Evaluating the effect of the Sensavis visual learning tool on student performance in a Swedish elementary school

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Dual coding theory implies that engaging multiple modalities (e.g., visual, auditory) in instruction enhances learning. Presenting information via 3D images and 3D animations appears to improve student performance but the results are inconsistent across multiple studies. The present study investigated the effect of the Sensavis visual learning tool, a 3D educational software, on performance in chemistry among students in a Swedish elementary school. Thirty-seven students from grades 7 and 9 received training involving a 3D animation on chemical bonds while nineteen students in grade 8 had traditional instruction. ANCOVA results controlling for age and average chemistry grade revealed a statistically significant difference in the posttest performance with the control group outperforming both experimental groups. These results indicate that the Sensavis tool did not have a positive effect on learning chemistry compared to traditional instruction. Interpretation of the results is presented in discussion.

Our world is changing rapidly due to breakthroughs in science and technology. We need to keep learning and acquiring new skills to successfully adapt to these changes. Designing effective learning methods should take into account current knowledge on how the human mind works. There is a view that learning can be enhanced if multiple modalities (e.g., visual, auditory) are engaged in the process. It is inspired by dual coding theory initially proposed by Paivio in 1971. The theory is based on the view that cognition consists of activities of specialized symbolic representational systems that evolved to serve specific adaptive behavioral goals (Paivio, 1971; Paivio, 2008a). This implies that representational systems integrate perceptual, behavioral and affective knowledge. Paivio draws a distinction between picture-like representations such as drawings, maps and diagrams, and language-like representations that include natural languages, mathematics, logic and computer languages (Paivio, 2008b). According to Paivio, these two types of representations are processed by two separate symbolic systems: nonverbal or imagery system and verbal or language-specialized system. The two systems are in turn made up of or depend on various subsystems corresponding to different modalities such as visual, auditory and kinesthetic.

Paivio claims that the two systems are functionally independent and can act separately and in parallel, but they are also structurally interconnected such that activity in one system can trigger activity in the other. According to Paivio, only certain kinds of representations are able to trigger activity in another system and only under certain conditions. Interconnections are assumed to be one-to-many in both directions, meaning...
that a single word such as "a chair" can trigger several images of the chair or a single image of a chair can trigger several descriptions of it. The likelihood of triggering activation in one system by the other depends on the relative functional strength of these interconnections, which is in turn determined by prior experience. Additionally, individual differences, instruction and context affect the probability of activation.

Paivio believes that dual coding theory can provide a good foundation for developing a psychological model of education (Clark & Paivio, 1991). According to the theory, instruction and contextual stimuli can temporarily enhance activation of some connections between the two systems and inhibit others. Presenting images or asking students to generate images for words can prime the nonverbal system and is more likely to activate it than presenting words alone. Paivio puts a special emphasis on the importance of imagery and concreteness in instruction and cites a number of studies in support of his theory. For instance, image generation and supplementary pictures improve text comprehension, and subjects receiving imagery instructions remember more than those who do not receive imagery instructions (Clark & Paivio, 1991).

Dual coding theory implies that if a concept can be encoded using multiple sensory modalities it has a deeper hold on the mind, since now there can be several interconnected representations of that concept. The theory inspired a new wave of research into the effects of presenting information both visually and verbally on learning in a school environment. This paper focuses specifically on 3-dimensional (3D) visualization since there has been an increased interest in the use of 3D in education thanks to advances in technology. There is evidence that presenting information via 3D images and 3D animations has a positive effect on learning, especially in medical education (Bhayani & Andriole, 2005; Marcus et al., 2014). In a study by Silén et al., (2008) medical students reported that seeing 3D images in lectures and self-study sessions was both motivating and helpful in understanding anatomy. 3D animations were found to be more effective than regular 2D video projections in periodontal disease training and knowledge recall among dental students (Dhulipalla et al., 2015), and 3D stereoscopic method produced better results than teaching with a slide projector among orthodontics students (Oropeza, Sánchez, & Villagómez, 2015). In a randomized study, Prinz, Bolz and Findl (2005) showed that the students who were exposed to a 3D animation tool, "Ophthalmic Operation Vienna", outperformed the control group in the topographical understanding tasks and the theoretical understanding questions for cataract surgery.

Learning in 3D also seems to produce positive results among younger students. Bamford (2011) conducted a study examining the effects of 3D visualizations on student learning in 15 schools across France, Germany, Italy, Netherlands, Turkey, United Kingdom and Sweden, involving 740 students, ages 10-13. On average, 86% of students improved from the pretest to the posttest in 3D classes, compared to only 52% in 2D classes\(^1\). The average score improvement for 3D groups was 17% versus 8% in 2D groups. Students in 3D classes performed better in open-ended tasks and modeling tasks, and could remember more of the material after four weeks than those in 2D classes.

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\(^1\) Posttest performance results were not compared between schools (due to lack of standardization of the curriculum) but only against the pretest performance of each student.
Kim (2006) investigated the effects of 3D Virtual Reality simulation of plate tectonics on achievement test scores and attitude toward science in fifth-grade classrooms. The experimental group was exposed to a 3D simulation while the control group saw a 2D animation covering the same topic by the same teacher. The experimental group wore polarized glasses and could interact with the material. There was no statistically significant difference between the 2D and the 3D group in the pretest performance. Students in the 3D group scored higher on the posttest than those in the 2D group, even after a robust regression analysis was performed to account for outliers and to control for gender and ethnicity. There was a statistically significant improvement on the 3D group's mean posttest scores compared to their mean pretest scores. The posttest improvement in the 2D group was not statistically significant. Kim believes that the interactive aspect in the 3D group contributed to the improvement in posttest performance. There was no statistically significant change in the average attitude scores for either group.

Some studies show that 3D visualization is not superior over traditional methods in learning (Vuchkova, Maybury, & Farah, 2011; Richards & Taylor, 2015; Noureldin, Stoica, Kaneva, & Andonian, 2016; Azer & Azer, 2016). Even within 3D visualization there are inconsistent results on which type of 3D (3D images, 3D animations or interactive 3D animations) is most effective (Korakakis, Pavlatou, Palyvos, & Spyrellis, 2009; Korakakis, Boudouvis, Palyvos, & Pavlatou, 2012). This lack of consistency in evidence may be due to the diversity of software tools, variation in quality of tools, differences in presentation methods (e.g., lectures vs. self-study sessions) as well as a wide range of subject matter (ranging from plate tectonics to dentistry) used in research. Given this, as well as the fact that most 3D software tools are designed for research purposes, it is important to evaluate 3D tools that are already available on the market and also in use in educational contexts.

The Sensavis visual learning tool is an educational software aid created by the Swedish company Sensavis AB for use by teachers and students both in classrooms and in distance learning. It was launched as the 3D Classroom tool in 2013. The latest version was rebranded as the Sensavis visual learning tool in 2017. Since its launch the Sensavis tool has been used in over 550 schools and colleges in 36 countries including Sweden, the US and Singapore. The tool is mostly used in elementary and middle schools with the focus on students ages 9-15. Although the Sensavis tool had been evaluated by several teachers in the past via assessment of student performance, no rigorous scientific study on its effects on learning has been done before. It is also of interest to learn about student attitudes towards the tool since that can be an important factor in the learning process while using the tool.

The Sensavis visual learning tool consists of 3D interactive images and animations with no text or sound. This allows teachers to tailor the tool by adding their own verbal and written instructions, creating videos or having students create their own videos. The tool has six subject categories: biology, chemistry, physics, mathematics, geography, and engineering. Each category contains several modules such as the heart module within the biology category (Figure 1). In the heart module, for example, a user

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can interact with the tool by rotating the heart, speeding up or slowing down the heart rate and zooming in or out of the organ to see it in more detail. There are two versions of the tool: Sensavis Premium and Sensavis Win 10 App. Sensavis Premium has the option to use it with a stereoscopic 3D screen or projector and 3D glasses. Both versions have the same content and allow users to interact with the information being presented.

A school located north of Stockholm purchased licenses to use the Sensavis Win 10 App in early 2017. None of the teachers or students had been exposed to the Sensavis tool before. The teachers were trained on the use of the tool on March 15, 2017. A teacher of natural science (physics, chemistry, biology) in 7th, 8th and 9th grades agreed to participate in the study. In this study the teacher used the Sensavis tool in chemistry lessons for 7th graders and 9th graders (experimental groups) and not in lessons for 8th graders (control group).

![Figure 1](image.png)

**Figure 1.** A snapshot of the Sensavis visual learning tool showing categories, modules and scenes. Adapted from Sensavis Win 10 App, 2017.

**Research Objectives**

The main aim of this study was to evaluate the effect of the Sensavis visual learning tool on student performance in a school environment. Specifically, the study attempted to answer the following question: Would the Sensavis tool improve test performance in chemistry among 7th and 9th grade students who were using the tool? The additional aim was to assess student attitudes towards the Sensavis tool as well as their perception of its effect on learning chemistry via a questionnaire.

**Hypotheses**

The null hypothesis was that the Sensavis tool would have no effect on test performance among students in grades 7 and 9. Specifically, there would be no statistically significant difference in the posttest performance between the control (8th graders) and experimental groups (7th and 9th graders). The alternative hypothesis was that the tool would have a
positive effect on test performance among 7th and 9th graders. Working memory plays an important role in verbal reasoning, concept formation and learning (Baddeley, 1974; Cowan, 2014), and it improves linearly from age 4 to 14 (Gathercole, Pickering, Ambridge, & Wearing, 2004). In the present study, median age for 7th graders was 13, for 8th graders – 14 and for 9th graders – 15. Considering this age disparity and therefore potential differences in the developmental trajectory for working memory among the participants and assuming positive effects of the Sensavis tool, it was expected that 7th graders using the tool would perform similar to or better on the posttest than 8th graders not using the tool, and that 9th graders using the tool would perform better than both 7th and 8th graders (8th graders <= 7th graders < 9th graders).

Method

Design
Since the study took place in a school setting during the school year it utilized a quasi-experimental between-subject design with one control group (8th graders) and two experimental groups (7th and 9th graders). The participants came from different age groups because the entire school has only 200 students and each grade has fewer than 20 students. The students and their parents were informed of the study by the teacher and gave their verbal consent\(^3\). The students were given an option to refuse having their test results published. None of the tests involved in the study were included in calculating the final grade for the participants. The names of the school, the teacher and the participants were not revealed. Only the grade, gender and age of the participants were used in the study.

In this study, the independent variable was training with or without the Sensavis visual learning tool and the dependent variable was posttest performance (Table 1). Both the control and experimental groups were exposed to the same lecture content on chemical bonds taught by the same teacher. None of the participants had been exposed to this material before.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Control</th>
<th>Experimental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade</td>
<td>8th grade</td>
<td>7th grade</td>
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<td>Prior to intervention</td>
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<td>Chemistry grades</td>
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<td></td>
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Table 1. An overview of the study design.

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\(^3\) The parents were informed of the study in the monthly newsletter and the students were informed by the teacher during lectures.
Prior to the intervention all participants took an educational attainment test (EAT) on the preceding topic (atoms) within chemistry to determine if there were performance differences as a function of age and grade. The design of both tests (EAT and posttest) and the contents for the intervention were left to the teacher's discretion.

Participants
The participants were students in present 7th, 8th and 9th grades (N=56). The control group was 14-year-olds in 8th grade (n=19, 11 girls, 8 boys, \( M=14.26, SD=0.45 \)) and the experimental groups were 13-year-olds in 7th grade (n=19, 10 girls, 9 boys, \( M=13.32, SD=0.48 \)) and 15-year-olds in 9th grade (n=18, 11 girls, 7 boys, \( M=14.89, SD=0.32 \)).

Educational Attainment Test
Prior to the intervention, all participants took the educational attainment test\(^5\) (EAT) designed by the teacher to measure their level of attainment in a preceding chemistry topic (atoms)\(^6\). This test was used to evaluate whether there were performance differences among the participants as a function of age and grade. There are 7 questions in the EAT and the highest score is 14. The teacher administered the EAT to 8th graders on March 3, to 7th graders on March 30 and to 9th graders on April 21.

Chemistry Grades
Chemistry grades from the fall semester 2015, spring semester 2016 and fall semester 2016 for all three groups were collected and used as a covariate in the analyses of the EAT and posttest performance.

Procedure

Control Group
The students in the control group were taught six 50-minute lessons on chemical bonds without the Sensavis tool during two weeks in March 2017. After the students completed the lessons they took a posttest\(^7\) during the subsequent lesson on March 24. The posttest was designed by the teacher to estimate how well the students understood the lessons on the topic of chemical bonds. There are 10 questions in the posttest and the maximum score is 12.

Intervention
The intervention targeting 7th and 9th graders consisted of the same lecture content and duration plus a two-minute 3D animation with no text or sound showing chemical bonds and interactions (Figure 2). The animation was created by the teacher using the Sensavis Win 10 App. The animation was not used in instruction, only in self-study sessions by students in the experimental groups.

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\(^4\) Mean age for all students was as of March 3, 2017, the date of administering EAT to 8th graders.

\(^5\) See appendix 1.

\(^6\) All participants had six lectures on this topic as well.

\(^7\) See appendix 2.
The students received the animation during the second lesson of the lecture series on chemical bonds and worked on it in pairs using school computers. Their task was to record a video where they describe what was happening in the animation. The animation contained several arrows drawn by the teacher to guide the students in their description. The students also had access to the animation after the lecture. They submitted their videos at the end of the sixth lesson. The teacher started with the intervention in the 7th grade at the end of week 13 and in the 9th grade during week 15.

Figure 2. A snapshot of the two-minute 3D animation designed for the intervention.

Posttest
After the students in the experimental groups submitted their videos, they took the same 10-question test as the control group during the subsequent lesson. 7th graders handed in their videos on April 20th and took the posttest on April 21st while 9th graders submitted their videos and took the posttest during the week of May 1st.

Questionnaire
A questionnaire with six questions was developed to evaluate student attitudes towards the Sensavis tool in the experimental groups (grades 7 and 9) and to determine the

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8 The reason for the discrepancy in intervention dates was due to the fact that 9th graders needed to prepare for national tests first.
9 See appendix 3 for the English version of the questionnaire.
amount of time they spent studying the animation outside lectures. The questionnaire contained the following six questions:

1. Did the Sensavis tool help you understand the topic (chemical bonds) better?
2. Did you enjoy using the tool?
3. Did the tool increase your interest in the topic (chemical bonds)?
4. Do you think that the tool helped you improve performance on the test (for chemical bonds)?
5. Do you want to use the tool in the future?
6. How much time (approximately) did you spend using the tool outside the classroom?

The students filled out the questionnaire after they completed the posttest.

Results

Statistical analyses for the educational attainment test (EAT) and the posttest were conducted using the following tools: SPSS 24 for detecting outliers and R version 3.4.0 for the two-sample independent t-test for gender differences in performance and ANCOVA analyses.

Initial analysis revealed an outlier\(^\text{10}\) in the posttest performance in 7th grade which was removed from subsequent posttest analyses. No other outlier was detected. The two sample independent t-test was done to determine if there was a difference in performance between boys \((n=24)\) and girls \((n=32)\) with regard to both the EAT and posttest. Levene’s test of equality of variance was non-significant for both, \(p > .18\). There was no statistically significant difference in the EAT performance between boys \((M=10.62, SD=3.13)\) and girls \((M=10.75, SD=2.54)\), \(t(54) = -0.16, p = .873\). Neither was there any statistically significant difference in the posttest performance between boys \((M=8.46, SD=1.74)\) and girls \((M=8.19, SD=2.09)\), \(t(53) = 0.5, p = .619\). Based on these observations, gender was not considered in the following analyses.

One-way analysis of covariance (ANCOVA) was performed to compare the performance of control and experimental groups on the EAT and posttest with age and average chemistry grade from previous semesters as covariates. While 9th graders \((M=11, SD=2.33)\) slightly outperformed both 7th graders \((M=10.68, SD=2.54)\) and 8th graders \((M=10.79, SD=3.33)\) and 8th graders slightly outperformed 7th graders, the difference was insignificant, \(F(2, 51) = 0.043, p = .958\). Given that the maximum score for the EAT was 14, 7th graders got 76% of answers correct, 8th graders got 77% correct and 9th graders got about 79% correct.

The ANCOVA for posttest performance revealed a statistically significant difference when controlling for age and average chemistry grade from the past semesters, \(F(2, 50) = 3.281, p = .045\), with 8th graders \((M=9.16, SD=1.61)\) outperforming both 7th graders \((M=7.83, SD=1.85)\) and 9th graders \((M=7.89, SD=2.11)\). Given that the maximum score for the posttest was 12, 7th graders got 65% of answers correct, 8th graders got 76% correct and 9th graders got 66% correct.

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\(^{10}\) See appendix 4.
Questionnaire answers from 7th and 9th graders revealed discrepancies in attitudes toward the tool between the two groups. Whereas 74% of 7th graders responded "more than somewhat" and "very much" to the question "Did the Sensavis tool help you understand the topic (chemical bonds) better?" (Figure 3), only 29% of 9th graders responded similarly (Figure 4).

Figure 3. Questionnaire answers from 9th graders to the following five questions:
1. Did the Sensavis tool help you understand the topic (chemical bonds) better? 2. Did you enjoy using the tool? 3. Did the tool increase your interest in the topic (chemical bonds)? 4. Do you think that the tool helped you improve performance on the test (for chemical bonds)? 5. Do you want to use the tool in the future?

Figure 4. Questionnaire answers from 9th graders to the five questions.
There was also a difference in student perception of the effectiveness of the tool on the posttest performance. While 59% of 7th graders responded "more than somewhat" and "very much" to the question "Do you think that the tool helped you improve performance on the test (for chemical bonds)?", none among 9th graders responded in that way, and instead 66% of 9th graders responded "none at all" or "very little". When asked if they enjoyed using the tool, 65% of 7th graders responded "more than somewhat" and "very much" while only 6% of 9th graders had a similar response. In response to the question "Do you want to use the tool in the future?" 65% of 7th graders replied "more than somewhat" and "very much" while none among 9th graders responded in that manner. In fact, 63% of 9th graders responded "not at all" to that question.

The majority of 7th graders (87%) and 9th graders (79%) spent less than 15 minutes on the animation. 12% of 7th graders spent more than 60 minutes and 21% of 9th graders spent between 30 and 60 minutes on the tool.

Discussion

This study was designed to evaluate the effect of the Sensavis visual learning tool on student performance in chemistry among 7th and 9th graders (experimental groups). The null hypothesis was that 7th and 9th graders would not perform significantly better on the posttest compared to 8th graders (control group). The alternative hypothesis was that the Sensavis tool would have a positive effect on test performance in the experimental groups. The results failed to reject the null hypothesis. The analysis showed that there was a statistically significant difference in the posttest performance with the control group outperforming both experimental groups when controlling for age and average chemistry grade from previous semesters. Interestingly, there was no statistically significant difference in the educational attainment test scores between the three groups when controlling for age and average chemistry grade suggesting that the students in all three grades were at a similar performance level prior to the study. The results indicate that the Sensavis tool had no positive effect on learning chemistry among 7th and 9th graders.

There are several factors that need to be considered when interpreting the results of this study. First, the tool was not used during instruction but only in self-study sessions by the students. In the aforementioned studies which demonstrated positive effects of 3D visualization, the 3D software tools were mostly used in instruction. There is a big difference between watching a video narrated by a teacher and attempting to narrate an animation oneself. Apart from experiencing potential technical difficulties, there is a possibility for misunderstanding the animation and describing it incorrectly. The tool may have a positive effect when used in instruction by a teacher as students can build correct associations between a concept and an image or an animation. The lack of positive effect of the tool may also be due to the length of the intervention and the time spent on it by the students. The animation was only two minutes long and most students in the experimental groups spent less than 15 minutes total outside the classroom to study the animation. It is also important to point out that performance on both tests (EAT and posttest) did not affect the final grade in chemistry for all participants which may
contribute to decreased performance in the experimental groups. The small sample size \((N=56)\) is yet another factor that needs to be considered when interpreting the posttest results. In order to assess more accurately the effects of the Sensavis tool on learning, a study with a larger sample size and a randomized design is required.

The questionnaire responses revealed a discrepancy in attitudes between 7th graders and 9th graders. It is of interest to note that most 7th graders found the tool helpful in understanding the topic of chemical bonds, enjoyed using the tool, believed that it helped them perform better on the posttest, and wanted to use it in the future. Among 9th graders, while a slight majority thought that the tool helped them understand the topic better, most did not enjoy using the tool, did not think that the tool helped improve their performance and did not want to use it in the future. Since the students filled out the questionnaire after the posttest, their performance may have affected the questionnaire responses. Given the negative results for the effects of the tool in both groups, these responses indicate that 9th graders are more aware of the effect of the tool on their performance than 7th graders. Needing to create a video may be a factor in having negative attitudes towards the tool among 9th graders since it could be viewed by the students as extra work. The results of the study highlight the importance of taking into account student needs and preferences when introducing new technologies in a classroom.

The study has several limitations such as the small sample size and nonrandom assignment which were unavoidable due to the fact that it took place in a school setting and the school has 200 students total. In an ideal experiment the participants would be randomly assigned to control and experimental groups. In this case, the participants were the students in current 7th, 8th and 9th grades. To account for that, an educational attainment test was taken by all participants prior to the study to determine if there were any performance differences among the three groups as a function of age and grade. Age was also used as a covariate in the analysis. The study does have a strong ecological validity since it took place in a natural setting with the teacher designing the contents of the tests and intervention. The tests and the material were typical of the curriculum for that school.

The results of the study indicate that 3D visualization does not necessarily improve learning, at least when used in self-study sessions by students. The effect of 3D tools may depend on the tool quality, method of instruction, subject matter and audience. While there is evidence for the beneficial effect of 3D visualization on learning among medical students, it is not as clear if younger students experience positive effects. Since any potential improvement on learning in childhood can have big effects later in life, future research should focus more on younger students with different educational levels and should take place in a school setting for strong ecological validity. It is also important to have a larger sample and cover a wide range of topics. Since the tool was not directly used in instruction in this study, it is hard to assess the implications of the study on dual coding theory.

In conclusion, it is hard to generalize if 3D visualization is superior to traditional teaching methods, and each tool needs to be assessed separately for its effectiveness in a specific setting.
References


Appendix 1: Educational Attainment Test

Namn:________________________________ Hjälpmedel:______________________________

Ett periodiskt system- Max 14 p

1a: Vilket atomnummer har syre? (1p)
b. Vilket atomnummer har klor? (1p)
c. Vilket ämne har atomnummer 13? (1p)


3. Rita en atom av kol, nr 6. Den ska ha 5 neutroner? (2p)

4. Vilket masstal har kolatomen du ritat? (1p)

5. Ädelgaser har något gemensamt. Vad? (2p)

6. Rita tre isotoper av väte. Bestäm själv vilka! (2p)

7. Varför säger man att atomen är neutral när den är full av laddningar? (1p)
Appendix 2: Posttest

Undersökning, kemisk bindning
Är du Pojke_____ Flicka_____ Årskurs:_______ Nr:_____


1                    2                    3                    4                    5
Dåligt                                  ok                                        utmärkt

1. Natrium har en elektron ytterst. Vad vill den helst göra? Ringa in
   - Släppa den elektronen
   - Ta upp en elektron
   - Sätta ihop sig med en till natrium

2. Kalium har en elektron ytterst. Vilket ämne kan den bilda ett salt tillsammans med?
   - Magnesium som har 2 elektroner ytterst
   - Jod som har 7 elektroner ytterst
   - Natrium som har en elektron ytterst

3. Väte har en elektron ytterst. Två väteatomer sätter sig ofta ihop. Varför?
   - De delar ett par elektroner och tror båda att de har fullt skal
   - Den ena ger en elektron till den andra
   - Det är en metallbindning

4. VARFÖR sitter ämnen ihop i en jonbindning?
   - De delar yttre elektroner
   - De har olika laddning
   - De har samma laddning

5. Rita hur brom med 7 elektroner ytterst binder sig till varandra i molekylen Br2.

6. Syre (O) med 6 elektroner ytterst binds till Strontium (Sr) med 2 elektroner ytterst. Rita hur det går till.

7. Varför har saltkristaller så regelbunden form?

8. Runt atomkärnan svävar ____________________________

9. Kärnans laddning är ____________________________

10. Vilken del av atomen är det som är aktiv i alla bindningar? (ringa in)
    protonen        neutronen         elektronen
Appendix 3: Questionnaire for students in the experimental groups, English version

Sensavis Questionnaire

The goal of this questionnaire is to learn what students think about the Sensavis visual learning tool.

1. Did the Sensavis tool help you understand the topic (chemical bonds) better?

   1  2  3  4  5
   Not at all  Very little  Somewhat  More than somewhat  Very much

2. Did you enjoy using the tool?

   1  2  3  4  5
   Not at all  Very little  Somewhat  More than somewhat  Very much

3. Did the tool increase your interest in the topic (chemical bonds)?

   1  2  3  4  5
   Not at all  Very little  Somewhat  More than somewhat  Very much

4. Do you think that the tool helped you improve performance on the test (for chemical bonds)?

   1  2  3  4  5
   Not at all  Very little  Somewhat  More than somewhat  Very much

5. Do you want to use the tool in the future?

   1  2  3  4  5
   Not at all  Very little  Somewhat  More than somewhat  Very much

6. How much time (approximately) did you spend using the tool outside the classroom?

   1  2  3  4  5
   <15 min  15-30 min  30-45 min  45-60 min  > 60 min
Appendix 4: A graph showing the outlier in the posttest performance in 7th grade