

IMAGINATION; WHERE SCIENCE FORMULATE DIFFERENT HYPOTHESIS AND EXPLANATIONS HELPING THE UNDERSTANDING OF THE LANGUAGE AND SOUL OF CHEMISTRY

Ann Mutvei¹, Ulrika Tobieson² and Jan-Eric Mattsson³

^{1,3} School of natural sciences, technology and environmental studies, Södertörn University,
Stockholm, Sweden,

² School of teacher education, Södertörn University, Stockholm, Sweden,

New understanding is realized by creative learning where students are involved in meaningful learning, ownership of learning, control of learning processes and innovation. In order to produce learning situations where creative learning is achieved, teachers have to create trustful atmospheres where students are allowed to think and discuss without critical evaluation from the teacher. It is also important to create practical exercises in which theoretical models are processed and connected to observations and subject matter. During several years we have developed courses in science with the goal to promote students to become independent learners and explorers out of their own prerequisites as future professional teachers. We have investigated different methods and designs of teaching; conceptual understanding and conceptual change theory, discourse-based understanding and Dewey's view of learning. In this study we are focusing on exploring the variation of students creative learning through a chemistry course. Permitting the particulate subject matter of chemistry to demonstrate as universal dramaturgical framework for conceptual learning and embodied experience. Chemistry involves considerable amounts of abstract conceptual thinking, molecular understanding and language. The focus of our study is the exploration of how conceptual abstract molecular understanding of phenomena in nature emerges through different teaching approaches, and imagination transformed into universal understanding, which provides the students with a sense of empowerment and a positive outlook on their future profession as teachers.

Keywords: knowledge construction, aesthetic learning process, reflection

INTRODUCTION

"Imagination is the meeting ground where old and new come together - what was, what is, and what could be. The imagination takes us beyond and behind the everyday." (Ellen Levine prof. EGS)

It is important for teachers to establish an environment for knowledge construction and creative learning that allow students to think and discuss without critical evaluation. In changing from teacher-centred to student-centred teaching, as well as ethically observing the boundaries where students are responsible for their own learning is part of achieving an open and trusting learning environment (Pollard et al., 2018). Creative learning emerges when learning is meaningful, self-motivated and innovative (Jeffrey, 2006). Teaching should be inquiry based

and connect observations to theoretical models for students to create their own knowledge (Jeffrey, 2006). By asking questions and solving problems during inquiry, students can make connections between theories and praxis (Jeffrey, 2006). Another important aspect of creative learning is when students are engaged, collaborating with others and enjoying further exploration (Gibson, 2010; Pollard et al., 2018).

Our work with aesthetic learning process is based in intermodal art theory and the philosophy of phenomenology (Knill et al., 2004). An aesthetic learning process is where one or more modalities are expressed through their specific language in art (music, art, dance, etc.). As one expression develops and encounters a second expression which then flows into a third modality of felt sense the dramaturgical sequence evolves and moves. In our study we implemented a five-part psychokinetic imagery model created by Daria Halprin. (Halprin, 2002; Knill et al., 2004) .

We have developed courses in science in order to achieve and motivate students to become independent learners focusing on their future as teachers. A variation of methods and designs of teaching have been investigated and the students creative learning has been equally analysed, to further develop an understanding of what signifies a trusting learning environment. In this study we have been exploring and focusing on a chemistry course for future 4 – 6 grade primary school teachers. Chemistry involves considerable amounts of abstract thinking. Furthermore, as many students have had bad experiences of chemistry from school the encounter with new knowledge of chemistry is in many cases perceived as a challenge.

OBJECTIVE

The focus of our study was the exploration if and how a universal understanding of conceptual abstract molecular thinking and language as well as phenomena in nature emerges and manifests itself through different designs of teaching and imagination.

Could the design of the course promote creative thinking and create conceptual understanding of chemistry? How do students experience aesthetic learning processes in connection to their own learning in chemistry?

COURSE DESCRIPTION

17 preservice teacher students were trained by one science teacher and one teacher in aesthetic learning process to foster their independent and creative learning of chemistry. The course consisted of 10 days over a four week-period, which included practical activities mixed with discussions in groups followed by discussions with the teacher in order to connect theory with practical exercises. The students wrote short reflections at the end of each week as well as a short reflection after the two sessions of aesthetic learning process answering the following two questions: “What do you take with you from your own learning process and/or in connection with other’s and/or the working process of the session?”, “What amazed and/or surprised you the most?”. Students were studying and working with questions in a science textbook in English as well as a textbook on chemistry education in Swedish during the campus

free days. A guided visit to the Vasa museum in Stockholm at the end of the course showed the chemistry around a wrecked ship from 17th century saved sixty years ago. At the end of the course the students were assessed through a written examination.

METHODS

The five written reflections were analysed by qualitative methods scoring demonstrations of professional development, process thinking and learning processes. The analysis was focused on six categories: A. changed attitude towards chemistry, B. connection to everyday life, C. importance of practical exercises for learning, D. importance of group discussions for learning, E. chemical descriptions using concepts and F. connection to future profession as teacher. The quality of the five individual written reflections were also analysed using the quality markers 4R's of Doll's, *Relations*, *Recursion*, *Richness* and *Rigor* (Doll, 1993) (Mutvei, A. et al., 2017). Recursion is understanding in depth by the connection of the past with the present in depth. Relations is understanding through interaction with and connection to the other unknown, things and people within the context. Richness is understanding and expressing different levels and dimensions of interpretations and perspectives, to give different interpretations, perspectives and possibilities. Rigor is consistently using knowledge in new ways and in new unexpected situations. The use of the R's was assessed using a scale 0–3 where 0 refers to the absence of the specific concept and 3 to regular and active use of the processes referred to by the concept. The aesthetic learning process sessions were analysed by ethnographic method making observation and taking careful and meticulous written notes (LeCompte & Goetz, 1982). The different steps of the five-part model during the aesthetic learning process (Tobieson, U. & Mutvei, A., 2017) were identified and the outcome was assessed by the students through oral reflections at the end of each session as well as a written individual reflection.

Table 1. Overview of the four weeks chemistry course.

Week 1	Week 2	Week 3	Week 4
Chemistry and didactic literature	Chemistry and didactic literature	Chemistry and didactic literature	Chemistry and didactic literature
Lab-exercises – inquiry based	Lab-exercises – inquiry based	Lab-exercises – inquiry based	Lab-exercises – inquiry based
Group discussions	Group discussions	Group discussions	Group discussions
Guidance by the teacher	Guidance by the teacher	Guidance by the teacher	Guidance by the teacher
		Guided visit to the Vasa Museum in Stockholm	
		Aesthetic learning processes	Aesthetic learning processes
Chemistry reflection 1	Chemistry reflection 2	Chemistry reflection 3	
		Aesthetic learning process reflection 1	Aesthetic learning process reflection 2
			Written exam

RESULTS

Our results showed that students with a negative conception to chemistry changed their opinion during the 10 days that the course lasted and thereafter enjoyed paying attention to phenomena in everyday life with a multiple of perspectives on chemistry. All students expressed the importance of practical exercises, aesthetic learning process and group discussions for their own learning skills. The reflections contained detailed explanations of chemistry, concepts used properly in describing their particulate learning through a universal language. They also used their experiences when they discussed how to design teaching situations and lesson content. The first week many students expressed their negative experience of chemistry at school and that they were more interested now and found it meaningful (Figure 1, A reflection 1). At the end of the course students described how they will teach as professional teachers (Figure 1, F reflection 3). Also, a few students reflected on chemistry as school subject and learning in more general terms at the end of the course.

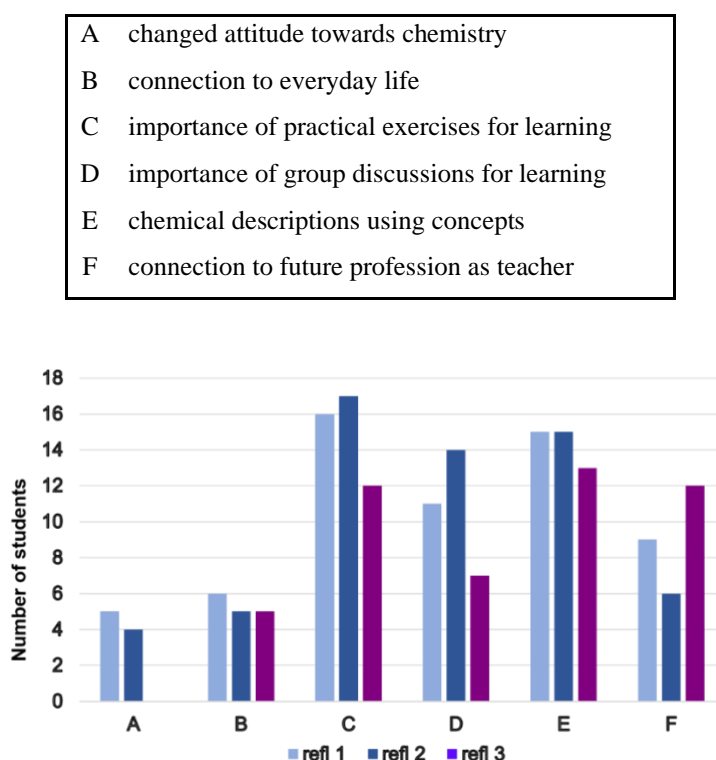


Figure 1. The graph shows the number of students using categories A – F in each reflection (refl. 1 – 3.)

How did the students express their learning in chemistry after one week of the course?

The chemistry reflections after one week of the course were analysed by using the 4R's of Doll's (Doll, 1993) to evaluate the students' learning of chemistry by using literature studies, group discussions, lab exercises and inquire based learning (Table 2). The quality of the students' understanding, by answering two questions about what they have learned and what surprised them, showed that they already after the first week, used concepts to explain different

phenomena, and especially, how to use their experience of learning in their professional lives as teachers. All students noticed the importance of interactions with and connection to the other, sometimes unknown parts of the content knowledge and persons within the context for their learning processes (Relation 2 and 3). Many of them could also describe the process (Relation 3) (Table 2). All students expressed their understanding by using factual terms that belong to the current discourse in everyday life and in their own language. The use of own words indicates acquired knowledge (Richness 2 and 3). A few students also could express their knowledge from several perspectives and dimensions (Richness 3). However, only two students described their knowledge related to new situations (Rigor) (Table 2).

Table 2. Qualitative analysis of students' reflection 1 using the 4 R's of Doll's. The lower row of the table shows the percentage of total students that had high quality (2 and 3) in their understanding (n=17).

level of 4 R's of Doll	Reflection 1 (number of students)			
	Recursion	Relations	Richness	Rigor
3	1	9	4	1
2	3	8	12	1
1	2	0	1	0
0	11	0	0	15
	35%	100%	100%	12%

Example of students' learning from reflections after the first week of the course:

“What surprised me most is probably how much the literature is linked to the practical parts that are carried out during the laboratory work and how to share the knowledge with my peers and connect their knowledge to and with my own.”

“To think about, in my future role as a teacher I have to let the students draw their own thoughts and ideas before using illustrations from different textbooks, maybe start from the students' own thoughts, questions and statements instead of – it is like this.”

“What surprised me was that because of the experiments we conducted, I more easily understood the connection between the different phases (liquid, solid and gas) as well as sublimation, diffusion and evaporation. This could then be reworked theoretically and related to one's own experiences in everyday life.”

How did the students express their learning in chemistry using aesthetic learning processes?

At the end of the course, the students had two sessions lead by an art teacher with the aim of connecting the knowledge in chemistry of the course with aesthetic learning processes, both for developing more and deeper perspectives and to use this in their own teaching. Through aesthetic learning processes, chemistry is repeated in new ways through the making of art, providing more perspectives and creating new knowledge (Knill et al., 2004). The artmaking

awakens emotions and creates experiences when using the whole body and all the senses, necessary to deepen the learning processes (Tobieson, U. & Mutvei, A., 2017). At the end of each session an aesthetic analysis of the shared and achieved experiences was done together in the class. The students shared their experiences of the importance to use representations from the theory of chemistry and how they realized the differences between everyone's view. The students showed each other different perspectives on the molecular world which gave them new experiences. They appreciated the group processes and the inclusive way of working, and also the way of repetition of concepts which gave a holistic view of chemistry. The students should also write a reflection on what surprised and amazed them and what they brought from their work process and content during the sessions.

The reflections from the aesthetic learning process were analysed using the 4R's of Doll's assessing the students' quality of description of their learning. The students' reflections showed a considerable increase in using their chemistry knowledge outside the context (Table 3). All students were better in seeing patterns in other areas (Rigor 1) and many could see patterns through unexpected orientations related to unrelated subject areas (Rigor 2). One third of the students were also able to see, pay attention and use other subject areas to show a deeper understanding and to generalize a complex content (Rigor 3). The students also saw the importance for learning out of previous experiences (Recursion 2) and noticed, described and explained moments of change in the learning process that have led to insight and/or understanding (Recursion 3) (Table 3).

Table 3. Qualitative analysis of students' Aesthetic learning process reflection 2 at the end of the course using the 4R's of Doll's. The lower row of the table shows the percentage of the total number of students that showed high quality (2 and 3) in their understanding (n=17).

level of 4 R's of Doll	Aesthetic learning process reflection 2 (number of students)			
	recursion	relations	richness	rigor
3	6	5	10	6
2	7	12	5	3
1	3	0	2	7
0	1	0	0	1
	94%	100%	100%	94%

Examples from aesthetic learning processes, reflection 2

“The practice of giving each other an aesthetic response, was a great way to interpret and connect different concepts that we have learned so far, together with the different paintings. It sounded a bit fuzzy at first but after two, three paintings I started to see the different concepts take shape and suddenly, I could name many of the concepts of chemistry. It surprised me that I knew more concepts than I thought. It was really a way of going from abstract to concrete.”

“We got to paint chemical reactions. To find new ways to create new perspectives on the theory was important. It gives joy but also greater understanding as the aesthetic gives new angles and

makes us think differently.”

“It was interesting partly that you got to take into account what you had already studied and worked with. Then, to have the opportunity to do something completely different during art-making was a chance to create a deeper understanding of the different parts of chemistry. A lot of the various chemical concepts that had been spinning around in the head were now actually being embodied.”

SUMMARY

It is important to design teaching using a variety of learning situations in order to reach a good understanding of chemistry where students use a particle model, show understanding of different chemical relationships, define concepts and make explanations. The students appreciated group discussions and practical exercises for their learning especially when they used their concepts to explain different phenomena in everyday life. Our results show that art making in the aesthetic learning processes deepens the understanding of concepts in chemistry as learning occurs beyond the usual environment. During the aesthetic learning processes students also expressed wonder and imagination for their own learning in their reflections.

CONCLUSION

All students expressed the importance of practical exercises, group discussions and art-making, as well as the wonder of imagination for their own learning. Our results showed that the course design promoted creative thinking and deepened the students understanding of chemistry, which provided them with a sense of empowerment and a positive outlook on their future profession as teachers.

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