Science learning with emotions: Preservice science teachers as drama facilitators

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Drama activities have been argued to engage students' cognitions, emotions and actions, making them a prospective, although not very well understood part of science education. The aim of this study is to understand pre-service science teachers' (PSSTs) experiences as drama facilitators for high school science students. The experiences of preservice science teachers' drama facilitation were explored in two cases, in which they designed and facilitated drama activities for high school students (13-15 years old). The PSSTs in both cases read a story to students, who were then given roles related to that story. The data consists of in-depth interviews with the PSSTs. In the interviews concerning their experiences, the PSSTs were found to to recognize science learning opportunities and challenges while taking care of student inclusion and showing sensitivity towards students' emotional expressions. The study illustrates a novel framework for working with science learning opportunities and challenges related to emotional expression in drama activities.

Keywords: scientific literacy, emotions, drama, solidarity

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1 Introduction

Science is a human endeavor and as such it is conducted and learned with a full range of emotions, such as joy, wonder, amazement, surprise, anxiety and fear, to name a few (Sinatra, Broughton, & Lombardi, 2014). However, science education has traditionally emphasized cognition at the expense of emotion (Bellocchi, Quigley, & Otrel-Cass, 2016). This is problematic, because cognitive processes are not detached from emotions, nor can they be fully understood without considering emotions that influence, for example, perception, attention, learning, memory, and problem-solving (Tyng, Amin, Saad, & Malik, 2017).

Drama activities, which have been asserted to engage students actions, emotions and cognitions (Ødegaard, 2003), are a prospective starting point for developing practices suitable for emotionally-engaging science education. Drama practices draw from professional theatre and drama groups, who employ mimicking, dance, role-play, improvisation and so on, in their work (Lee, Patall, Cawthon, & Steingut, 2015). Previous studies illustrate how these activities enable exploration of abstract scientific ideas on a more personal level (Close & Scherr, 2015; Danckwardt-Lillieström, Andrée, &

Enghag, 2018). However, science teachers rarely adopt drama activities in their daily practice (Barbalet, 2011). Therefore, researchers have suggested that science teacher education should introduce more research and strategies in order to promote science teachers' confidence with drama practices (Belova, Eilks, & Feierabend, 2015; Braund, 2015).

To understand the aspects of drama facilitation that require more support, we need to explore the experiences of those who do not yet have a lot of experience with drama. And since emotions have traditionally received less emphasis in science education, a special focus should be placed on science teachers' capacities to work with students' emotions within drama activities. Therefore, this study aims to better understand the experiences of preservice science teachers (PSSTs) as drama facilitators with high school students. To do so, we investigated two cases in which PSSTs facilitated drama activities for high school students. In these activities, students enact roles based on PSSTs' narration, which created possibilities for the PSSTs to observe and interact with students' emotional expressions.

The goal of the study is to help close the gap between cognition and emotion in science education and to provides tools to meet some important aims of critical scientific literacy, such as solidarity and empathy within science education (Sjöström & Eilks, 2018). Drama activities that engage students' emotions can here be a useful tool. However, this might require that science teacher i) knows about and ii) feels confident about working with both emotions and drama in science education.

2 Emotions

There is no scientific consensus on the definition of emotion. Researchers often agree that emotions are episodes that involve cognitive evaluations, physiological reactions, motor expressions and experiences (Scarantino & de Sousa, 2018). Moors, Ellsworth, Scherer, and Frijda (2013) suggest that emotions can be understood as responses to events that are significant for an organism's well-being. Emotions are differentiated from moods, which are emotional states with a less specific object focus and persist for a longer time (Pekrun & Linnenbrink-Garcia, 2012).

Emotions are interwoven with cognitions. The assumption of one key cognitive theory is that an individual needs to cognitively evaluate, or appraise, the significance of the perceived event before emotion is elicited, although this evaluation can happen unconsciously (Moors et al., 2013). Indeed, emotions can guide attention to significant events before they reach consciousness. It is possible to sense fear before realizing the approaching danger. Emotions influence cognitive processes. Meta-analysis indicates that emotions influence at least perception, attention, learning, memory, and problem solving (Tyng et al., 2017).

Emotions involve motor expressions, or actions, and they have the power to interrupt other competing processes such as memory or attention and prepare the individual for immediate action (Scarantino & de Sousa, 2018). Frijda (2010) characterizes emotional actions as impulsive because they require no reflection, no foresight, nor planning. He adds that impulsive actions are still intentional because they are directed towards a desired end point. He then elaborates that an impulse does not determine which action an individual chooses: reflective actions are chosen when there are no adequate action schemata available or when impulsive action may have negative consequences.

Emotions can also be understood as social. In sociological emotion research (Turner, 2009) the focus is on social interaction, observing groups and their social behavior rather than individuals. This line of research has anthropological roots, such as the investigation of emotion as interaction rituals (Collins, 2004). His findings indicate that emotions can synchronize group actions and focus a group's attention towards one target, creating experiences that lead, for instance, to solidarity. Prosocial emotions (directed towards other instead of self) such as outrage and empathy are important for action, because it has been suggested that they motivate social change (E. F. Thomas et al., 2009).

Moreover, Hareli and Parkinson (2008) characterize social emotions, such as shame, jealousy and embarrassment, as being social in a different way than other emotions, because they necessarily depend on other people's thoughts, feelings, and actions directly or through norms and generalizations in the surrounding social context. They elaborate that these social emotions are caused by appraisals, or social concerns, related to status, power and attachment within a group. Adolescence is a period spent looking for personal social groups and is thus a remarkable time for social emotions. The importance of social emotions is confirmed by neurological studies in experimental settings that indicate a heightened emotional impact caused by social rejection during adolescence (Sebastian, Viding, Williams, & Blakemore, 2010).

3 Emotions in science education

Science learning is a process full of different emotions, including joy, wonder, amazement, surprise, anxiety, and fear (Sinatra, Broughton, & Lombardi, 2014). We will briefly elaborate on emotion research and teachers' facilitation of emotions in science education. For a broader account we advise the reader to see, e.g., Sinatra et al., (2014) or Bellocchi et al., (2016).

Research indicates that certain emotional states are better than others for science learning. For example, positive moods (joy, enjoyment, hope) lead to creative engagement with flexible, resilient, and holistic ways of problem-solving, while negative moods (anger, fear) lead to the use of systematic 'safe' strategies for problem-solving (Pekrun & Linnenbrink-Garcia, 2012; Shen et al., 2019). Likewise, teachers' emotional obstruction in the form of disregard, disrespect, and cynicism has been found to negatively correlate with student engagement with challenging tasks (Strati, Schmidt, & Maier, 2017).

However, categorizing emotions as negative and positive has been criticized because it simplifies the complexity of emotions and their functions (see e.g. Bellocchi & Turner, 2019). For example, confusion has been found to be both beneficial and obstructive to learning (D'Mello, Lehman, Pekrun, & Graesser, 2014).

The continuous experience of certain emotions with science activities has been argued to have longer lasting effects relevant to science education. For example, enjoyment with science has been found to correlate with interest in science (Ainley & Ainley, 2011). Enjoyment with science is facilitated in diverse ways. For example, a teacher's display of enthusiasm has been found to have a positive correlation with students' enjoyment (Frenzel, Goetz, Lüdtke, Pekrun, & Sutton, 2009). Similarly, humor and jokes have been found to be related to enjoyment and anxiety reduction during scientific inquiry (Lamminpää & Vesterinen, 2018; Tobin, Ritchie, Oakley, Mergard, & Hudson, 2013). The facilitation of positive emotions can be even more subtle. For example, aesthetic judgements during inquiry such as "neat" or "disgusting" can help the teacher to discern relevant scientific knowledge and teach about norms and participation in science (Jakobson & Wickman, 2008).

It should be noted here that, in science education, there are far fewer studies focusing on emotions in social interaction based on sociological theories. Nevertheless, social emotions can certainly shape the fluency of teaching (Bellocchi et al., 2014; Tobin et al., 2013). This line of research could offer more insights into the understanding of emotions in science education.

4 Drama in science education

Drama in science education refers to collective, multimodal activities drawn from the performing arts, such as improvisation, role-play, storytelling, and mimicking. These have been adapted in science education into different types of activities, which range along two continuums, as illustrated in Figure 1.

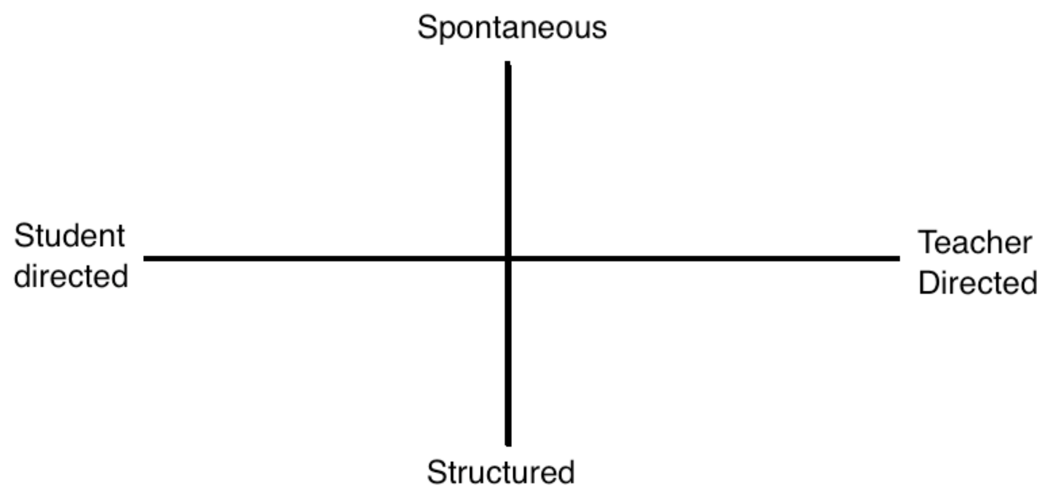

Figure 1. Dimensions for categorizing drama activities in science education (Ødegaard, 2003)

The x-axis concerns who decides on the topics, the content, the goals and the strategies, in alignment with the ideas of student-centered education (Herranen & Aksela, 2019). The y-axis concerns the kinds of expression that occur during the drama activities, which can either be pre-meditated and structured to optimize the illustrative potential of drama, or they can be more immediate, spontaneous or improvisational, aiming at exploring more intuitive ideas about science (Ødegaard, 2003). Another viable interpretation of this axis is agency/passivity, as illustrated in recent studies on drama in chemistry education (Danckwardt-Lilliestróm et al., 2020).

Alternatively, previous studies on drama integration in science education can be divided by their topic, either illustrating i) science concepts and thus non-human characters, or ii) scientists and other human characters. A similar division has been described, for example, as physical or social simulations (Dorion, 2009). Examples of these, as discussed in previous studies, can be found in Table 1.

Table 1. Non-human topics explored in studies on drama in science education

Topic	Explanations for science learning
Electrolysis of water (Saricayir, 2010)	Active participation, engagement and discussion explains learning
Ecosystem and matter cycles (Çokadar & Yılmaz, 2010)	Active participation, interaction between students and incorporation of emotion with the content
Photosynthesis (Carlsson, 2003)	Emotions, fantasy, metaphors, distance and intimacy are incorporated into the knowledge in a holistic manner
Reactions with copper (Aubusson & Fogwill, 2006)	Clear portrayal of scientific ideas through analogical modelling accompanied by social interaction
Energy transfer and transformations (Close & Scherr, 2015)	Body motions, gestures, and coordination of speech become blended with the concepts
Chemical bonding (Danckwardt-Lillieström et al., 2018)	Socio-semiotic meaning-making, recreation, and reinterpretation of meaning between bodily, written and verbal modes of communication
States of matter and heat transfer (Abed, 2016)	Bodies as tools, humorous conversations with peers, anxiety reduction
States of matter and food web (Varelas et al., 2010)	Negotiating meaning through bodies, gestures and talk, embodied learning

Table 1 illustrates the different approaches taken by these studies in explaining science learning. They are elaborated below.

4.1 Science learning with drama

A meta-analysis of drama-based pedagogy made by Lee et al. (2015) indicates that drama activities have significant positive outcomes on student achievement in science subjects, and the effects are stronger when drama activities are instructed by teachers or researchers, rather than by a teaching artist, and are included in more than five lessons, and are integrated into an English language arts or science curriculum. While there are various theories that can explain the academic achievement, the general idea is that non-human drama activities bring the abstract, non-visible concepts to a more concrete and personal level and activate thinking processes. Theoretical explanations for academic achievement range from embodied learning to communicational support for the understanding of learning.

Embodied learning theories (Fugate, Macrine, & Cipriano, 2019) are often included when explaining academic success with drama. Embodied learning is often implicit in discussion about students' bodily experience as a starting point for conceptual learning (Abed, 2016; Close & Scherr, 2015; Saricayir, 2010; Varelas et al., 2010). Studies may refer to embodied learning directly, such as in explorations of Energy Theater (Close & Scherr, 2015) or states of matter (Varelas et al., 2010). There is some evidence to support the role of embodied learning for certain concepts. For example, learning about centripetal force in embodied conditions enhances students' performance in post-testing (Johnson-Glenberg, Megowan-Romanowicz, Birchfield, & Savio-Ramos, 2016). Their advice for drama activity design is to include gestures that are congruent with the learned concept.

One prevalent explanation is that drama activities create opportunities, motivation or support for dialogue or discussion about science. These align with sociocultural learning theories indicating that meanings of concepts are made through their use in social interaction (Lemke, 1990). This communicational support has been explained by taking students' bodies as an extra resource and multimodality of representation (Dorion, 2009), thus embodied and communicative explanations are often used interchangeably. Students need to translate meaning when moving from one communicative mode to another, which essentially activates more thinking about the concept, which thus leads to more learning (Danckwardt-Lilliestrӧm et al., 2018).

However, there are limitations to learning scientific concepts with bodily expressions only. For example, concepts may be used in a simplified form, which can then provide drama experiences that serve as an anchor for continued conceptual learning (Danckwardt-Lilliestrӧm et al., 2018). Moreover, a study of critical episodes in teacher students facilitating drama indicates that they often fail to verbally connect scientific phenomena, concepts and processes with students' simulated actions (Braund, Ekron, & Moodley, 2013).

So far, the role of emotions in science learning has gained little attention. Dorion (2009) reports that one of the teachers' objectives in conducting non-human character drama activities is to give science de-facto relevance through conveying the image of the science classroom as a community of enjoyment. Heyward (2010) reflects on his own drama practice in higher education and suggests that group roles can be used to enable participants to be emotionally supported by their fictional colleagues. He suggests that teachers should be careful not to push involuntary students into high-profile roles, because that ruins the experience for other participants. He elaborates that it is crucial that participants are not rushed into roles but are gradually introduced to the imaginary world and its conventions.

5 Methods

The goal of this study is to help close the gap between cognition and emotion in science education. One prospective way to engage student emotions in science education is drama. It has been suggested that science teacher education should introduce more research and strategies in order to promote science teachers' confidence with drama practices in science education (Belova, Eilks, & Feierabend, 2015; Braund, 2015). Promoting confidence in working with students' emotions in drama requires a better understanding of how student teachers can become aware of students' emotions. Therefore, the first research question was: how do PSSTs experience students' emotional expression during drama activities?

Closing the gap between emotion and cognition implies that student teachers learn how to connect emotional expression with science learning. Thus, the second research question was: What kind of science learning opportunities and challenges do PSSTs find with drama activities?

We answer these questions with a qualitative case study (Stake, 2013). Yin (2014) asserts that a case study is justified when the researched phenomenon is interwoven with the context and when in-depth knowledge is needed to understand the phenomenon. In this case, we considered drama facilitation in science education to be such a phenomenon. The power of case studies is in the exemplary knowledge they produce that does not permit waterproof generalizations but helps to develop pragmatic theories that offer the best possible explanations for contextualized phenomena with a human element (Thomas, 2010). We start by elaborating on the context of the study.

5.1 Case studies

The study explores two cases in which PSSTs facilitate drama activities with high school students. The PSSTs in this study were not experienced drama facilitators, which makes these key cases for understanding science teachers' drama practices, as it has been suggested that they lack confidence with these strategies (Belova et al., 2015; Braund, 2015). Their experience in drama facilitation is based on an introductory (2h) session of drama in science education as part of a course named Chemistry in the Environment that aimed at promoting future teachers' skills in facilitating engagement with science. Some of the pre-service teachers already had previous teaching experience in mathematics, physics, and chemistry.

The introductory session was facilitated by one of the authors, who has experience with drama education. The PSSTs participated in the drama activities and were given the ten-minute task to design an activity for their peers related to chemistry topics such as polarity and the carbon cycle. These were then tested during the introductory session, after which the PSSTs were divided into five groups to design drama activities for student groups. The task was to design a short lesson plan for a drama activity that could be facilitated and could be linked to the following chemistry lessons or experimental work. Each of the designed activities were tested with different high school groups.

We selected two representative cases out of the five. The two were selected because they used a similar drama strategy but were offered to two very different high school student groups. The drama strategy used in these cases included dividing roles to the students and narrating a science-related story to them. The students were then instructed to enact their part of the story. These designs resembled the drama activities that had been tested during the introductory lesson, which meant that the PSSTs had had some experience with a similar strategy. The lesson plans for the two cases are elaborated below.

5.1.1 Case 1 - Cooking an egg

This lesson plan was designed and facilitated by two PSSTs (PSST 1 and 2) for a high school student group to learn about proteins. The high school students had chosen to study extra chemistry and were characterized as “really mature and cooperative for their age (15 yrs)”. The PSSTs’ lesson plan started with a drama warmup in which the collective task for the students was to say numbers from 1 to 10 without over-lapping each other’s speech and with no premeditated order. If overlapping occurred, they had to start from the beginning. PSST 1 commented that they were lucky that the students managed to reach 10 on their last try, because this probably created a sense in the students that they would succeed in the next drama activity as well.

The main science learning activity was introduced to the students as a task to enact a story related to the boiling of an egg that would be narrated by one of the facilitators. The key scientific aspect of the story is represented in Figure 2 and was provided by the PSSTs in the lesson plan.

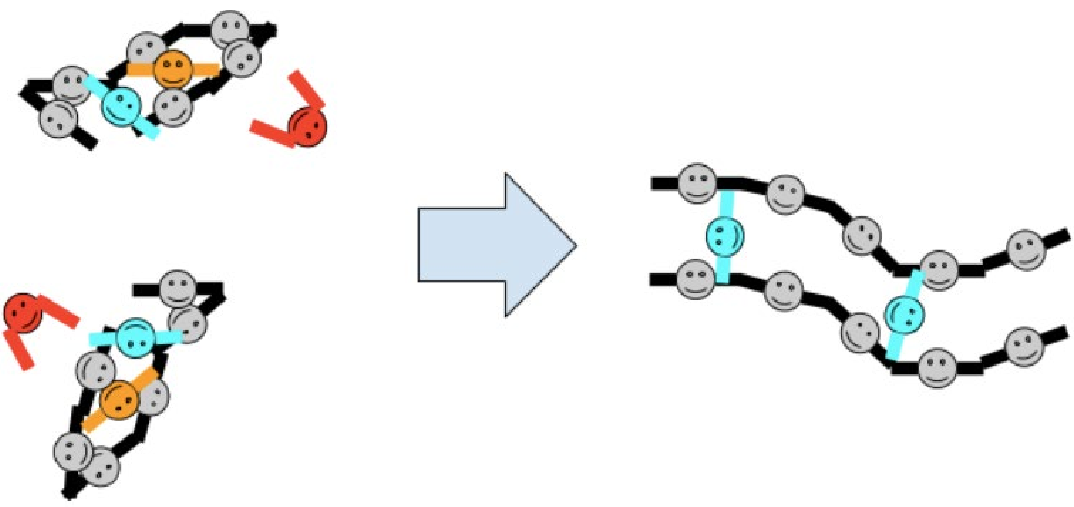

Figure 2. The picture illustrating tertiary and secondary protein structure in the PSSTs' drama plan.

PSST 1 first divided out role cards to the students so that they could check which role they were supposed to mimic. The roles represented different scientific agents related to the scientific process, as illustrated in Figure 2, and include Protein 1, Protein 2 (Grey), Hydrogen bond (teal), Sulfur bond (orange) and Heat energy (red). The PSST 2 then narrated the story while giving expression advice that simultaneously explains the science in between the lines.

The verbal script written by PSST 2 went as follows. Lisa has a raw egg, which she wants to boil. Egg contains proteins. The structure of proteins resembles a chain. Now, the ones belonging to Protein 1 group form a chain by taking the hand of the other members. Protein 2 group does the same. Sulfur bonds and hydrogen bonds hold protein in a so-called tertiary structure, which is basically 'a tight clump'. The sulfur bonds and hydrogen bonds now go the protein chains to keep them in the tight clump. The bonds act as a bridge. There are more of these bonds. Now Lisa starts to boil the egg in a pan. The heat energy affects the proteins by making them move about more. Because of the heating, the sulfur and hydrogen bonds break or detach. The tight clump of proteins opens up as a chain. The hydrogen now has a new role as it forms a bridge between the two chains. The sulfur bonds do not participate in this. Now the protein has been transformed from a tertiary structure to a secondary structure, which is called denaturation. This means that the egg is now done.

5.1.2 Case 2 - Flirting metals

This lesson plan was designed and facilitated by three PSSTs (PSST 3, 4 and 5) for high school students to learn about metals. Their idea for the activity was quite similar to that of Case 1. It had non-human roles such as anions and cations (Zn, Cu^{2+}, SO_4^{2-} and H_2O) that were played by the student groups and a story told by a narrator that featured “Carolyn the Chemist”. Carolyn has prepared three blue copper sulfate solutions consisting of copper cations, Cu^{2+}, that are positively charged and sulfate ions that are negatively charged, SO_4^{2-}. The facilitator then narrated the script illustrated in Table 2.

Table 2. Script for a drama facilitator in a play about galvanic series

Speaker	Lines
Narrator	When the solutions are ready, Carolyn the Chemist places a piece of Zn into the first solution.
Narrator	The outer atom layer of Zn is in contact with the solution. The H_2O molecule collides with the zinc atom, but after the collision the water continues on its path
Narrator	Next, the SO_4^{2-} anion collides with the zinc atom, but after the collision the anion continues on its way
Narrator	Next, the Cu^{2+} cation collides with the zinc atom. Now things start to happen.
Copper cation	(admiring): Look at those electrons, so nice. You are neutral, aren’t you?
Zinc atom	(sighs): It would be so nice to be positive for once! Not just being boring and neutral like I am in this metal crystal. Here I am, in one place, unable to move around.
Copper cation:	I’d be happy to receive your outer electrons, if you don’t mind.
Narrator:	So, the zinc atom gives away two outer electrons to the copper cation thus transforming and becoming free to do whatever pleased the new cation in the solution.

The lines, illustrated in Table 2, that the students were expected to say were given to them on a separate piece of paper, a role-card, so that the lines of the other students would come to them as a surprise. The purpose of this was to encourage the students to concentrate on the lines. In addition to the lines, there were some expression instructions on the role-cards.

5.2 In-depth interviews

The purpose of the interviews was to explore the PSSTs’ experience of facilitating the drama activities described above. The open-ended nature of our case study and the need to deeply explore the topic called for the use of in-depth interviews (Guion, Diehl, & McDonald, 2001). The PSSTs were interviewed by the researcher one or two weeks after they had facilitated the drama activity for the students. In the interviews the PSSTs could draw from their experience in the introductory sessions as well as their shared experience of designing and facilitating the drama activity. The PSST group's written plan was used to enhance their memory.

In practice, the interviews were conducted in the following way. The interviewer first asked questions related to drama facilitation. For example, the questions could be related to the first things that came to mind about the experience, or perceived changes in students' actions, or high or low points of the activity. These questions were followed by probing questions that focused especially on the aspects that seemed important for the subjects as well as for the purpose of the interview (Guion et al., 2001). The in-depth interviews often followed their own path as the interviewer was committed to listening to what the interviewees were saying and emphasizing, and in this case it led to the interviews lasting an hour. Please see the Appendix for a list of example questions.

5.3 Inductive content analysis

The interviews were analyzed using inductive content analysis, which is warranted when prior knowledge on a topic is limited (Elo & Kyngäs, 2008). Inductive content analysis starts by deciding what to analyze. The preliminary analysis of the interviews indicated that PSSTs frequently used emotional labels to explain students' actions, which guided our selection of emotion as a topic for this research.

After this decision, we could select the relevant parts from the massive interview data for transcription. The data was then coded into one-sentence-long units. The context for interpreting a code was set to be the entire case, acknowledging our premise that the phenomenon is interwoven with the context. A further criterion for coding was that they ought to be at the practical level, thus reflecting the vocabulary and experience of PSSTs as accurately as possible and being more aligned with the pragmatic theories developed by case studies (Thomas, 2010). The codes were then grouped to reduce the number of higher-order categories to provide a comprehensible summary of the data (Elo & Kyngäs, 2008).

After pilot coding, the categories were revisited to see whether they were too specific or too general and whether they would address the research questions in a relevant way, and this eventually led to adjustments to the categories. The categories were, firstly, too focused on emotion labels, failing to acknowledge the purpose of these activities for the PSSTs. Secondly, the categories were too theoretical, involving concepts such as appraisals and interaction rituals, which no longer reflected how the PSSTs understood students' emotions. Each adjustment to the category led to a new round of coding. The final codes are presented (in italics) in the Results section alongside examples from the data.

5.4 Trustworthiness

Trustworthiness refers to validity and reliability issues in qualitative studies. The case study researcher needs to guarantee the trustworthiness of their constructs; by triangulating and chaining multiple sources of evidence; by using established analytical methods; and by checking external validity through analytic generalizations (Yin, 2014). We sought to improve the trustworthiness of our constructs by analyzing and chaining multiple sources of data (two group interviews, lesson plans, researcher observation notes) and we ensured that the constructs were interconnected when we looked for over-arching factors beyond individual cases by negotiating the constructed categories between researchers.

5.5 Limitations

All interpretations of emotions of others are indirect. There are two layers of interpretation at play here that create biases. First, the PSSTs interpreted the students' emotions and then the researchers interpreted the PSSTs' interpretations of these emotions. Both stages create biases in knowledge, because a person cannot fully understand the mind of the other. Moreover, the interviews are a form of self-report and as such generally sensitive to bias, memory loss, uncertain access to consciousness, self-deception or distortion of past events (Do & Schallert, 2004). Moreover, labeling discrete emotions poses another acknowledged challenge in emotion research as there might not be clear boundaries between discrete emotions. This is reflected in the disagreement over the number of emotion labels in the field of emotion research (Hannula, 2020).

5.6 Research ethics

The interviews began by informing the students that recording was taking place and asking the participants for research permission. The reflection on drama activities leads to the sharing of personal stories that might be embarrassing when made public. To protect the participants, we have not used their names and we have left out unnecessary description of context that would make identification easier. The study follows the ethical conduct rules of our university.

6 Results

The results are divided into two parts. The first part illustrates the important role of students' emotional expressions in the PSSTs' drama facilitation experience. The second part elaborates the PSSTs' reflections on the science learning opportunities and challenges associated with drama. These are then discussed through emotion theories in order to find the best possible explanation for the phenomena explored. This is the typical approach for case studies (Thomas, 2010). The analytical categories related to this reflection are written in *italics*.

PSSTs' experience of student emotional expressions in drama

While it is impossible to open up the entire PSSTs' drama facilitation experience, there were certain experiences that stood out and inspired in-depth reflection. These were related to students' *hesitation* and *spontaneous expressions*. The following quote demonstrates how the PSSTs experienced the transition from hesitancy to spontaneity.

> Yes, they were a little hesitant at first, but then in the end some of them started to be like "That one is trying to flirt with the other one". And they started to enjoy colliding with each other. Our activity was kind of fun. (PSST 3)

The quote illustrates how important students' emotions are to the PSSTs facilitation experience. Here, they directly associate spontaneous actions with enjoyment and in the later stages the PSSTs talk about the experience of fear or shame in relation to hesitation in drama activities. Moreover, they associated these emotions with social concerns, which aligns with theories of social emotions (Hareli & Parkinson, 2008).

The following example illustrates the spontaneous action of one student. The example is related to the first case, in which the PSSTs facilitated drama for a group that was characterized as mature and cooperative. One would expect that in this context high school students would obediently follow instructions, and yet, in the following extract, PSST 2 describes an example of spontaneity:

> It was a really good moment there when the hydrogen connected the two protein chains. The one boy was extremely fast. He just said "Okay" and took their hands (hands of students playing the role at the ends of two protein chains) and

> connected them. [*laughter] It was like instant. Then I went in and showed a picture with the Hydrogen there in between. (PSST 2)

PSST 2 characterizes "Hydrogen Boy's" action as extremely fast and instant and at one point refers to this student as "spontaneous". PSST 1 reflects on the action described in the quote above, saying that "the student did not think on a chemical level". Both the speed of the action and the idea that action does not require reflection, planning or foresight aligns with the idea that emotional actions are impulsive (Frijda, 2010). Moreover, spontaneity aligns with the idea of spontaneous drama activities aiming to explore more intuitive ideas about science (Ødegaard, 2003).

The following example illustrates individual *students' hesitation*. This example is drawn from the beginning of the same activity as above. PSST 2 describes the following event in which the other students have formed a group while one student is standing still:

> There was this one boy who was left out, that 'Sulfur Bond'. He did not know how to get into the group. I went in to encourage him and asked about his role. (PSST2)

PSST 2 describes "Sulfur Bond's" hesitant action as "not knowing how to get into the group", which has two interpretations. First, the "Sulfur Bond" might not have known enough about the concept of protein bond to find the correct place in the student formation and thus the PSST went to help the student. This kind of worry is a feature of structured drama activities that have a predetermined "correct" outcome in mind (Ødegaard, 2003). Second, the PSSTs brought up the point that the student did not necessarily know the group members and was thus preoccupied with social concerns about the situation. Nevertheless, the student is actively thinking about the situation and demonstrates willingness to participate, which can be understood as a sign of agency (Danckwardt-Lillieström et al., 2020).

Science learning opportunities and challenges with drama

The PSSTs elaborated on their science learning opportunities and challenges related to students' spontaneity and hesitancy during the drama activities. Table 3 summarizes the key aspect of the analysis.

Table 3. PSSTs experience of science learning opportunities and challenges with drama.

Science learning opportunities and challenges with drama	
Opportunities	**Challenges**
collective fun	individual misery
sense of community	bullying
memorizing concepts	blocked scientific thinking
science talk	inaccurate models

The four opportunities and challenges are assembled as pairs, because they often depend on the point of view of the PSST. These pairs are elaborated below.

Spontaneity was often associated with an opportunity for a *collective fun* experience with science. The PSSTs' responses always assigned fun to a larger group of students as indicated by comments such as "The students were having fun" or that "it feels really important that students are having fun with drama". Moreover, science teachers' rationale for using drama has been found to be related to displaying science as a community of enjoyment, as reported by Dorion (2009).

The challenge with collective fun is that it may exclude individual students for one reason or another. The PSSTs sense this in moments of hesitancy. They empathized with *individual student's miserable experiences*. For example, PSST 3 reflected that "there are always people (students) who hate or are disgusted by drama" and continued that "it feels horrible for teacher to cause terrible anxiety for someone with drama activities". The PSSTs then discussed the sensitive inclusion of everyone by using group roles or background roles for those who feel terrified by drama. Similar strategies for promoting emotional engagement have been discussed in previous studies of drama in higher education (see e.g. Heyward, 2010).

When sensitive inclusion succeeds there is an opportunity to promote *a sense of community*, as discussed by PSST 2, who encouraged "Sulfur Bond" to participate. The PSSTs then further explained that a sense of community is promoted by the physical proximity, which enables students to connect with new and surprising people in the group. Moreover, PSST 2 reflected on "Sulfur Bond's" hesitancy by suggesting that "students' hesitancy could sometimes help identify *bullying* in the group". Paying attention to this particular challenge is especially important for high school teachers considering that neurological studies point towards the heightened emotional impact of social rejection in adolescence (Sebastian et al., 2010).

The PSSTs discussed the opportunity to promote *memorizing scientific concepts*. For example, they said that "It might be the physical action that sticks into your mind" and "emotional experiences anchor the scientific concepts", which is closely related to the opportunity for collective fun through spontaneous actions. This opportunity is partially justified by the substantial evidence claiming that emotional events are remembered more clearly, accurately and for longer period of time than neutral events (Tyng et al., 2017). The PSSTs' comments align with embodied learning theories, which had been introduced to them in advance. However, embodied learning would require that students' gestures are congruent with the learned concepts, which does not often happen with spontaneous actions.

In contrast, the PSSTs were concerned that spontaneous actions could *block scientific thinking*. For example, PSST 1 comments that "Hydrogen Boy" did not think at a chemical level', thus suggesting that actions embedded with emotion can block out cognitive processes related to scientific thinking. Moreover, PSST 3 suggested that "They (the students) should have listened to the lines to know what was happening, I think they did not concentrate at all". This comment aligns with another norm related to how science is learned. The PSSTs' perceptions of the challenges are understandable due to the cognitive emphasis in science education traditions, in which emotions are seen as a nuisance for cognitive learning (Bellocchi et al., 2016).

The PSSTs argued that the challenge with spontaneity is that it can lead to *inaccurate physical models* of the explored scientific phenomena. For example, PSST 4 commented that "metal pieces did not stay at their designated places", meaning that the students acting as zinc atoms left their positions when students acting as sulfate ions collided with them. This created an inaccurate physical model for the redox reaction. The PSSTs' immediate worry relating to these inaccurate expressions is that abstract science may become even more difficult to understand. This challenge is evident in PSST4's comment, "We had thought that it (the physical expressions we devised) can cause difficulties and confusion". However, research indicates that confusion is not necessarily contrary to learning because confusion can lead to frustration and disengagement but also to engagement (D'Mello et al., 2014). Moreover, when discussing possible improvements in the PSSTs' drama activity, PSST 1 sought to avoid confusion by "changing the narration to avoid inaccurate expressions for the next occasion of drama". This type of modification would lead to a more structured drama activity with less room for spontaneity.

On the other hand, an opportunity connected to inaccurate expressions is that they allow PSSTs to step in and *talk about science*. This opportunity was not directly mentioned by the PSSTs, but it was apparent in the way they talked about the events. For example, PSST 3 reflects that the drama "had good elements. We had beanbags as electrons and when they dropped them, we could say that it doesn't go like that, they go directly from one molecule to another". This type of immediate intervention can be understood as scaffolding, which has been found to promote students' engagement with challenging tasks (Strati et al., 2017). Scaffolding is warranted in these types of drama activities, because creating physical expression based on narration is not an easy task. Physical expressions require a person to make translations and transformations between different modes of communication, for example, from written to physical (Danckwardt-Lillieström et al., 2018). This transformation process was found to continue for the PSSTs even after the activity ended. PSST 3 starts asking "how to express a lack of electrons" and PSST 4 suggests that "We could have used red caps to illustrate positivity, or wooden cups".

7 Conclusion and discussion

The results of this study illustrate PSSTs' capacities for engaging and analyzing drama activities with students (age 13-15). The PSSTs were able to recognize science learning opportunities and challenges while taking care of student inclusion and showing sensitivity towards students' emotional expressions. They discussed the emotional expressions that were related to spontaneous and hesitant actions during drama and the associated science learning opportunities and challenges that emerge. This encouraged the creation of a novel framework (Table 3) for working with students' emotional expressions in drama activities in science education. The framework illustrates how emotional expressions can be understood as either opportunities or challenges, depending on the point of view, as seen in the examples of "Hydrogen Boy" and "Sulfur Bond".

The example of "Hydrogen Boy" illustrates spontaneous action as one of the opportunities and challenges related to science learning. Spontaneity is important in drama because being able to act on impulse is necessary when aiming at intuitive exploration of science (Ødegaard, 2003). Moreover, the importance of spontaneous expressions is confirmed by studies arguing that much of the intellectual work accomplished by adults progresses through improvised action (Close & Scherr, 2015). Nevertheless, the PSSTs considered spontaneous actions to be a challenge during structured activities because they can lead to inaccurate models. However, this can be turned into an opportunity to talk about science. This approach to talking about science is different from previous facilitation strategies that often position teachers' scientific verbal explanations at the end of the activity (see e.g. Dorion, 2009) although the general view of learning due to enhanced communication aligns with previous studies of drama in science education (Danckwardt-Lillieström et al., 2018). A key difference here is that inaccurate expressions work as a starting point for science talk, thus aligning with comparable ideas about student-centered learning, such as inquiry that starts from the students' own questions (Herranen & Aksela, 2019). A more opportunistic approach to inaccurate expressions could encourage PSSTs to work with more abstract concepts, which they otherwise consider to be more confusing for students.

The example of "Sulfur Bond" illustrates students' hesitant expressions as one the opportunities and challenges. The PSSTs empathize with hesitant students and in relation to this they discussed student anxieties, fears, and bullying, all of which limit opportunities for participation. In essence, being able to sensitively include hesitant students creates opportunities to promote a sense of community in the student group. The inclusion strategies discussed by the PSSTs include encouragement by the facilitator, warm-ups, group roles and background roles. These align with strategies that have been suggested as useful for emotionally-engaging drama activities in higher education (see e.g. Heyward, 2010). The PSSTs went on to say that a sense of community is promoted due to the physical proximity, which enables students to connect with new and surprising people in the group. Similarly, drama facilitators could draw from interaction ritual theory to design synchronous movements and a joint focus of attention in order to promote group solidary (Collins, 2004).

8 Implications for science teacher education

The PSSTs in this study demonstrate abilities to engage and analyze drama activities for high school students indicating that drama workshops are a prospective approach for supporting science teachers' drama facilitation in general. In addition, the analysis points towards areas of drama facilitation in which PSSTs might require more support.

The first area is related to spontaneous actions. The PSSTs tried to avoid these by giving as detailed instructions for expression as possible. However, spontaneous actions could be embraced as valuable intellectual work, rather than as a nuisance. They may lead to inaccurate expressions, but this gives science teachers the opportunities to talk about science. However, the interviews indicate that students' spontaneous actions are corrected, rather than being acknowledged or appreciated. This was a missed opportunity considering that aesthetic judgments, such as "wow, that was great" in class, promote meaning making, understanding the norms of science and inform students about their possibilities for participation in activities (Jakobson & Wickman, 2008). Another viable option for inaccurate expressions is to save the opportunity to the end of the activity and then turn it into a follow-up task that starts by discussing key elements of the scientific concepts. A prompt would help students to figure out how these elements could be included in their initial physical expression.

The second area is related to the gap between cognition and emotion in science learning. The PSSTs are sensitive towards students' emotional expressions and even find science learning opportunities in such expressions, but they may consider emotions to be an obstacle to thinking or they may avoid emotions that could actually be beneficial to learning, such as confusion (D'Mello et al., 2014). With this in mind, it could prove to be useful to introduce to PSSTs the idea that students' emotions can open up science learning opportunities or challenges, as depicted in Table 3. Finally, we note that critical scientific literacy goals such as solidarity and empathy call for action that goes beyond familiar groups (Sjöström & Eilks, 2018). This calls for taking a broader perspective on the role of emotions in the society. This implies further research on drama activities, such as role-plays, that enable the exploration of multiple perspectives and take a direct approach to the role of emotions.

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Appendix

A list of the core themes and examples of questions used in the interviews. The interviewer modified the questions to suit the interviewing situation, as is advised when using in-depth interviews.

- What is the first thing that comes into your mind when you think about your experience of facilitating drama?
- What was the best part of drama facilitation?
- How did the students feel about the drama activity?
- What caught your attention?
- Did you notice any changes in the students’ actions?
- Where did you succeed and why?
- What went well and why?
- What went wrong and why?
- What would you do differently next time?