonstrated that students in remote settings can be active, situationally engaged, and actively collaborating. This study presents a step in bringing the SP approach and inquiry-based learning to remote settings and can be a take-off point for further research investigating ways to adopt similar assignments in wider contexts to improve science education.

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