Students and teachers use of instructional videos

Suggestions for further development of instructional videos to promote active learning

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Abstract

The use of technology in education (so-called e-learning) has seen a rapid development over the last decades. From being small systems that might assist lectures it has developed into systems that could potentially replace the lecture altogether, chief amongst these systems is blended and flipped learning. Blended seeking to combine e-learning with face-to-face instruction in the classroom, while flipped delivers e-learning outside the classroom while using class time to promote active learning. E-learning now seeks to replace what it once assisted. The research on blended and flipped learning often shows that it is more efficient than the traditional classroom, at least when measuring learning outcomes and that it is an effective way of promoting active learning amongst students. Similarly, the development of educational content for use in e-learning has evolved, from simple animations to more complex and interactive systems. Given these developments, and the wealth of material available (such as Khan Academy and iTunesU) it seems that it should be possible for all teachers to use blended or flipped learning in their classrooms.

Therefore, it is of interest to see how educators use the instructional material, and how the students react to the uses, and how the material can be improved. This thesis examines these factors by delivering the same three instructional videos (IVs) to three chemistry-1 teachers, gathering responses from both the teachers and their students (n=58) on how the IVs were used, the student's attitudes towards how the IVs were used, and teachers and students suggestions for improvements. These responses were analysed, and the results were viewed in the light of the theoretical knowledge on e-learning. The contributions of this thesis to the field of e-learning are twofold:

How should IVs be designed? The study shows that IVs should utilize macro-level interactivity to scaffold students learning, as they tend to self-regulate poorly in an e-learning setting. This support for macro-level interactivity is well backed up in the literature. Additionally, IVs should be segmented as to apply the pacing principle.

How should IVs be used? The study shows that the students most enjoyed a blended approach, utilizing collaborative problem-solving. Although many other factors could influence the student’s enjoyment, such as previous experience with e-learning. Furthermore, it was shown that pre-training in the use of interactive elements could be utilized, which also is a point is made in the literature.

The study was a relatively small, qualitative study, but it gives some useful suggestions for how educators could use e-learning in their classroom, and how e-learning content could be designed as to optimize active learning amongst students.

Acknowledgments

This thesis is set to be delivered by May, 2017, but the work put in to it actually started a lot earlier, in the winter of 2015 when I as a young undergraduate was deciding where I wanted to write my master thesis. Naturally, I started out at the school-laboratory in chemistry. Where I arrived with a rough sketch of an idea of what this thesis would become, in the spring of 2016 I started creating the instructional videos that were used in this thesis, and in the spring of 2017 I started writing this text based on that work. I would like to thank my supervisor Karoline Fægri, for assisting me in every step on the way, for her patience with my efforts, and exemplary feedback. Without her guidance this project would not be what it is, and would be poorer for it.

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Table of acronyms

C1 = Classroom 1

C2 = Classroom 2

C3 = Classroom 3

CTML = Cognitive load theory of multimedia learning

DFW’s = D’s, F’s and Withdrawals

IV = Instructional video

MOOC = Massive open online courses

SOLO = Structure of observed learning outcomes

STEM = Science, technology, engineering and mathematics

TEL = Technology enhanced learning

1 Introduction

The didactic lecture model has come under criticism recently for several reasons. Critics argue that: It reduces the student to a passive listener, at least when the student has limited motivation for the subject (Kember & Wong, 2000). Student attention span is limited and not long enough for the duration of a typical lecture (Bunce, Flens, & Neiles, 2010). And that it leads to a “sink or swim” attitude amongst students (Seery, 2015). Furthermore, research has shown that students learn more effectively when engaging in active learning compared to students taught using the traditional lecture format (Freeman et al., 2014; Prince, 2004). Active learning being a form of learning where the students actively work with the learning content (Freeman et al., 2014), active in the sense of cognitively active, meaning that the students actively process the information they are learning (Mayer, 2002). In response, many researchers have suggested making lectures more interactive, in order to get the students to actively participate (Steinert & Snell, 1999; Tam, Leung, & Koo, 1993). Others have taken it a step further, dropping the lecture model entirely and using alternative means to deliver content electronically to the learner via the internet, i.e. e-learning (Welsh, Wanberg, Brown, & Simmering, 2003).

The diverse forms of e-learning are used to convey information to students, often with the goal of promoting active learning (Delen, Liew, & Willson, 2014; Leo & Puzio, 2016; Mennella, 2016; Seery, 2015). Either by combining e-learning and traditional face-to-face learning, which is known as blended learning (Kerres & Witt, 2003). Or by delivering e-learning outside of the classroom, and devoting the class time to active learning activities, which is known as flipped learning (Seery, 2015). Finally, tutorials are also used to learn practical skills (Back et al., 2016). The educational material in e-learning is often presented to the students using some form of instructional videos (IVs) (Seery, 2015; Wells, Barry, & Spence, 2012) which are essentially video versions of lectures (Liu & Kender, 2004). Studies conducted on e-learning using IVs generally shows positive results for student learning of the subjects (He, Swenson, & Lents, 2012; Schultz, Duffield, Rasmussen, & Wageman, 2014; Shattuck, 2016; Wells et al., 2012). And that students are mostly positive in their reactions to the use of IVs (Schultz et al., 2014; Shattuck, 2016; H. van der Meij & van der Meij, 2016).

It might seem that Frederick (1987) was premature when he stated that the lecture is here to stay, at least in an educational context. Studies conducted on instructional videos have shown that they potentially can be more efficient in conveying information to students than the traditional lecture counterpart. Regardless of which methods (such as flipped, blended, etc.) are used to implement IVs in education (Seery, 2015; Wells et al., 2012; Zhang, 2005). There have been several guides published on how to design such instructional videos (or other e-learning material) to create optimal learning outcomes (Alonso, López, Manrique, & Viñes, 2005; Clark & Mayer, 2011), often with differing theoretical perspectives. In the theory section, I will summarize some of these theoretical perspectives on the design of instructional videos.

This project examined how educators choose to use IVs, and students' attitudes towards the way they used the videos, while also analysing the teachers and students suggestions for improvements to IVs. Specifically, the focus was on how IVs are used in chemistry education. The project mentioned above consisted of a trial where three teachers at different Norwegian high schools each received the same set of instructional videos covering the development of the atomic model. The videos were made so that they could be used in a flipped classroom (Seery, 2015), in a blended classroom (Kerres & Witt, 2003) or as tutorials (Back et al., 2016). The teachers were free to choose how they used the videos, although suggestions were included (see Appendix C), in which the teachers were encouraged to use the IVs in a flipped classroom. Open-questionnaires were distributed to the teachers and their students to gather information on how the videos were used, students' attitudes towards the way the videos were used, and students and teachers feedback on the design of the videos. The data will be analysed in light of the two main research questions of this thesis: How should IVs be designed for use in classrooms? And how should educators use IVs in their classrooms?

The study was relatively small, with three teachers and 58 students participating, and is a qualitative study. Which means that the results uncovered cannot be used to state the answers to these research questions (Fraenkel, Wallen, & Hyun, 2012). Nevertheless, it gives some interesting suggestions on the two main research questions.

2 Theory

This study will as previously mentioned examine some factors in how IVs should be used, and how they should be designed. So the first matter of business is to summarize some theoretical perspectives on designing and using e-learning. The first thing to consider is how the mind processes e-learning.

2.1 Cognitive load theory of multimedia learning

Cognitive load Theory of Multimedia Learning (CTML) is a theory describing how the mind works when processing multimedia instructional messages (such as instructional videos) (Mayer & Moreno, 2003). It relies on three assumptions about the mind:

> The dual-channel assumption assumes that humans have two separate channels for processing visual and auditory information (Mayer, 2002; Paivio, 1991).
>
> The limited capacity assumption assumes that the amount of information human beings can process in each channel at one time is limited (Baddeley & Hitch, 1974; Mayer, 2002).
>
> The active processing assumption assumes that humans learn actively by attending to relevant information, organizing the selected information into coherent mental representations and integrating the mental representations with their previous knowledge (Mayer, 2002; Wittrock, 1989)

These assumptions, in turn, leads to the conclusion that one should aim to reduce the learner's cognitive load, i.e. the amount of cognitive processing devoted to learning the material. So that the amount of cognitive processing needed does not exceed the learner's cognitive processing capacity, if so the learner experiences a cognitive overload (Clark & Mayer, 2011). Cognitive overload is created when the cognitive load generated by the educational material exceeds the processing capacity of the cognitive system, i.e. the working memory, which has been shown to negatively influence student learning (Mayer & Moreno, 2003). Working memory refers to a cognitive systems ability to hold and process information at any given time (Baddeley & Hitch, 1974). Cognitive overload could happen for instance, if the instructional video presents too much text and animations, so that the visual channel is overloaded. If the visual channel is overloaded the learner will not be able to process any auditory information contained in the video, since the working memory is overloaded by the visual information (Mayer & Moreno, 2003).

Instructional content generates three types of cognitive loads, Intrinsic, extraneous and germane:

> **Intrinsic load** is the cognitive load inherent to the learning material, i.e. the more complex the theme is, the higher the intrinsic load (DeLeeuw & Mayer, 2008).
>
> **Extraneous load** is the cognitive load exerted by activities that do not support learning, such as superfluous text or pictures (DeLeeuw & Mayer, 2008).
>
> **Germane load** is the cognitive load generated by the effort the learner exerts to process the new information and integrate it with existing knowledge (DeLeeuw & Mayer, 2008)

Note that the different texts in this article denote these three load differently. For instance Clark and Mayer (2016) define these as extraneous processing (extraneous load), essential processing (intrinsic load) and generative processing (germane load).

However, their definition is essentially the same as the one used by DeLeeuw and Mayer (2008), and for coherence's sake, these constructs will be referred to as intrinsic, extraneous and germane load in this thesis. If too much germane, intrinsic and extraneous load is generated by the learning material, it can lead to cognitive overload. So the goal of the designer is to minimize the extraneous and intrinsic load from the multimedia content to prevent a potential cognitive overload (Clark & Mayer, 2011). Meanwhile, the germane load should be kept as high as possible, as it should be beneficial for student learning (Clark & Mayer, 2011; Schnotz & Rasch, 2005). Mayer & Moreno (2003) presents five cognitive overload scenarios and nine ways to reduce the cognitive load, shown here in Table 1:

Table 1: Mayer & Moreno's nine methods for reducing cognitive load in Multimedia

Overload scenario	Method for reducing cognitive load	Effect Size (numbers of experiments)
Visual channel is overloaded by germane load	Off-loading: Move some of the information from visual to auditory	1.17 (6)
Both channels are overloaded by germane load	Segmenting: Divide the video up into several bite-size segments Pre-training: Train students, before viewing the video, in names and characteristics of the components in the video	1.36 (1) 1.00 (3)
One or both channels are overloaded by germane and extraneous load (due to extraneous material)	Weeding: Eliminate extraneous material from the videos Signalling: Give cues for how to process the material, so to reduce processing of extraneous material	0.90 (5) 0.74 (1)
One or both channels are overloaded by germane and extraneous load (due to confusing presentation)	Aligning: Place text close to related parts of the graphic presentation, so to reduce the need for visual scanning Eliminating redundancy: Avoid presenting the same material both auditory and visually	0.48 (1) 0.69 (3)

Overload scenario	Method for reducing cognitive load	Effect Size (numbers of experiments)
One or both channels are overloaded by germane and intrinsic load	Synchronizing: Present narration and animations simultaneously.	1.30 (8)
	Individualizing: Train learners in holding mental representations.	1.13 (2)

All these methods are backed up by studies conducted by the researchers, showing median effect sizes when subjects were tested for problem-solving transfer tests ranging between 0.48 – 1.36 (Mayer & Moreno, 2003), i.e. the median improvement in problem-solving transfer tests ranged from a 0.48-degree improvement to a 1.36-degree improvement. Some of these methods have sounder empirical backing than others (number of experiments), but it seems all of them are effective in reducing the cognitive load from multimedia learning and so should be considered when designing multimedia content. As can be seen from Table 1 almost all the methods proposed by Mayer & Moreno (2003) are concerned with reducing extraneous or germane load. The reasoning behind this is that intrinsic load often was considered to be constant since the material being taught is the same regardless (Sweller, 1994). However, more recent research suggest that the intrinsic load can be reduced by separating the information contained in a high-complexity interactive element into two successive less complex interactive elements (Lee, Plass, & Homer, 2006), and so should be considered. Additionally, one study has shown that reducing the germane load seems to have a negative effect on student learning (Schnotz & Rasch, 2005) and so one needs to increase the germane load while decreasing the intrinsic and extraneous load (Clark & Mayer, 2011). Most multimedia content, such as IVs, can go under the term e-learning, which will be covered further in the next section.

2.2 E-learning

E-learning has certainly been in vogue in the last two decades or so, as can be determined by a bibliometric search of the term in a scientific database, such as the Web of Science. It can be considered an umbrella term encompassing all electronic based learning delivered through an intra- or internet (Welsh et al., 2003). As such it spawns over everything from massive open online courses (MOOCs) (Liyanagunawardena, Adams, & Williams, 2013) to short narrated animations (Mayer, 2002). Larger system can even be able to distinguish between the learners learning styles and adapt to it, a so-called intelligent tutoring system (Klašnja-Milićević, Vesin, Ivanović, & Budimac, 2011). Interestingly, a learner's previous experiences with e-learning seem to affect their impressions of new e-learning interventions (Mitra, Lewin-Jones, Barrett, & Williamson, 2010). To avoid confusion, I will first specify the kind of e-learning this thesis is primarily concerned with, which are instructional videos (IVs). In the next paragraphs, the theoretical view of IVs will be shown along with results from previous studies.

2.2.1 Instructional videos

Instructional videos (IVs) are, as previously explained, videos made with the goal of conveying the same information as a lecture (Liu & Kender, 2004). These can take a multitude of forms, from a nature documentary (Ibrahim, Antonenko, Greenwood, & Wheeler, 2012) to whiteboard imitations (as popularized by Khan Academy) (Chen & Wu, 2015). The common denominator is that they present information to the learner in the form of animations and texts and speech at the same time, although not necessarily all at once. Studies on e-learning have often used IVs as a way of delivering content to the students (Merkt & Schwan, 2014; Seery, 2015; Zhang, 2005) with the goal of promoting active learning amongst the students.

There has however been precious little research on how different educators' different uses of IVs promote or negate active learning amongst the students. If IVs are considered a tool for promoting active learning, then there must be some methods for using IVs in education that is more successful in promoting active learning than others. Furthermore, Hobbs (2006) found that educator's practices could weaken the educational value of IVs; these momentums will be covered further in section 2.3.2.

2.2.2 Video format

The format of instructional videos can as previously stated vary quite a lot. An interesting point that several researchers have brought up is that those formats may produce different amounts of cognitive load, even though the material is the same (Homer, Plass, & Blake, 2008). This is due to their different methods of presenting multimedia content (Chen & Wu, 2015), and so the format could potentially affect the intrinsic, extraneous and germane load of IVs.

Chen & Wu (2015) performed a study on different formats and their associated cognitive load, the formats used were: Lecture capture, talking head and picture-in-picture (see Figure 1). Of these, the talking head generated the most cognitive load in students, as measured by a cognitive load scale. The reason for this might be due to the splitting of attention such a presentation style creates since learners have to be attentive visually both to the lecturer and the learning material (Chen & Wu, 2015; Homer et al., 2008). Here the lecturer can be considered a form of extraneous load, as long as the visual of the lecturer does not contribute to the students learning (DeLeeuw & Mayer, 2008). Interestingly learning performances were better for the lecture capture and picture-in-picture format than the talking head format (Chen & Wu, 2015), showing the same positive correlation between reducing cognitive load and improving learning performances as demonstrated by other researchers (Mayer & Moreno, 2003). However, the same study also showed that the talking head generated the highest sustained attention which should be positive for student learning, together with the highest cognitive load (Chen & Wu, 2015).

One needs to consider what type of cognitive load one reduces with the format, reducing intrinsic and extraneous load should be beneficial for student learning (Clark & Mayer, 2011; Mayer & Moreno, 2003) while reducing germane load might have a negative effect on student learning (Schnotz & Rasch, 2005). Chen & Wu's (2015) study did not, however, consider which of the extraneous, intrinsic or germane load that was reduced or increased due to the format.

The study did not consider the whiteboard imitation format (Chen & Wu, 2015). Theoretically, the whiteboard imitation should not produce the same split-attention problem as the talking head format, since the whiteboard imitation format only contains one area where the learner's attention is needed (see Figure 1), which should reduce the extraneous load (Mayer & Moreno, 2003).

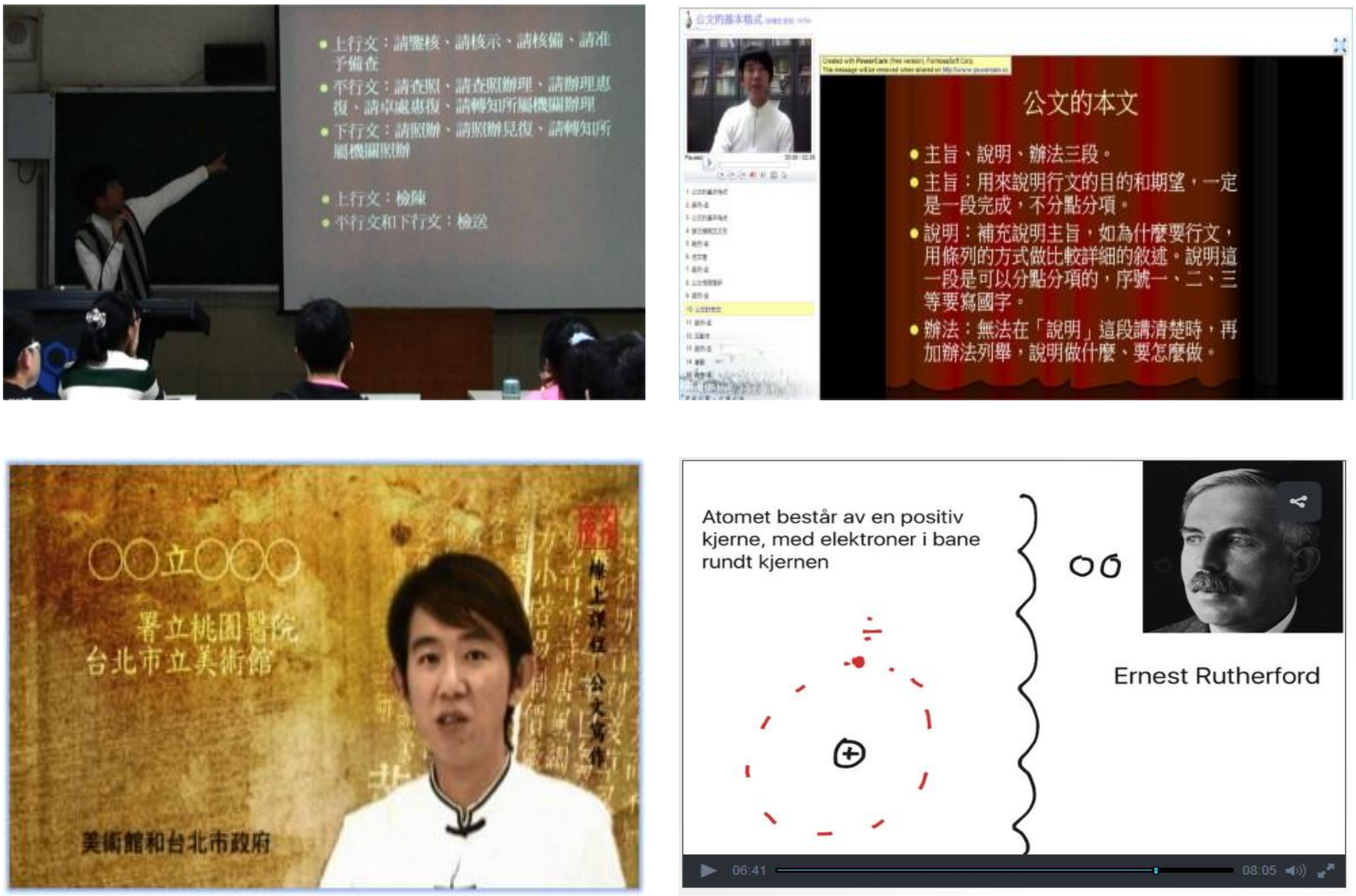

Figure 1: From left to right, top to bottom: Lecture capture, talking head, and picture-in-picture, from Chen & Wu (2015), whiteboard imitation, from author

Another study compared the picture-in-picture format with a format using only words, pictures, and narration to explain a procedure, which is similar to the whiteboard imitation format, and found no significant difference in cognitive load between the two, as measured by a Cognitive load questionnaire (Yang & Tao, 2015).

Furthermore, a study compared the “talking-head” format with the whiteboard imitation. The video classified as ‘talking head’ showed a teacher alongside a chalkboard, explaining and drawing (Ilioudi, Giannakos, & Chorianopoulos, 2013) which is typical for the lecture-capture format (Chen & Wu, 2015) (Figure 1), and is considered in this thesis a form of lecture-capture. The study did not specifically measure cognitive load, only learning performances, which were higher for the lecture capture format than the whiteboard imitation format (Ilioudi et al., 2013). Which is unexpected, since Homer, Plass and Blake (2008) found that having video, as well as PowerPoint slides, lead to a split-attention effects which increased the cognitive load (Homer et al., 2008), which is backed up by other researchers (Chen & Wu, 2015). One should expect the same split-attention-effect for a video combined with a chalkboard as used by Ilioudi et al. (2013).

Given that learning performances and the amount of cognitive load seems to be correlated as previously shown (Chen & Wu, 2015; Mayer & Moreno, 2003). It might be assumed that the cognitive load was higher for the whiteboard imitation format in the study of Ilioudi et al. (2013). However, this would contradict the theoretical view, since there are fewer areas of attention (DeLeeuw & Mayer, 2008; Homer et al., 2008) in the whiteboard-format, and the findings of Chen and Wu (2015) and Yang and Tao (2015). Complicating things further is the fact that the studies were not conducted by the same researchers, and so the quality of the videos produced by Chen and Wu (2015) might be vastly different to the quality of the videos produced by Iloudi et al. (2013). It seems more studies are needed on the subject, especially one that compares the whiteboard imitation format with the other formats and measures cognitive load. What can be said is that the format of instructional videos seems to have an effect on cognitive load. Furthermore, one should try to avoid splitting the learner’s attention between several areas of interest since the learner then needs to visually scan those areas for information, which could increase the extraneous load (Mayer & Moreno, 2003).

2.2.3 Deep learning

Instructional videos have been shown to promote deep learning amongst students (Mitra et al., 2010). Deep learning is a form of learning style applied when solving problems, where the learner focuses on understanding what the teacher wants to communicate and understanding the relationships between what he or she is learning and what they already know. It is often compared with surface learning where the learner focuses on learning the text (or another instructional medium) itself (Chin & Brown, 2000). Studies indicate that the deep approach is more effective when it comes to retention and free recall of information (Säljö, 1981). Biggs (2012) separates between academically motivated students, who naturally apply a deep (and therefore active) learning approach to their work and non-academically motivated students who do not naturally apply a deep learning approach to their work, they tend to have more of a surface approach. He suggests that the non-academic students need to be encouraged to apply deep learning, by utilizing active learning such as problem-based learning (Biggs, 2012). Note that when this text refers to deep and surface learners, it only considers their learning styles, not whether the person itself is 'deep' or 'surface.'

Instructional videos can potentially promote deep learning by combining auditory and visual information in the presentation. This combination can be used to engage students directly with problems, and apply their knowledge to new contexts which promote a deep learning approach (Mitra et al., 2010). A lecture can combine auditory and visual information, but seldom engages the students directly with problems, and does not necessarily prompt them to apply their knowledge to new contexts. Furthermore, deep learning can be seen as something that creates a higher degree of germane load. Given that students are more focused on organizing their new knowledge and integrating it with their existing knowledge (Säljö, 1981), which is what germane load is (DeLeeuw & Mayer, 2008), increasing the germane load should be beneficial for student learning (Schnotz & Rasch, 2005). So increasing the amount of deep learning would be effective as long as the intrinsic and extraneous load are not too high, which would lead to a cognitive overload scenario (Mayer & Moreno, 2003).

An important point in instructional videos is that the mind remembers a picture better than the verbal names of pictures (Mitra et al., 2010). Since a well-designed instructional video encourages both auditory and visual processing, there is less of a risk of cognitive overload, since the information is divided between the two processing channels (Mayer & Moreno, 2003). So IVs can seemingly promote deep learning. However, the learner needs to engage critically with the material through questioning and discussion for deep learning to occur (Mitra et al., 2010), at least for the students who do not naturally apply a deep learning approach (Biggs, 2012). The need for engaging with the material brings us neatly into the next paragraph.

2.2.4 Interactivity

Another point researchers have made concerning the design of instructional videos is the need for interactivity (Delen et al., 2014; Merkt & Schwan, 2014; Zhang, 2005). What is meant by interactivity is that the learner has the possibility of interacting with the video with the goal that the learner's actions should foster their learning (Moreno & Mayer, 2007). Interestingly, interactive videos could potentially increase the extraneous load and therefore lead to cognitive overload in the learner lessening the learning outcomes (Moreno & Mayer, 2007; Schwan & Riempp, 2004). However, this is not the case, studies have shown that if anything interactivity in instructional content increases the learning outcome (Merkt & Schwan, 2014) and that the more interactive the videos are, the better the learning outcomes are (Delen et al., 2014; Zhang, 2005). IVs should also theoretically lower the cognitive load by allowing learners to control the pace of the IVs, which would allow the learners to reduce the amount of representational holding, a form of extraneous load, by dividing the material into smaller segments at their behest. This effect is known as the pacing principle (Moreno & Mayer, 2007).

Interactive elements in IVs are divided by Delen et al (2014) into two types; Micro-level interactivity, which is the pausing, playing, rewinding/forwarding which is common for all IVs. Macro-level interactivity such as the videos providing opportunities for note taking, self-evaluation and seeking supplemental resources (Delen et al., 2014). Other researchers have created other forms of interactive elements than can be considered macro-level such as the ability to choose and skip segments from a pull-down menu, as well as viewing lecture notes and associated slides (Zhang, 2005) and manipulating speed and direction (Merkt & Schwan, 2014). To achieve clarity all interactive elements that are not micro-level will be referred to in this thesis as macro-level regardless of whether or not the authors dubbed it macro-level. Moreno and Mayer (2007) describes five types of interactivity which are considered in the thesis, along with their theoretical basis:

Controlling. Learner controls the pace and/or order of presentation. It is based on the pacing principle as described earlier. Controlling can be macro- or micro-level depending on the degree of control the learner have. The primary goal is to transform the learner from a passive processor to an active processor of the material by allowing them to manipulate the tempo and order of the presentation. Controlling would also encourage learners to pace their learning, according to the pacing principle

Navigating. Learner can move between different themes by selecting them. This should also engage the learners by allowing them to choose for themselves what they wish to learn. As such it can be thought of as similar to controlling, and can also be considered both micro and macro-level depending on the degree of control. The rest of the interactivities are macro-level.

Dialoguing. Learner receives questions, answers and/or feedback. Dialoguing is a form of guided activity in which the students are encouraged to actively process the information available to respond to questions, which lead to a deeper understanding than passively processing the material.

Manipulating. Learner can move objects around on the screen, zoom out and/or set parameters for simulations. Manipulating could encourage the learner to actively engage with the material at hand, and reflect on the consequences of their manipulations, especially when setting parameters.

Searching. The learner is encouraged find new content material not originally found in the videos. Searching engages the learner in information searching of their own accord, again encouraging them to actively engage with the material (Moreno & Mayer, 2007).

Studies have shown that using videos with both macro- and micro-level interactivity increases student learning more than videos with just micro-level interactivity (Delen et al., 2014; Zhang, 2005). There does not seem to be any studies on which of these interactivities are the most efficient (see 2.4). The interesting point is that all these macro-level interactive elements aim to actively engage students in processing the material at hand (see 2.3.1 for further elaboration).

2.2.5 Criticism of e-learning

Given the remarkably good results implementation of e-learning (by using IVs) often shows, it would be easy to start preaching the gospel of e-learning. However, e-learning does have its fair share of critics as well. One point is that researchers often fall into the fallacy of technology determinism, the belief that social progress (such as more effective learning) is driven by technologic innovations which follow an inevitable course (Clegg, Hudson, & Steel, 2003; Friesen, 2008). A formulation of technologic determinism is that video games cause violent behaviour (Selwyn, 2010), another formulation is then that e-learning in itself generates more knowledge than traditional learning. Obviously, this is not the case; it is dependent on how the e-learning is used. There have also been calls for researchers to look beyond the view that technology has inherent qualities which are capable of having given impacts or effects on learners (Selwyn, 2010). Given that many researchers on e-learning are enthusiasts who have themselves implemented e-learning in some form or another in their teaching and then researched the results (Chao, Chen, & Chuang, 2015; Hoogerheide, van Wermeskerken, Loyens, & van Gog, 2016; Seery, 2015; Zhang, 2005). They could potentially fall into technological determinism.

There are also some negative results from studies on e-learning; one such found that reducing the cognitive load had an adverse effect on students learning, possibly due to unnecessary reduction of the germane load (Schnotz & Rasch, 2005). Other researchers have also found negative learning effects from e-learning (Zhang & Nunamaker, 2003), although they are seemingly in the minority.

Kirkwood and Price (2014) found in their review of the e-learning literature that the term technology enhanced learning (TEL) was often applied and that enhancement often was reported in the form of higher test scores (Kirkwood & Price, 2014; Seery, 2015), which were considered to equal more learning. The studies did not examine whether the students developed a deeper or richer understanding of the subject (Kirkwood & Price, 2014). The same authors in another article concluded that educators did not back their TEL-interventions in evidence from literature, but rather from colleagues and other faculty members (Price & Kirkwood, 2014) which can be considered problematic as the studies are not conducted from the right perspective. Nevertheless, studies have shown that e-learning lead to higher scores amongst students in many cases (Seery, 2015; Wells et al., 2012; Zhang, 2005). The question is rather if those higher scores necessarily mean that the learning is enhanced, higher scores do not necessarily mean deeper or richer learning (Kirkwood & Price, 2014).

2.2.6 Possibility of bias in e-learning

Much of the research conducted on IVs and other e-learning is undertaken by researchers who have themselves used IVs in their classrooms (He et al., 2012; Shattuck, 2016; Weaver & Sturtevant, 2015; Wells et al., 2012). This can potentially create a data collector bias, i.e. the possibility of data collectors/scorers unconsciously distorting data to make outcomes supporting the hypothesis more likely. This is not to say that there necessarily exists a data-collector bias, but rather that there is a possibility of it. For instance, Shattuck (2016) decided to flip two classes taught by him. No considerations were taken by him in the article when it came to possible data-collector bias on his part (Shattuck, 2016).

Wells et al. (2012) also created and refined their own IVs, used to teach a programming module, and used them in a blended approach and did not seem to consider the possibility of data-collector bias (Wells et al., 2012). These studies seem to be reflective of the greater trend in the research on IVs. Within the e-learning sphere there also exists the possibility of publication bias, i.e. that editorial boards tend to publish positive findings, leading researchers not to submit negative results, or not to be accepted when they do so (Thornton & Lee, 2000). Take the journal Computers & Education, which has been quoted from in this thesis, which states that its aim is to: “increase knowledge and understanding of ways in which digital technology can enhance education, through the publication of high-quality research, which extends theory and practice. [...] Selection criteria Papers must: align with the aims of the journal” (Computers & Education, 2017).

First of all the term enhanced is poorly defined within the field of e-learning and tends to be used as an improvement in grades, which is a problematic view, given that it only focuses on test-improvements, not whether the learning is deeper or gives a richer understanding (Kirkwood & Price, 2014). Secondly, the journal explicitly states that any paper not aligning with the journal’s aims will not be selected, which could lead researchers into believing that studies where the results indicate that technology does not enhance learning will not be considered, a form of publication bias (Thornton & Lee, 2000). Thirdly, the journal here seems to be almost technology-deterministic in stating that technology can enhance learning (Clegg et al., 2003), it just depends on the way it is used. These factors do not necessarily imply that the journal is biased, but it might seem so for a researcher.

2.3 Active learning

Active learning is as previously stated fairly a simple concept: The goal is simply to engage students in actively working with the theme, through activities or discussions, in order to learn, as opposed to the passive listening students often experience in traditional classrooms (Freeman et al., 2014).

There are two types of active learning: behavioural active where the learner is simply physically active (by for instance pressing buttons on a keyboard), and cognitive active where the learners is engaged in deep mental processing (Mayer, 2002). Active learning in this thesis refers to cognitive active. This form of active learning can be divided up into several forms such as collaborative (Keyser, 2000), problem-based and cooperative (Prince, 2004). Active learning builds on a constructivist view of learning in which the focus is primarily on the students and their construction of knowledge. The ultimate goal of learning in the constructivist view is that the student should be able to conduct independent inquiry, structure and restructure their knowledge and applying their learning to new contexts (Niemi, 2002).

Active learning is more effective than traditional learning (Prince, 2004). So much so that Freeman et al. (2014) in their large meta-study on STEM-courses (225 studies) implementing active learning concluded that active learning was more effective than traditional lecture teaching. And suggested that one should no longer compare active learning with traditional learning, instead one should start researching which varieties of active learning is the most effective (Freeman et al., 2014). Other research has also shown that students tend to enjoy an active approach (Jensen, Kummer, & Godoy, 2015; Stowell & Nelson, 2007). Given the empirical support for active learning, one should expect it to have been or be implemented in most STEM-courses, both in higher and lower education. However, many teachers struggle with implementing active learning due to reasons such as curriculum overload and lack of time, too large student groups, weak learning conditions, pupil’s poor metacognitive skills, other teachers cynical attitude and parents traditional expectations (Niemi, 2002). As previously mentioned some students need to be actively engaged for deep learning to occur (Biggs, 2012), which means that they could potentially suffer if active learning is not applied in the classrooms. So the need for implementing active learning, and its potential hurdles brings us into the topic of e-learning and active learning.

2.3.1 E-learning and active learning

Given the reasons many teachers struggle with implementing active learning (Niemi, 2002), it might be argued that e-learning could potentially alleviate some of those concerns, especially large student groups and perhaps curriculum overload. E-learning, in the form of electronic audience response systems, has been shown to be effective in large student groups (Gauci, Dantas, Williams, & Kemm, 2009). Furthermore, flipping the classroom lead to improvements in student attendance, engagement and learning performances in a large student group (271 participants) when compared to an equally large group (267 participants) taught traditionally (Deslauriers, Schelew, & Wieman, 2011). The studies seem to show that e-learning is effective in promoting active learning for large student groups. E-learning might also be able to alleviate curriculum overload, since the “basic” facts can be delivered to the students in their own time, freeing up more time in the classroom, this is, however, purely speculative as there does not seem to be any research on the subject. E-learning and curriculum overload might be an interesting topic for a future study.

E-learning studies often report a higher degree of student enjoyment, when compared to the traditional classroom (Chao et al., 2015; Leo & Puzio, 2016; Seery, 2015; Wells et al., 2012) which might indicate that the students learned more actively. Within the context of e-learning, one of the guiding principles is that instructional content should be designed and used to promote active learning amongst the students (Mennella, 2016; Mitra et al., 2010; Seery, 2015; Zhang, 2005). There are essentially two schools of thoughts:

> The interactivity school which states that e-learning must be interactive so that the students actively engage with the material (Delen et al., 2014; Zhang, 2005).

> The flipped/blended-school: E-learning frees up class time in which to engage students in active learning (O'Flaherty & Phillips, 2015; Seery, 2015).

Of course, these two schools are not mutually exclusive; an IV can be made interactive and used in a flipped or blended classroom.

It seems instructional videos can be considered a multi-purpose tool for promoting active learning amongst students. As with any other tool, it can be used in right or wrong ways; the instructional videos could be designed in a way that is not optimal for learning (Mayer & Moreno, 2003). For instance, they could be lacking macro-level interactive elements. Or they can be designed correctly but used wrong so that the educator's practices weakens the educational value of the videos (Hobbs, 2006). For instance, the class time freed up by the flipped approach could be used for repetitive problem-solving. So whether instructional videos are successful in promoting active learning is both down to how they are designed and how they are used in the classroom. O'Flaherty & Phillips (2015) in their scoping review of the flipped classroom literature suggest that educators need to integrate the pre-class activities into face-to-face classes with active learning approaches (O'Flaherty & Phillips, 2015). Mitra et al. (2010) suggest that the way the lecturer uses IVs is a major influence on whether they promote deep learning, which is built on active learning (Mitra et al., 2010). So the way IVs are used should influence students who do not have a natural deep learning style (Biggs, 2012). While Hobbs (2006) suggest that non optimal uses of video in the classroom include: No instructional purpose and no use of pausing, rewinding or review, both of which is important factors in promoting active learning.

To, summarize it has been well established that instructional videos can promote active learning amongst students if used correctly, regardless of which methods for implementing IV's are used (Merkt & Schwan, 2014; Seery, 2015; J. van der Meij & de Jong, 2006; Zhang, 2005). However, little research has been conducted on how different educators' different use of IVs promotes active learning. Are there some implementations that are more efficient than others in promoting active learning? To answers this, one would need to distribute the same instructional video(s) to several educators, document how they choose to implement the videos in their classrooms and gauge the students' responses to how the videos were applied.

2.3.2 Methods for using IVs to promote active learning

As described in the previous paragraph one of the main reasons for using IVs in education is the possibility of promoting active learning. Given that there are different methods for using IVs in education (Kerres & Witt, 2003; Seery, 2015; Wells et al., 2012) and that there are optimal and non-optimal ways for using IVs (Hobbs, 2006; Mitra et al., 2010). It seems clear that we need some clarity in the methods for using IVs to promote active learning. Here I will summarize three of the more common methods: flipped learning, blended learning and tutorials and their documented effects.

Flipped learning

Flipped learning is perhaps the method for using IVs with the most ‘buzz’ in recent years. It is often defined as “a pedagogical approach for presenting material to students in advance of class and enabling active learning environments to take place during formal class time” (Seery, 2015). The material is often presented to the students with instructional videos (Bishop & Verleger, 2013). Interestingly flipped learning is not anchored in educational theory, rather it emerged from classroom practice as a technique that seemed to work well (Seery, 2015). Later a theoretical framework was developed, based on student centred learning (Bishop & Verleger, 2013). Student centred learning incorporates both constructivism and socio-cultural learning theory which emphasizes that the students are active in their learning (Hannafin & Land, 1997).

Successful incorporation of flipped learning should actively engage students, which should improve student learning, for the naturally non-deep learners (Biggs, 2012). This improvement has also been shown some studies in both Seery’s (2015) (6) and O'Flaherty and Phillip’s (2015) (5) literature studies demonstrated when comparing flipped learning to traditional lecture-based learning.

Additionally, several studies in Seerys (2015) literature study found an decrease in DFW's (D's, F's and Withdrawals) when flipped learning was implemented, which is also backed up by other research (Shattuck, 2016). So it seems that using IVs in a flipped setting is effective in promoting active learning.

Blended learning

Blended learning has been around for a longer period of time than flipped learning, having originated around the year 2000 (Bliuc, Goodyear, & Ellis, 2007). There are many definitions of the term, so to clarify what is meant by blended learning in this thesis is a combination of instructional technology with face-to-face learning in the classroom (Kerres & Witt, 2003; Rosenbaum, 2012). The justification of this type of blended learning being a 'best of both' scenario where you can bring online courses together with face-to-face classes (Woltering, Herrler, Spitzer, & Spreckelsen, 2009).

The content is delivered to the learner in a typical e-learning format (such as IVs), and the teacher is available for questions and to guide their exploration (Means, Toyama, Murphy, & Baki, 2013). Researchers have shown that the learning outcomes were not significantly different between a group receiving purely online instruction, and a group receiving blended instruction. However, the online group self-reported higher workload and less learner support than the students in the blended group (Lim, Morris, & Kupritz, 2007). A large meta-study, on the other hand, did find that blended learning was more effective when considering learning outcomes, than both face-to-face and online learning (Means et al., 2013). Additionally, students have self-reported higher learning outcomes and higher satisfaction in a blended classroom when compared to a face-to-face classroom (Woltering et al., 2009). So there is no reason to believe that blended learning will not actively engage students, although the time available for active learning may be less than what is the case for flipped learning. It would also be dependent to what degree the learning material and the instructor promotes active learning.

Tutorials

Many studies conducted on instructional videos have chosen to use them as tutorials, often for learning practical skills (Back et al., 2016; He et al., 2012; Schwan & Riempp, 2004; H. van der Meij & van der Meij, 2016). These have shown to increase the learning outcomes of the students when compared to regular non-video learning (Kelly, Lyng, McGrath, & Cannon, 2009; H. van der Meij & van der Meij, 2016; Wells et al., 2012). The reason behind this is that it allows students to apply what they have learned to new contexts (Wells et al., 2012), that they actively engage the students (Merkt & Schwan, 2014), and gave them the opportunity to self-manage their learning flexibly (Kelly et al., 2009). Again the case seems to be that a tutorial promotes active learning just as the flipped and blended methods. When compared to viewing a demonstration, which is an essentially passive activity.

2.4 Students self-regulation in e-learning

The use of instructional videos, regardless of the method, requires that the students can self-regulate their learning (Delen et al., 2014) since a large part of the learning is directly controlled by them. So it is of interest how learners self-regulate when using instructional videos. Self-regulating is an active and constructive process, wherein the learner makes their own goals for learning, and try to monitor their progression while regulating their cognition, motivation, and behaviour using their learning goals and the context of the environment (Schunk, 2005). Students with higher regulatory skills have a tendency to be more academically motivated and learn better than their counterparts with lower regulatory skills (Pintrich & De Groot, 2003). Biggs (2012) describes deep learners as academically committed, and so it is reasonable to suggest that deep learners also have higher regulatory skills than surface learners.

Furthermore, learners tend to struggle with self-regulating their learning when using computer-based learning environments and fail to gain conceptual understanding when the learning environment lacks scaffolding (Azevedo & Hadwin, 2005). The student's poor self-regulation is why IVs need to assist students in developing self-regulatory skills by scaffolding their learning. Scaffolding is the process in which the learner at first is helped along in their learning by hints, coaching and task structuring by a peer, teacher or other factors that assist the learner in constructing a mental framework which supports the learner in making sense of what they are learning. As the learner progresses, the scaffold can be removed and the learner will be able to make sense of what they are learning on their own (Hmelo-Silver, Duncan, & Chinn, 2007).

It could be argued that scaffolding reduces the extraneous load (the cognitive load generated by unnecessary activities (DeLeeuw & Mayer, 2008)) by making it easier for the learner to process the information. While at the same time increasing the germane load (the cognitive load the learner exerts to process and integrate new information (DeLeeuw & Mayer, 2008)). Due to the learner being encouraged to construct a mental framework for organizing their knowledge (Clark & Mayer, 2011), increasing the germane load could potentially be beneficial for student learning (Schnotz & Rasch, 2005). So how can a scaffold be built into instructional videos?

It seems that macro-level interactivities such as Dialoguing, which allows the learner to receive questions, answers and/or feedback and Searching, which allows the learners to search for new material (Moreno & Mayer, 2007), can be effective as scaffolds. These scaffolding properties were shown by Delen et al. (2014) who choose to implement a scaffold in an IV by inserting the following macro-level interactive elements into an IV: Supplemental resources, which is a form of searching type interactivity, and practice questions, which is a form of dialoguing type interactivity. Additionally, the students could take interactive notes with the videos. While a control group was given the same video with only micro-level interactive elements. They found that the macro-level IV both increased learners self-regulating and their learning performances.

Another study compared the results of two student groups working on problem-solving interactive tasks. One group worked with a plain version, while the other used a version which implemented the following self-regulation activities: Self-metacognitive questioning, metacognitive feedback and being asked for explanations, which all are types of dialoguing interactivity. The students working with the self-regulatory interactive elements outperformed the other group in both problem solving and self-monitoring (Kramarski & Gutman, 2006).

So it seems that the right types of macro-level interactive elements can support students' self-regulatory learning as a scaffold. It should be noted that both micro- and macro-level interactive elements can be considered tools for student self-regulation (Delen et al., 2014). Consider the following scenario; A student views an IV, and finds he or she does not understand the content covered earlier, he or she then pauses the video and starts exploring what he or she did not understood before rewinding to that point and views that segment again. So he or she uses micro-level interactivity to regulate their learning. However, this is solely down to the student and whether he or her self-regulates their learning, and students left to their own devices often do not self-regulate their learning (Azevedo & Hadwin, 2005). Although deep learners probably self-regulate effectively (Biggs, 2012). Macro-level interactivity can scaffold students' self-regulation (Delen et al., 2014; Kramarski & Gutman, 2006), which micro-level cannot. So students who do not effectively self-regulate, i.e. surface learners (Biggs, 2012), should be helped in their learning by the scaffolding properties of macro-level interactivity.

2.5 Curriculum

Both teachers and students work under the “hidden” curriculum, which is the part of the curriculum made relevant by former exams on the subject (Ringnes, 1993). I.e., the teacher chooses which part of the curriculum he or she chooses to teach in class based on previously given exams; this might be due to curriculum overload, which also hinders teachers from enabling active learning amongst students (Niemi, 2002). These factors could lead to different interpretations of the curriculum between different teachers and different faculties and may constrain the teacher’s ability to change their teaching (Cotton, 2006).

2.5.1 Chemistry 1 curriculum

The three videos made for this study covered the curriculum goal in chemistry-1 of: “the students should be able to elaborate on the historical evolution of the atom concept and describe and compare Bohr’s atomic model with the current atomic model” (my translation) (Utdanningsdirektoratet [Udir], 2006). Here I will examine the chemistry-1 textbooks interpretation of the curriculum-goal which is interesting since the three textbooks used in chemistry-1 have chosen to interpret the current atomic model differently. Ranging from interpreting it as the electron cloud model, with a brief explanation on the splitting of Bohr’s shells (Brandt & Hushovd, 2010), to dedicating a whole chapter to the orbital theory (Steen, Fimland, & Juel, 2010) and dedicating a two-page fact-box to the orbital theory (Grønneberg, Hannisdal, Pedersen, & Ringnes, 2012). Given this seems to be no clear consensus amongst textbooks in chemistry-1 on what constitutes the current atomic model.

It is logical that the textbooks interpretations of the curriculum could affect the teacher’s interpretation of the curriculum, and research has shown that two different teachers can be influenced differently by the same curriculum materials (Collopy, 2003).

Given this, there are likely to be quite substantial variations amongst teachers on what the current atomic model constitutes. When creating the teaching program used in this study the author’s view was that the current atomic model was the orbital theory, since it is the model that dominates university-level chemistry, and since the students should be able to compare it with Bohr’s model (Udir, 2006). It is possible that this might conflict with the teachers participating in this study’s interpretations.

3 Methods

This chapter presents an overview of how the instructional content (the IVs and control questions) were made and the considerations that went into creating them (3.1). The conduction of the study, and how the student's answers were coded will be described in section 3.2 and 3.3 respectively.

3.1 Development of instructional material

To research how different educators uses IVs in their classes a set of three IVs and corresponding control questions were made and distributed to three chemistry 1 teachers. The videos were developed in a separate project by the author and colleagues. Here I will present some of the considerations taken when creating the IVs and control-questions

3.1.1 Design of instructional videos

The aim of the IVs used in this project was to meet a curriculum goal in chemistry 1, which is generally taught to second-year students at Norwegian high schools. According to the curriculum the student ought to be able to "elaborate on the historical evolution of the atom-concept and describe and compare Bohr's atomic model with the current atomic model" (my translation) (Udir, 2006). To cover the curriculum goal three instructional videos ranging from 5 to 14 minutes in length were made using the program ExplainEveryhing. Which creates a virtual whiteboard onto which the author drew, wrote, imported pictures, animated and narrated to create the instructional videos (see Figure 1 and 2 for illustrations of the finished product). The length of the videos was kept down through several revisions-stages to reduce the extraneous load (Mayer & Moreno, 2003).

The first video covered the evolution of the atom-concept from Democritus, and up to Rutherford's model. The second video covered Bohr's atomic model. The third video covered orbital theory, which was considered to be "the current atomic model." Efforts were made to ensure that the videos were coherent, and could be viewed independently of each other. For instance, video 1 ends with a formulation of the problem with Rutherford's model, which video 2 picks up on and demonstrates how Bohr's model "fixed" the problem. Afterward, video 2 elaborates on Bohr's, model and at the end, some problems with Bohr's model was shown. Video 3 picks up on this and shows how orbital theory can explain the discrepancies in Bohr's model which was done to establish a narrative along the three videos of the constant development of the atomic models. This linking of the videos was also intended to show the historical evolution of the atom concept, in keeping with the maximum view of teaching scientific history (Knain, 2001). Efforts were also made to limit the number of representations used in the videos since the number of representations used should be the minimum of what is needed to explain the concept (Ainsworth, 2008).

The videos did not feature macro-level interactivity, the only exception being a segment of video 3 in which the students are asked to pause the video and then fill up the orbitals of an atom (a still can be seen in Figure 2). After clicking play the students were shown the correct answer. This is a form of feedback macro-level interactivity, i.e. dialoguing (Moreno & Mayer, 2007). Other than the aforementioned macro-level interactivity the videos were only interactive on a micro-level, i.e. the students had the opportunity of pausing, rewinding, forwarding, skipping randomly and increasing/decreasing tempo as described by (Zhang, 2005).

The videos were not segmented other than the division into three separate videos, but signalling, in the form of a laser-pointer, and weeding were used to reduce the extraneous load according to the CTML (Mayer & Moreno, 2003) (Table 1). Of the other techniques described by Mayer and Moreno (2003) (Table 1) we used: Off-loading, Aligning, Eliminating redundancy and Synchronizing.

Off-loading was performed by moving some of the essential information from the animations to the narrations. Aligning was done by placing printed words close to their corresponding of the animation. Eliminating redundancy was performed by avoiding presenting identical texts and narrations. Synchronizing was done by timing the videos so that animations and their corresponding narrations came at the same time. Pretraining and Individualizing would have been impossible to do since we did not have any direct access to the students who participated in the study.

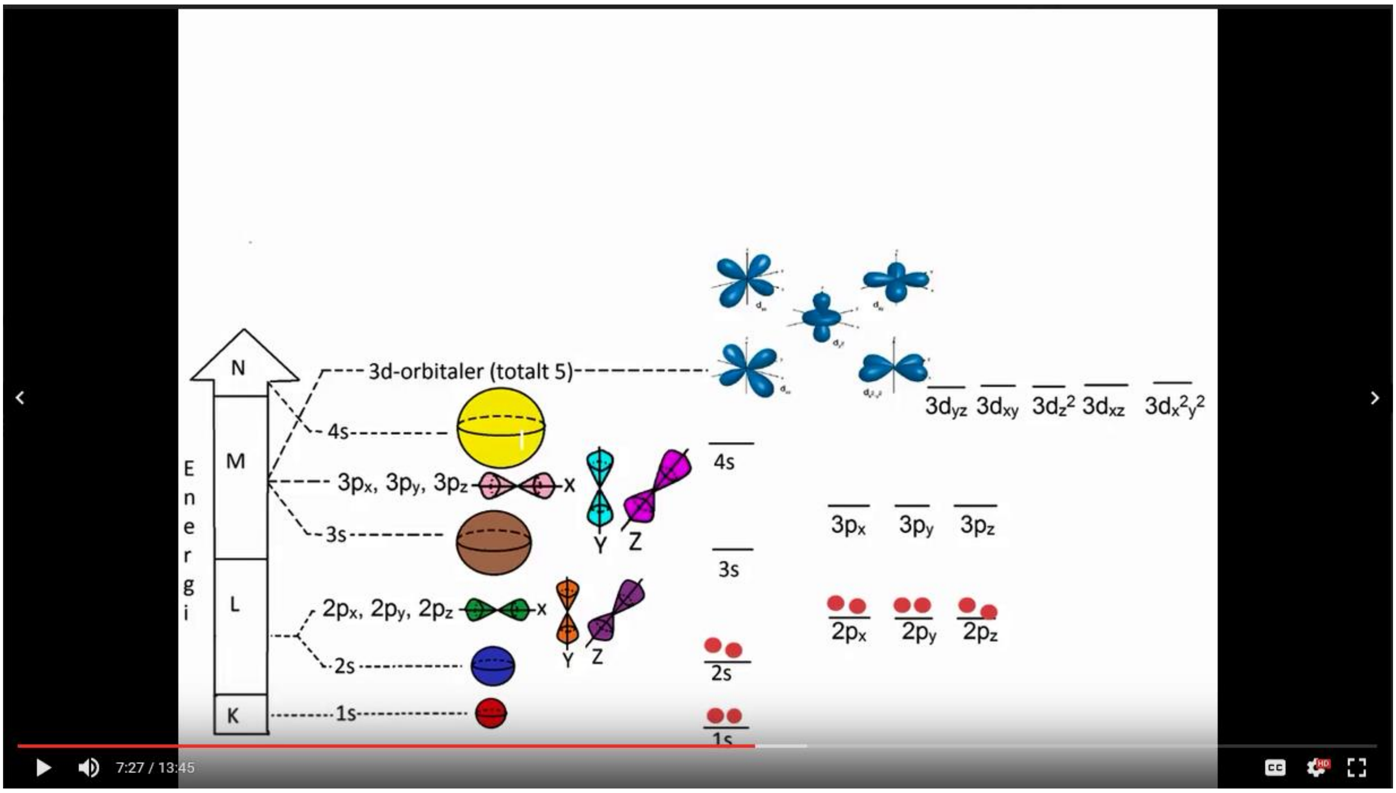

Figure 2: Macro-level interactivity in video 3, from the author

The resulting three videos could said to be a typical kind of instructional video, in the whiteboard format (as popularized by Khan Academy). The videos can be viewed, by following this link (https://goo.gl/a0Ftur), and it is recommended that they are viewed as improvements on the videos will be suggested later on.

3.1.2 Development of control questions

Several control questions were created to be handed out along with the videos; these were designed according to Bloom's taxonomy, where he divided the cognitive aspect of learning into six categories: Knowledge, Understanding, Application, Analysis, Synthesis and Evaluation (Krathwohl, 2002). These constructs are listed in order of increasing complexity and degree of abstraction in Table 2 (Halawi, McCarthy, & Pires, 2009). Each control-question was made to correspond to one of Blooms categories. The principle was to encourage the students to move beyond merely remembering facts from the instructional videos which is covered in the first questions, towards synthesising and analysing the content of the videos. Table 2 contains the control questions, along with which category in Blooms taxonomy which they correspond too.

Table 2: Bloom's Taxonomy and control-questions

Category (Halawi et al., 2009)	Description (Halawi et al., 2009)	Control-question
Knowledge	Focuses on learning of memorization, recognition, and recall of information	What separated Jameson's, Rutherford's, Bohr's and Heisenberg/Schrödinger's atomic models?
Understanding	Focuses on organization of ideas, interpretation of information and translation	Make a timeline where you summarize the most important steps in the development of the atomic model from Democritus to Heisenberg/Schrödinger and explain the basis of these steps in your own words
Application	Focuses on problem solving	A Scientist in the 1900s (short time after the publication of Bohr's atomic model) has discovered a new element. The problem is that when it excited, it sends out electromagnetic radiation with the "wrong" wavelengths according to Bohr's model, how can you explain this?
Analysis	Focuses on finding the underlying organization	Compare Bohr's model with the orbital model, what are the differences? And what are the similarities?

Synthesis	Focuses on combining of ideas to form something new	Compare the electron-pair binding of carbon monoxide (CO) with the help of the octet rule, and the orbital theory, which would you, say best explains the electron-pair bindings?
Evaluation	Focuses on making judgments on issues, resolving discrepancies	Discuss which problems the other atomic models has when compared to the orbital model and discuss why the orbital model is considered a more correct model of the atom

Bloom's taxonomy is not the only taxonomy dividing learning up into several cognitive aspects. There is also the SOLO (Structure of Observed Learning Outcomes) taxonomy (Biggs, 2012). The taxonomy is divided up into several levels: Prestructural, Unistructural, Multistructural, Relational and Extended Abstract. Prestructural means the learner is incompetent in the area. Unistructural means that one relevant aspect in the areas is known. Multistructural signifies that the learner knows several aspects in the area. Relational means the aspects known to the learner is integrated in a structure, and that the learner can see the relations between them. Extended abstract means that the aspects known are applied to new areas (Biggs, 2012; Boulton-Lewis, 1995). One can see that Unistructural and Multistructural relates to Bloom's construct of Knowledge, Relational relates to Analysis, and Extended abstract relates to Synthesis and Evaluation (Boulton-Lewis, 1995; Halawi et al., 2009). Given that these two taxonomies are relatively similar it was decided to go along with Bloom's taxonomy.

3.2 Collecting teacher and student responses

The instructional videos and control questions were distributed to three volunteer teachers who taught chemistry 1 along with suggestions for how they could be used as part of a flipped classroom (see Appendix C). The videos were made available via Youtube. Two short, open-ended, web-based, questionnaires were also distributed one for the teachers and one for the students. The questionnaires were not created by the author, but by my supervisor.

The primary goal of the questionnaires was to gather information about how the instructional videos and the control questions were used, and how this affected student enjoyment. Additionally, some questions asked about concrete aspects of the videos, such as tempo and illustrations. Both the teachers and students were asked how they thought the videos could be improved. For a complete list of questions, along with the student and teacher answers, see appendix A (students) and B (teachers). The questionnaires were kept short to limit a common problem in web-based surveys, that individuals are often not motivated to complete the questionnaire without communicating with another person, which in turn can lead to them abandoning the survey (Reja, Manfreda, Hlebec, & Vehovar, 2003). It was open-ended for two reasons: to avoid suggestion-bias on our part and to find the individuals spontaneous responses to the questions. However, open ended questions also have the drawbacks in that the answers require extensive coding and larger item non-response, i.e. respondents not answering the given questions (Reja et al., 2003). There are generally two methods for reducing data-collector bias: standardizing all procedures which require some training of the data-collector and ensuring data-collectors lack the information they would need to distort the results (Fraenkel et al., 2012). For this study the data-collectors lacked the information needed to distort the results, however, the data-coder had all the information needed to distort the results.

3.3 Coding of student answers

As mentioned in the previous paragraph, open-ended questions need to be extensively coded; which was also the case for the responses gathered in this study. So a system for coding the answers was designed, and the answers coded accordingly. Only the student's answers were coded. As only three teachers participated in the study, their answers will be presented as given. The coding was performed by the author; there were no intercoder testing (coding by two or more independent coders) of the coding results as such *a posteriori* methods conducted after the coding system has been created has been shown to be of limited assistance in improving coding reliability (Montgomery & Crittenden, 1977).

An alternative could have been to employ an *a priori* method where the data is coded independently before the final coding system is designed, which has a higher reliability (Montgomery & Crittenden, 1977). However, it would have required resources not available for this master thesis. Additionally, most of the coding was of the type requiring the coder to find a specific answer to a specific question at a given place on the instrument, so -called type A-coding by Montgomery & Crittenden (1977). Type A-coding has a high initial reliability, and so *a priori* and *a posteriori* methods might not be warranted (Montgomery & Crittenden, 1977). To assure some reliability the coding system was developed early on in the project and applied to the questions, and three months later I applied the same coding system to the same questions. The coding was the same for 93.9 % of the answers, i.e. there was a discrepancy in 6.1 % of the answers, and so it is reasonable to suggest the coding is somewhat reliable. However, as stated previously such *a posteriori* methods are of limited value (Montgomery & Crittenden, 1977).

3.3.1 Coding system

In this paragraph, the coding system designed is shown, with their corresponding questions, along with examples of the student's answers. A complete list of answers and their codes can be found in Appendix A.

Question 2: Where and how did you work with the material after watching the videos?

For this question, there were three different kinds of answer, depending on which classroom the student belonged to. The answer was used to group the students into three groups according to the classroom. The three different classrooms were labelled C1 (n=17), C2 (n=21) and C3 (n=20). The following is a typical statement for a C1 student "We did not work with the material, but we did get the opportunity to ask questions and do tasks related to the theme" (my translation). The following is a typical statement for a C2 student "We went in groups of 3 and 3 in the classroom and used the class-time to watch the videos.

The following is a typical statement for a C3 student “We worked with the videos at school, by answering questions relating to the videos” (my translation). The codification-scheme will be kept for the remaining questions i.e. the answers to question 3-9 will be given individually for the C1, C2, and C3-students, and the teachers will be labelled as the C1, C2 and C3-teacher.

Question 3: How did you enjoy the way you worked with the teaching program? Were there any advantages or disadvantages compared to how you normally work?

For this question, two main categories were created. Enjoyed (E) and Disliked (D) an example of an answer that was coded Enjoyed is “I like this way of working with a subject on”, an example of an answer that was coded Disliked is “I like it better when the teacher explains than watching videos.” Some students did not answer whether they liked or disliked the way of working. Which was to be expected from the open-ended questions (Reja et al., 2003), those were coded No Answer (NA), examples are: “Did not really matter” and “The advantage was that if I did not understand something, I could watch that part again. The disadvantage was that I could not ask questions to the lecturer”.

The students gave several different advantages and disadvantages, those were not coded but statements with similar meaning were grouped together, for instance, if eight students said that not being able to ask questions (or similar) were a disadvantage it was noted in the table form below.

Advantage (number of responses)	Disadvantage (number of responses)
	Not being able to ask questions (8)

In some cases the students gave similar advantages or disadvantages, there were further grouped into larger categories denoted by *. For instance, the C2-students gave the following advantages: Short videos to keep concentration, easier than reading the material, reviewing the material, easier to focus, easier to take up information, slow tempo so everyone can understand, covered a lot of material quickly and easier to understand information. All these advantages concerns taking in information, and so they are all coded further within the overreaching category: Ease of learning*. Whenever something is coded this way it is noted in appendix A. Similarly, the overreaching category difficulty with learning from videos* were created for the disadvantages

Question 4: What did you think about the pictures and tempo in the instructional videos?

Answers that are positive or negative to the pictures will be coded positive to pictures (P1) or negative to pictures (N1). Answers that were positive or negative to the tempo will be coded positive to tempo (P2) or negative to tempo (N2). Examples along with coding group are shown in Table 3.

Table 3: Coding groups for question 4

Code	Typical answer
P1	"The pictures were helpful."
N1	"Some things went too quick and the drawings were a bit complex. Some places the whole text came at once and it was not easy taking notes of the video due to this."
P2	"Pictures and tempo was good."
N2	"slow tempo, nice illustrations."

As can be seen from the N2-answer students often held differing views on tempo and illustrations, which is why they were separated. The N2-answer, for instance, was also coded P1.

Question 5: Was the content of the instructional videos understandable? Here you can feel free to write different things about the different videos

Here three categories were made: affirmative answers (A) such as “Yes, it was understandable”, mixed answers (M) such as “the two first films were good, but video 3 was difficult” and disagreeing answers (D).

Question 6: Did you experience that you understood the content better after having worked with it through questions and/or discussion.

Here the C1 classroom will not be included as they did not work with the control questions or discussed the content. A typical C1 answer is: “We did not work with the content”. The answers from the C2 and C3 classrooms were coded as affirmative (A) such as “Yes, I did”, mixed answers (M) such as “I understood the content of the first two videos well. It was nice to have control-questions to reflect over. The last module and its associated questions were too difficult” and disagreeing answers (D) such as “No, not very much.”

Question 7: What do you think was the most important you learned?

Question 8: What is it that you still do not think you understand?

Question 9: How can the teaching program be improved?

Here the answers will not be coded, as they vary quite a lot, but rather grouped. So that all answers mentioning for instance orbitals will be counted together. If an answer mentions several groups, the answer will be counted individually for each group, so an answer mentioning both orbitals and Bohr’s atomic model will be counted once for each of the groups.

4 Results

This segment will present the main results from the questionaries' that will be used in the discussion. Both the teacher's complete answers (4.1) and the student's coded and grouped answers (4.2) will be presented. Appendix A (students) and B (teachers) contain all the data gathered from the study if the reader wishes to dive deeper into the data set.

4.1 Teacher feedback

As remarked in the method section only three teachers participated in the study, their answers to the questionnaires gave some valuable insights, and those that are relevant to this thesis are shown in the next paragraphs. The full list of the teacher's answers and their translations can be found in appendix B.

4.1.1 How the instructional videos were used

To determine how the IVs were used, I looked at the teacher's answers to the question "where and how did you work with the content after viewing the videos?" as are shown in Table 4.

Table 4: Where and how did you work with the content after viewing the videos?

C1	C2	C3
The students had the opportunity of to ask questions.	They worked approximately two school-hours with the themes. They viewed the videos and answered the control questions simultaneously. Some asked questions underway.	At the school and we discussed what the students had learned with the help of the videos.

4.1.2 Control-questions

The teachers were asked, "If you did use the control questions, did you experience that they contributed to increasing the students understanding?" The teachers' feedback on this question is shown in Table 5.

Table 5: If you did use the control questions, did you experience that they contributed to increasing the students understanding?

C1	C2	C3
No answer	Answers to control questions were handed in to the teacher, and many students answered those thoroughly. The last video/theme was probably a bit difficult, and some students gave feedback that they thought it was difficult.	Absolutely yes

4.1.3 Picture and tempo

The teachers were asked, “What did you think of the pictures and tempo in the videos?” The teachers’ feedback to this question is shown in Table 6.

Table 6: What did you think of the pictures and tempo in the videos?

C1	C2	C3
Some pictures were a bit too small for the screen size I used myself. The tempo is a bit fast, but it is saved by the opportunity to pause and rewind	Good	It was okay. The person talking can with benefit talk a bit faster (personal opinion)

4.1.4 Content of instructional videos

The teachers were asked several questions on the content of the videos. The first question is: “Was the content of the videos understandable for the students? Here you can feel free to write different things about the different videos?” The teachers’ feedback to this question is shown in Table 7.

Table 7: Was the content of the videos understandable for the students? Here you can feel free to write different things about the different videos?

C1	C2	C3
Video 1 was very straightforward for the students. It became repetition of what we have been working on in class. Video 2 contained some new material but were mostly understandable for the students. Video 3 demands knowledge of some themes they have never heard of; that makes the students frustrated when they feel they don't even have the opportunity to get it.	Think it was understandable. As mentioned I think the students used to much time individually on the program. I should have planned it so that the students first viewed the videos and that we then answered/discussed the control questions together or in groups	Yes it was

Another question concerning the content was "Did you experience that the students understood the content better after having worked with it through questions and/or discussion?" The teachers' feedback to this question is shown in Table 8.

Table 8: Did you experience that the students understood the content better after having worked with it through questions and/or discussion?

C1	C2	C3
To some extent	Yes, but the orbital theory was probably a bit difficult for some, and not all got finished with that theme, as they used «too much time» on the first two videos.	Yes they did

One last question concerning the content was: "Did you find the teaching programme relevant for chemistry-1 students? Feel free to explain why or why not." The teachers' replies to this are shown in Table 9.

Table 9: Did you find the teaching programme relevant for chemistry-1 students? Feel free to explain why or why not.

C1	C2	C3
Especially video 3 goes much deeper into modern atomic theory than there is consensus for amongst the teachers at my school. It is therefore not relevant at all for the instruction	Yes I think so. It was a fine run trough of the history.	It was relevant. I would recommend it in flipped classroom

4.1.5 Suggestions for improvement

The teachers were also asked: "How can the teaching model be improved?" The suggestions are shown in Table 10.

Table 10: How can the teaching model be improved?

C1	C2	C3
The main focus and questions must in a larger degree be adapted to the interpretation of the curriculum that there is a consensus of amongst teachers in high school	Possibly a bit shorter videos? Some questions where they have to think for themselves/find information online.	Feel free to include more examples and show differences between Bohr's model and the orbital model

4.2 Student feedback

Here the students' answers to the questionnaires will be presented. These were coded, and so it mostly presented in figures. As with the teachers, only the relevant answers will be highlighted, for the rest of the answers see Appendix A. The answers that were coded will be given in percentage of students (nC1=17, nC2=21, nC3=20), since there was some differences in the student numbers between the three classes, it is important to note that this does not imply that the data is quantitative, rather these percentages are used to show the qualitative differences amongst the three classes. The answers that were grouped will be given in number of students.

4.2.1 Student attitudes to working with the instructional videos

The students were asked: "Did you enjoy the way you worked with the teaching program? Were there any advantages or disadvantages to how you normally work?" The answers were divided into two parts. Figure 3 shows the students enjoyment. Table 11 presents a list of advantages and disadvantages listed by the students when answering the same question.

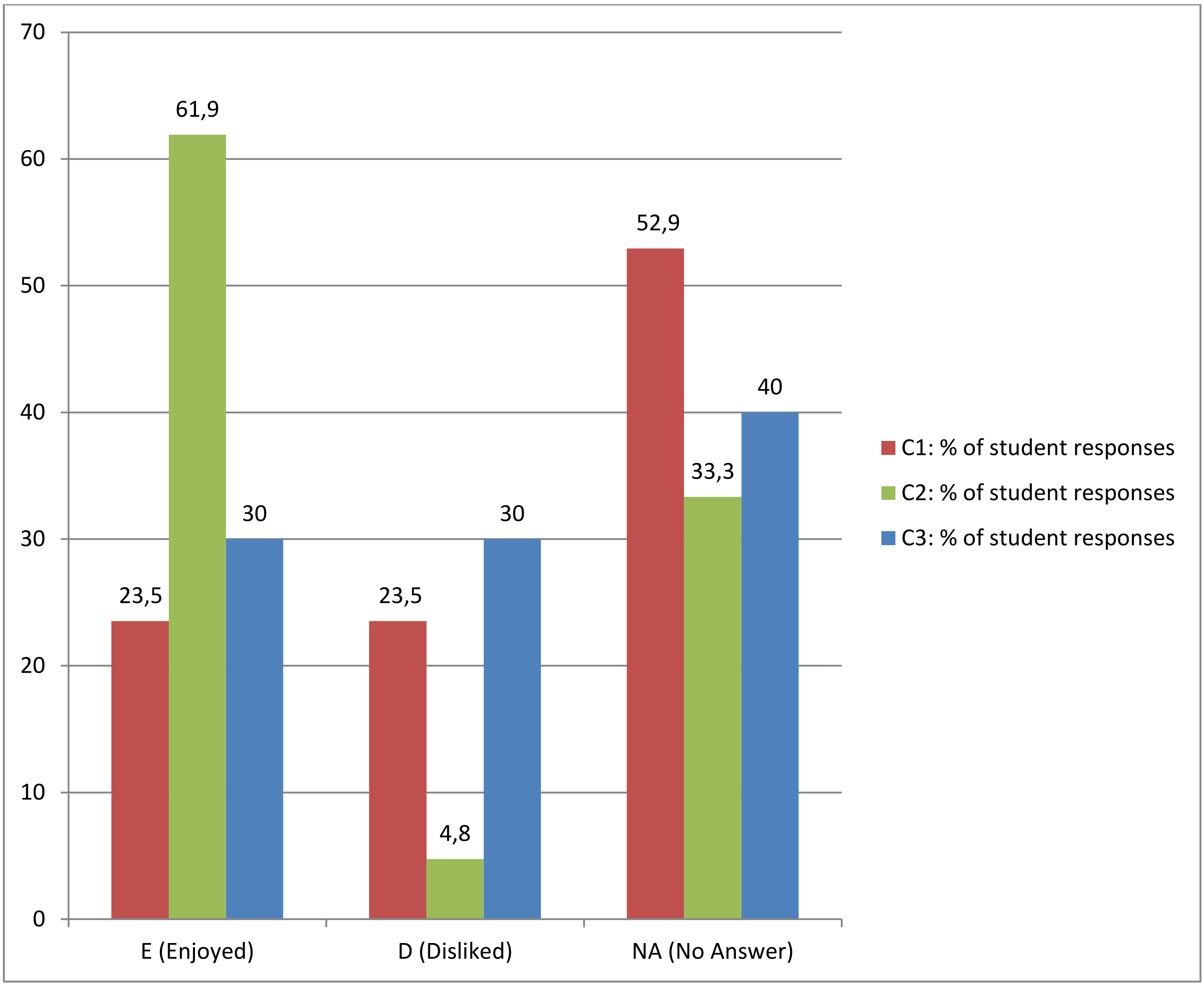

Figure 3: Did you enjoy the way you worked with the teaching program?

Table 11: Were there any advantages or disadvantages to how you normally work?

	C1	C2	C3
Advantages (number of responses)	Stopping/rewinding videos to catch up (4)	Stopping/rewinding videos to catch up (3)	Stopping/rewinding videos to catch up (5)
	Ease of learning* (3)	Ease of learning* (8)	Ease of learning* (1)
		Discussing with others (2)	Working together (1)
		Working with control questions (2)	Working with control questions (2)

	C1	C2	C3
Dis-advantages (number of responses)	Not being able to ask questions (3)	Not being able to ask questions (3)	Not being able to ask questions (2)
	Boring video (1)	Slow video (1)	Boring video (6)
	Difficulty with learning from videos* (6)	Difficulty with learning from videos* (3)	Difficulty with learning from videos* (2)
	Slow voice (1)		
	No follow up (1)		
	Needed more time to work with and discuss content (1)		
			Modul 3 was too complicated (2)
			Repetive and similar questions (1)
			Not educational (1)
			Difficult control-questions (1)

* Here denotes that the advantages/disadvantages belong to the overarching group, as noted in the methods section.

4.2.2 Pictures and tempo

The students were asked: “What did you think about the pictures and tempo in the IVs?” The students’ answers to this question are shown in Figure 4.

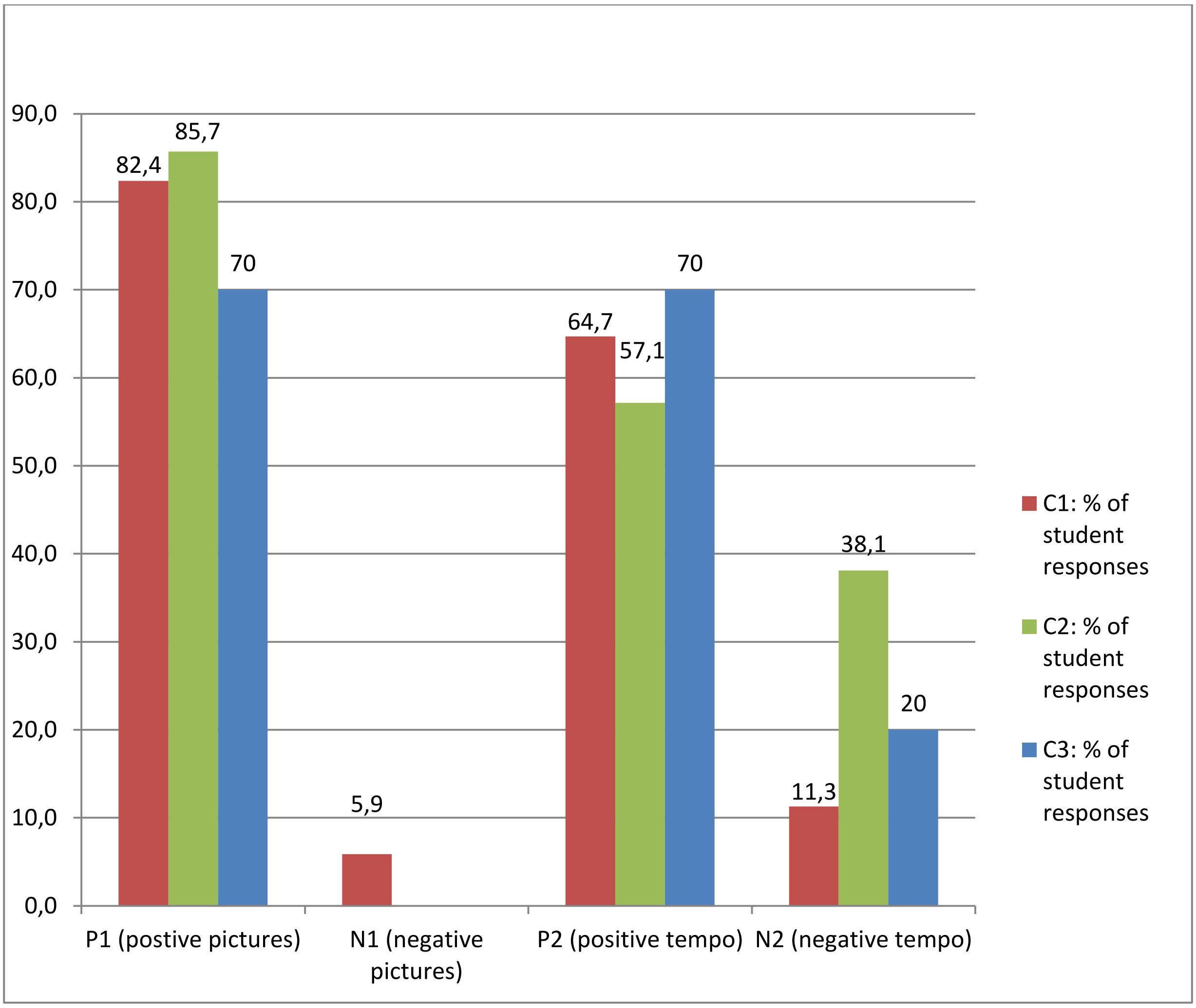

Figure 4: What did you think about the pictures and tempo in the IVs?

4.2.3 Content of IVs

The students were asked: “Was the content of the videos understandable?” The students’ answers to this question are shown in Figure 5.

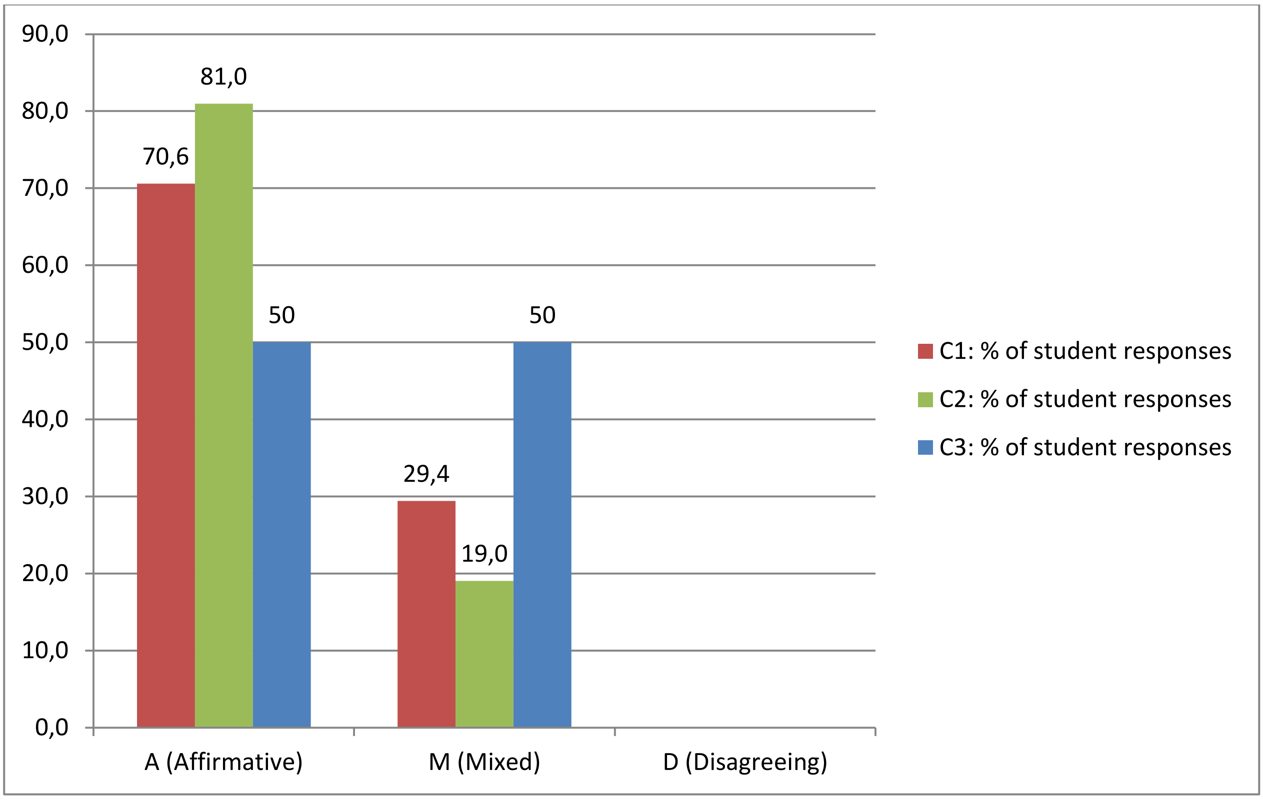

Figure 5: Was the content of the videos understandable?

Interestingly of the students who gave a mixed answer. 17.6 % of the C1-students gave a mixed answer concerning video 3, such as “Video 1 and 2 were fine. Video 3 on the other hand was a bit difficult in my opinion. I feel I struggle with the orbital theory, after all it was pretty new to me.” 19.0 % of the C2-students gave a similar mixed answer, as well as 45 % of the C3-students.

Furthermore, the students were asked: “Did you experience that you understood the content better after having worked with it through questions and/or discussion?” The students’ answers are shown in Figure 6. The C1-students are not included here as they did not work with the content at school.

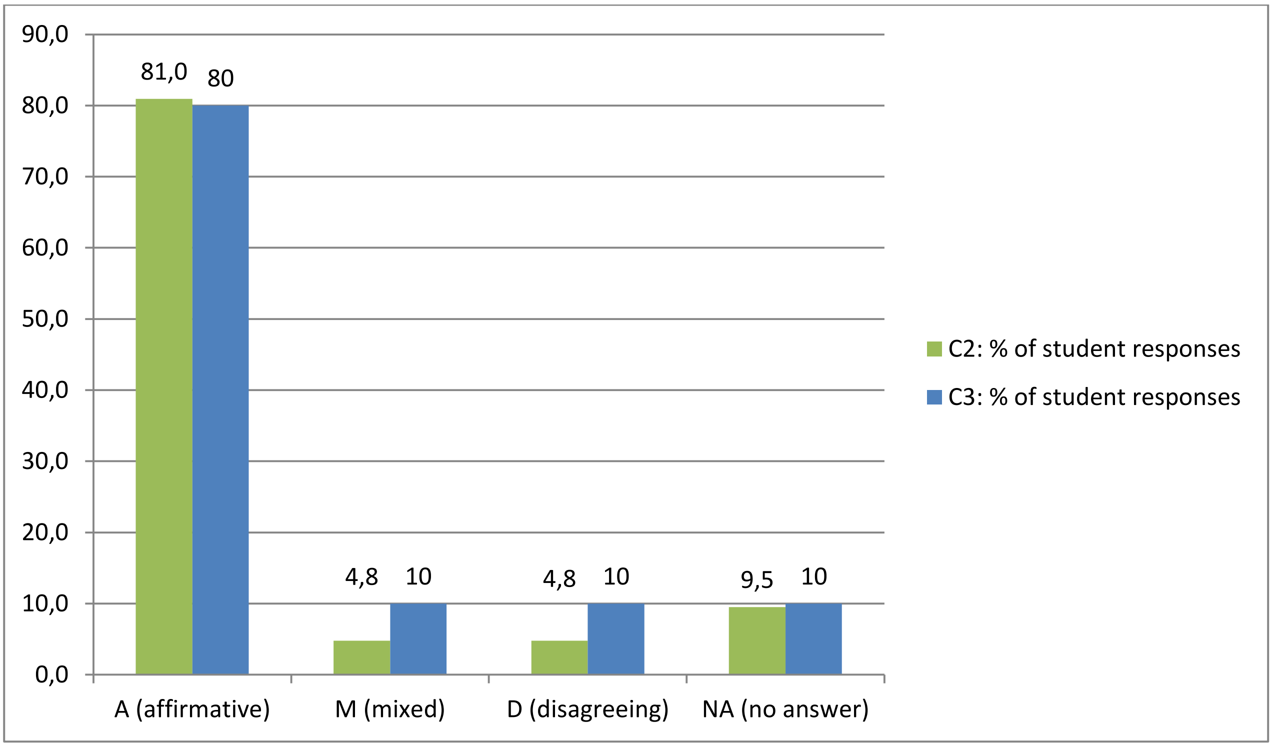

Figure 6: Did you experience that you understood the content better after having worked with it through questions and/or discussion?

Finally, the students were asked: “What is it that you still do not think you understand?” The answers are shown in Table 12, number of answers in parenthesis.

Table 12:What is it that you still do not think you understand?

C1	C2	C3
Nothing (9)	Nothing (6)	Nothing (2)
Orbitals (3)	Orbitals (9)	Orbitals (14)
	Electron distribution (1)	Electron distribution (1)
	Don’t remember (1)	Don’t know (1)
Exication/de-excitation of atoms (2)		
Revision facts (1)		
	Difference between Bohrs model and orbitals (1)	
	Important researchers (2)	

4.2.4 Suggestions for improvement

The students were asked: “How can the teaching model be improved?” The students’ answers are shown in Table 13, number of answers in parenthesis.

Table 13: How can the teaching model be improved?”

C1	C2	C3
Nothing (3)	Nothing (1)	Nothing (1)
Faster tempo (2)	Faster tempo (4)	Faster tempo (2)
Using more visual effects (1)	Using more visual effects (1)	Using more visual effects (1)
More interactive (1)		More interactive (1)
More enthusiasm in the voice (2)		More enthusiasm in the voice (1)

C1	C2	C3
	More basic questions, less discussion-questions (3)	Simpler control-questions (1)
Explaining why it is so, not just what it is (1)	Explaining why it is so, not just what it is (1)	
Present the content more thoroughly (1)	More thorough coverage of orbitals (2)	
Using more time (1)		Slower tempo (1)
Ending video with quiz about the video (1)	Summary at the beginning/end (3)	
More discussion about the videos (3)		Discussion in class at the end (1)
	More videos covering all the themes (1)	More modules that go faster trough the theme (1)
	No answer (2)	No answer (2)
Making the content more interesting (1)		
More comprehensible illustrations (1)		
	Using more comparisons (1)	
	Less discussion (1)	
	More questions (1)	
	Teacher must get everybody onboard (1)	
		More thorough explanations (4)
		Simplify orbital-theory (2)
		Run-trough of questions (1)
		Variation (1)
		Simpler/more specific explanations (2)
		More coherent videos (1)

5 Discussion

In this segment the two research questions will be analysed in light of the results of the study (section 4) and the theory (section 2), also, quotes from the student's answers will be used where appropriate. The first research question, how should IVs be designed? Is discussed in section 5.1, the second one, how should IVs be used in education is discussed in section 5.2. Sections 5.3 cover areas of further interest that have been uncovered in the study, while section 5.4 discusses the limitations of the study.

5.1 How should instructional videos be designed?

This is the central question of this thesis, as it is primarily the area which can be controlled from a designer point of view (as shown from this study one has limited ways of influencing how the IVs are used). Here I will compare the results from the study with the theoretical knowledge presented in theory. Since this segment is concerned with the IVs themselves, which were the same for all three classes, I will mainly focus on answers that are given by two or more classes. The reason for this it that issues relating to the IVs themselves is likely to show up across all three groups, regardless of how they were used.

5.1.1 Tempo

The students gave somewhat mixed feedback on the tempo used in the videos. Most seemed positive to the tempo (as can be seen from Figure 3), but some felt that the tempo was too fast or too slow. We can also see the same trend in the students' suggestions for improvements (Table 13), some of the students from the C1 (2), C2 (4) and C3 (2)-classroom suggested a faster tempo. One C1 and C3-student suggested a slower tempo.

The teachers also were in disagreement on the tempo, with the C1-teacher considering the tempo too fast, and the C3-teacher considering it too slow (Table 6). It seems it is impossible to satisfy all parties, tempo-wise.

The students, who felt that the tempo was too fast, might have self-regulated their learning poorly. They could essentially have used the micro-level interactive elements in the video to regulate the tempo of their learning, as formulated by the pacing principle (Moreno & Mayer, 2007). The assertion that students tend to self-regulate poorly in an e-learning setting is also supported by Azevedo and Hadwins (2005) study. Pre-training in the form of training in the use of micro-level interactive elements (Mayer & Moreno, 2003) might have supported these students in their self-regulation. Another intervention that could have been made on their behalf is segmenting the videos into several smaller bites, which the students can choose freely between, which has been shown to be effective in supporting student learning (Mayer & Moreno, 2003). The segmenting could also be combined with an interactive menu which allows the learners to choose segments, which would be a macro-level interactivity of the navigating type (Moreno & Mayer, 2007), which has been shown to be beneficial for student learning (Zhang, 2005). Using segmenting would presumably "force" the students into applying the pacing principle since the content would be divided up for them, instead of them being required to do it by themselves.

The students who felt that the tempo was too slow are another issue. Here it is not necessarily so that they self-regulated poorly. Many of the C2-students did solve the issue by self-regulating their learning, by applying the tempo-adjustment available on YouTube-videos as can be seen from the following C2-students quote "[...] but the tempo was a bit slow. But I just turned the tempo up to 1.5 then it went fine". The C1 and C3-students did not seem to be aware of the function or at least did not mention it. Pre-training in the use of the tempo-adjustment function could have made them aware of it, and might have solved the issue for them as well (Mayer & Moreno, 2003). The pre-training might have benefitted those who felt the tempo was too fast as well, as the function allows one to both increase and decrease the playback tempo.

One should, however, be wary of using segmenting and pre-training, as both these techniques can potentially reduce the effort the learner exerts to process new information and integrating it with existing knowledge, i.e. the germane load (DeLeeuw & Mayer, 2008). Reducing the germane load might have a negative effect on student learning (Clark & Mayer, 2011; Schnotz & Rasch, 2005).

5.1.2 Interactivity

An underlying factor in the previous segment seems to be that not all the students used the micro-level interactive elements in the video, which is reinforced by the students' suggested improvements of increasing the interactivity (Table 13). There were, however, some from all three classes who used the micro-level interactive elements and were pleased with them, as can be seen from the numbers of students considering stopping/rewinding videos to catch up as an advantage (Table 11) (C1=4, C2=3, C3=5). This is further illustrated by the following C1-students quote: "The tempo was not a problem, because you can stop and take notes if you want to." These numbers were relatively similar, and might represent the students who had an natural deep learning style (Biggs, 2012) as they would probably self-regulate more effectively (Pintrich & De Groot, 2003), although this is by no means certain. The students answers appears to support the assertion that only macro-level interactive elements can scaffold students self-regulation of their learning (Delen et al., 2014).

It is probable that including macro-level interactive elements would have scaffolded the students' self-regulation (Delen et al., 2014; Moreno & Mayer, 2007) for the students who did not have a natural deep learning style (Biggs, 2012). Of the macro-level interactive elements that could be included are:

Dialoguing, where the learner receives questions on the content and feedback on their answers, which could have led to a more active processing of the material by giving them feedback on their thoughts.

Manipulating, where the learner can directly interact with the material at hand, where the students could have interacted with the content directly, by for instance selecting their own parameters, and doing their own simulations.

Searching, where the learner find new content material not originally found in the IVs which could have engaged the students in information searching on the content (Moreno & Mayer, 2007), which was also echoed by the C2-teacher in his or hers suggested improvements (Table 10).

Including these macro-level interactivities could have made the content more interesting, and provided by more variation as suggested by the students (Table 13). Specifically, it could have been done by: Including an intelligent tutor system (Klašnja-Milićević et al., 2011), or adding a feedback function to questions in the IVs (Clark & Mayer, 2011) which both would be examples of dialoguing. Another option could be to include a form of manipulating, by including a simulator where the students could set their own parameters, this could have been done for instance by including the simulation program "Hydrogenic Atom Viewer" (https://goo.gl/hN7j9) (Hydrogenic Atom Viewer, 2017). Finally, a form of searching could have been included by giving control questions that went beyond the content of the IVs.

Of these macro-level interactivities, searching seems the least useful since the knowledge on orbitals is pretty much set in stone, it is unlikely that the students would find something new by searching (although they could, of course, find new explanatory angles better suited to themselves). Dialoguing would demand quite a lot of resources if an intelligent tutor system was used (Klašnja-Milićević et al., 2011), a simpler form of dialoguing as used in video 3 could have been used more often. Through these interactions, the students could be scaffolded by encouraging them to actively process the information, in order to answer questions on the videos, and receiving feedback on their answers (Moreno & Mayer, 2007).

Additionally, there seems to some quite useful simulations that could be embedded in the videos trough hyperlinks (such as the Hydrogenic Atom Viewer). This manipulating form of interactivity would presumably scaffold the students learning by letting them try out their ideas and thoughts on the subjects, and seeing if those ideas work out (Moreno & Mayer, 2007). There seems to be no research on which of the macro-level interactive elements are the most effective, which is pointed out as an area of interest by Delen et al. (2014), for further discussion on the subject see section 5.3.

One last element to consider is the possibility of the interactive elements increasing the cognitive load (Moreno & Mayer, 2007), i.e. the amount of cognitive processing devoted to learning the material (Clark & Mayer, 2011). Studies have shown that this does not seem to occur (Delen et al., 2014; Zhang, 2005), but one should still be careful not to include unnecessary interactive elements just for the sake of interactivity. Since multiple unnecessary representations could potentially negatively influence the students learning (Ainsworth, 2008), as this would increase the extraneous load (the cognitive load created by superfluous materials), associated with the content (Moreno & Mayer, 2007).

5.1.3 Control-questions

The control questions included were only used by the C2 and C3-teacher, in different ways (see Table 5). 81 % of the C2-students and 80 % of the C3-students seemed to consider the questions beneficial to their learning (Figure 6) which was also reflected by the teachers' responses to whether the control questions contributed to the students learning, both answering affirmatively (Table 8). However, as can be seen in Table 13 three C2-students and one C3-student suggested more basic/simple questions. These answers might be reflective of how the control questions were made.

As outlined in the methods section there was only one question for each of Bloom's categories (Halawi et al., 2009). Which might have been problematic, and potentially more questions should have been included for the lower categories of Bloom's taxonomy, for students who did not immediately grasp the concepts. This need for more "simple" questions is exemplified by the following reply from a C2-student when asked for improvements "That the tasks could have been a bit easier and more concrete so that we got simple and straightforward repetition." The C2-teacher suggested more questions were students had to think for themselves or find information online as an improvement (Table 10, which might indicate that he or she considered that there were too few questions corresponding to the higher categories of Blooms taxonomy, and so more questions corresponding to those categories should probably also have been included. Another possibility could have been to embed some of the control questions into the IVs, which would be a form of dialoguing macro-level interactivity (Moreno & Mayer, 2007) as discussed in the previous segment.

5.1.4 Reducing cognitive load?

As outlined in the CTML-theory, managing the cognitive load (the amount of cognitive processing devoted to learning the material) of IVs are a crucial element in designing IVs (Mayer, 2002). However, the focus needs to be on reducing the extraneous (activities that do not support learning) and intrinsic load (complexity of the subject), which is effective for student learning (Clark & Mayer, 2011). Reducing the germane load (processing new information and integrating with existing knowledge) might have a negative effect on student learning (Clark & Mayer, 2011; Schnotz & Rasch, 2005). The feedback from the students seems to indicate that the cognitive load of the first two videos were mostly fine, while the cognitive load of video 3 might have been too high (Figure 5 and Table 12), which is also illustrated by the following C3-students quote: "The two first videos were good, but video 3 was difficult." If the cognitive load of video 3 was too high it could have created a cognitive overload scenario (Mayer & Moreno, 2003).

Interestingly the C1-students seemed to think that they understood orbital-theory better than their C2 and C3-counterparts (Table 12) three of the C1-students gave that they still did not understand orbitals compared to nine (C2) and fourteen (C3) of the other students. However, the C1-students did not specifically work with the content (see 5.2.1 for elaboration).

So the data seems to indicate that the students considered video 3 the most difficult which is to be expected since the intrinsic load probably was higher for video 3 which covered a more complex and unknown theme than the two other videos. The extraneous load was also higher since it was the longest video, requiring a higher student attention-span (DeLeeuw & Mayer, 2008), at least if the students self-regulated poorly. The same trend is reflected in the C1 and C2-teachers feedback (Table 7 and 8 respectively) where they indicated that video 3 was frustrating (C1) and difficult (C2); nonetheless, some students struggled with video 2 as well, as can be seen from Table 12. So the question is how the extraneous and intrinsic load of the IVs might be reduced.

Most of the methods for reducing cognitive load outlined by Mayer & Moreno (2003) (see Table 1) concerns reducing extraneous or germane load, and most of them were used in designing the IVs to reduce the extraneous load. These techniques were used during the design of the videos, and so the extraneous load should have been pretty minimal (except for the length of the videos). The intrinsic load has earlier been thought to have been constant (Sweller, 1994). However, the research of Lee, Plass, and Homer (2006) suggest that the intrinsic load can be reduced in a visual display by separating one high complexity interactive element into two less complex interactive elements. This could have been done for the macro-level interactive element in video 3 (Figure 2), which could have been separated into two less complex macro-level interactive elements. This is also shown by the following C1-students suggestions for improvement "More clear drawings. Not too much on one page. You can divide up some parts, and then combine them -> to show the context."

Specifically, it could have been done by dividing the element up. Instead of showing all the orbitals at the same time and asking how they would be filled for a given element it could be built up gradually for each element. By first showing the 1s-orbitals (for instance Helium), then 2s and 2p (for instance Nitrogen) and so on, and afterwards showing the electron distribution. This technique for reducing the intrinsic load should be considered for all manipulating and dialoguing macro-level interactive elements included in the videos, as proposed in section 5.1.2.

Another option could have been to reduce the intrinsic load by simplifying the subject in video 3, which would also bring it closer to the C1-teachers interpretation of the curriculum. However, the whole point of the videos was to introduce orbital theory to the students according to our interpretation of the curriculum goal. Video 3 could have been made shorter, or segmented into two videos, which was suggested by the C2-teacher (Table 10). However, this would not have reduced the intrinsic load (given that the content stays the same), but it could have reduced the extraneous load (Mayer & Moreno, 2003), and made the videos more in tune with student attention span (Bunce et al., 2010), and so should also be considered. One could additionally consider changing the format of the videos. However, the research on which format produces the highest and lowest amount of cognitive load is not conclusive (Chen & Wu, 2015; Ilioudi et al., 2013; Yang & Tao, 2015).

5.2 How should instructional videos be used in education?

Earlier studies have shown that educator’s use of IVs can lessen the educational value (Hobbs, 2006).Given this, how different educators implement IVs in their classroom, is likely to affect the students learning outcomes.

Of the methods for using IVs in the classroom, flipped and blended learning both have the rationale of freeing up class time for active learning, both methods often showing higher learning outcomes and students satisfaction when compared to a traditional classroom (Means et al., 2013; Seery, 2015; Woltering et al., 2009).While the tutorial method focuses more on allowing the students to apply their learning to a real-world setting, while still promoting active learning (Back et al., 2016). In this segment, the focus will be on the different teachers' uses of the IVs and what effects it had on the student's attitudes.

5.2.1 Did the teachers approach facilitate active learning?

In the present study, the C1-teacher did not use a technique that can be considered flipped learning, as the students did not work with the content in the classrooms (Table 3) a central part of the flipped model (Seery, 2015). As demonstrated by the students' advantages and disadvantages, four C1-students actively engaged with the material, by stopping/rewinding the videos, and three students generated questions to the content (Table 11). However, it is unlikely that this is down to how the C1-teacher used the videos, as the method employed by the C1-teacher did not engage them with the content in the classrooms. More likely it was down to whether the student had an natural deep learning approach or not (Biggs, 2012).

Additional information can be found in the C1-students 'suggested improvements, where three of them suggested having more discussion about the video (Table 13) indicating that they felt the need to process the videos in the classroom. One of the C1-students suggested that the teacher employed a blended approach when suggesting improvements "[...] and that the videos are used as a support in regular teaching." When asked whether they felt the content was understandable, 70.6 % of the C1-students answered affirmatively, while 17.6 % of them gave a mixed answer concerning video 3 (Figure 3) and they listed few elements they still did not understand (Table 12) than the C2 and C3-students.

One should, however, be wary of concluding that the C1-students understood video 3 more than the C2 and C3-students. The C1-students did not work with the content. It is easy to watch a video/lecture, and believe you understand it; it is when you try to solve tasks related to the theme that one can uncover whether one understands it or not. Learning, after all, is not just acquisition of information, but also the conceptual change created by the information (Biggs, 2012).

The C2-teacher used a blended approach (Kerres & Witt, 2003), where the students were required to work cooperatively in groups which is a form of active learning (Prince, 2004) (Table 4). Given this and the fact that the C2-students' listed as advantages: working with others (2) and with control questions (2) (Table 11) it seems safe to say that some of the C2-students did actively engage with the content, as is exemplified by the following C2-students quote: "The advantage was that we could rewind the videos if there was something we did not understand [...]." This rewinding indicates that they actively engaged with the content. Given that the C2-teachers approach promoted active learning it could be assumed that there was more active learning in the C2-classroom than the C1-classroom. Additionally, the C2-students were the only group where none suggested more discussion about the theme, one actually suggested less discussion (Table 13). Indicating that they felt they had processed the content (too much?) in the classroom. The C2-students also answered more affirmatively, 81 %, when asked whether they felt the content was understandable than the two other groups, 70.6 % (C1) and 50 % (C3) (Figure 5), again indicating that they might have more actively processed the information. Although one could have actively participated and still not felt that the content was understandable. When suggesting improvements, one C2-student stated that the teacher needed to get everybody on board (Table 13) indicating that not all the C2-students actively participated.

The C3-teacher also used a blended approach (Kerres & Witt, 2003) where the students first viewed the videos and then engaged in a plenary discussion on the control questions (Table 4).

Given the C3-teachers approach and the students' advantages and disadvantages, where they listed working together (1) and with control questions (2) as advantages it seems safe to say that some of the students engaged in active learning. As exemplified by the following C3-student: "The advantages is that one can rewind and listen to the videos several times if you did not catch all the first time." Again the fact that they used the rewind function indicates that they were cognitively active The C3-teachers approach would have also prompted active learning amongst the students, however, possibly not as much as a plenary discussion is an activity where students can opt in or out, as opposed to working in groups. Additionally, one C3-student suggested discussion in class at the end as an improvement, which might indicate that not all the students participated in the plenary discussion.

Furthermore, the C3-students answered far less affirmatively when asked if the content of the videos were understandable (50 %) than the C1 and C2-students. This does not, however, mean that the C3-students were less active than the C2-students, as there are many other factors that could influence their understanding of orbitals. For instance, how much previous experience the students had with orbitals and e-learning, which in retrospect should have been documented with a pre-questionnaire. Studies have shown that the student's experiences with e-learning influence their subsequent encounters with it (Mitra et al., 2010). Another factor would be the teachers' attitudes towards orbital theory, which we know varied (Table 9); this is discussed further in section 5.3.1.

So we know that the three teachers employed different methods. The C1-teacher used an approach that probably did not promote active learning at all, while the C2 and C3-teachers used blended approaches that probably facilitated active learning, although this study does not give any concrete indications which were the most successful in promoting active learning. What can be stated is that the C2 and C3-teachers approaches to using IVs promoted active learning more successfully than the approach used by the C1-teacher.

5.2.2 Student's attitudes to using instructional videos

As one can see from Figure 3, the C1 students had an equal ratio of enjoyed to disliked towards the teaching program. While most of them did not give an answer to whether they enjoyed or disliked the program. The C2-students seemed to enjoy the program far more, with fewer dislikes, although there were still many who did not answer the question. The C3-students had the same ratio as the C1-students, and most of them did not answer the question. The trend is also reflected in the number of advantages/disadvantages listed (Table 11), the C2-students listed more advantages and fewer disadvantages than their C1 and C3-counterparts, the C3-students listed the most disadvantages. So it seems that the C2-teachers approach was the one most positively received by the students, while the C1 and C3-teachers approaches had a more mixed response.

The differences between the C2 and C3-students is interesting because both the C2 and C3 teacher used a blended approach (Kerres & Witt, 2003), but those approaches were received differently by the students (Figure 3). Studies have shown that students who learn actively tend to enjoy the process more (Jensen et al., 2015; Stowell & Nelson, 2007). So the higher enjoyment reported by the C2-students (Figure 3) gives some indication that the C2-teachers approach facilitated more active learning than the C3-teachers approach. However, there are many other variables to consider such as previous experience with e-learning (Mitra et al., 2010), previous knowledge of orbital theory, teacher enthusiasm and so on in addition this was a qualitative study and so it cannot be stated that the C2 approach was more effective than the C3-approach. Additionally, there were many non-responses to the questions, which were expected (Reja et al., 2003), but nonetheless reduces what can be learned from this study. So it seems educators need to have a clear plan for how the videos are used in the classroom to facilitate active learning amongst the students (Leo & Puzio, 2016; Merkt & Schwan, 2014; Seery, 2015). One cannot just hand out IVs to the students and expect learning to occur, the belief that IVs or other e-learning in themselves will generate learning is naive, and a form of technology determinism (Selwyn, 2010). Studies have also shown that e-learning in itself does not necessarily improve student learning (Schnotz & Rasch, 2005; Zhang & Nunamaker, 2003).

5.3 What areas of interest warrant further studies?

There are several interesting areas that have been uncovered by the study, where it seems more research is needed. In this segment, I will summarize some of them, and suggest how they could be investigated.

5.3.1 Curriculum

“Both teacher and student work within the "hidden" curriculum. Previous assignments given to the written exam indicate the range of study materials that the students should especially work with to achieve the best results for the exam” (my translation) (Ringnes, 1993, p. 56). It can seem that the C1-teacher decided to work within this “hidden” curriculum of which orbital theory is not an important factor, which might have lead him or her to consider module 3 superfluous to his or hers teaching (Table 9). The C2 and C3-teacher then might not consider the hidden curriculum that much in their teaching or they consider orbital theory as a part of the “hidden” curriculum. Which is shown by both the C2 and C3 teacher stating that they thought the programme was relevant for chemistry-1 students (Table 9). So there seems to be no clear consensus of whether the curriculum goal of modern atomic theory does include orbital-theory. Neither amongst the teachers who participated in this study, nor the textbooks used in chemistry-1 (Brandt & Hushovd, 2010; Grønneberg et al., 2012; Steen et al., 2010), and presumably the authors of the textbooks. An interesting way forward could be to analyse chemistry-1 exams to examine their view of the issue. However, the chemistry-1 exam is a locally given, oral exam, and so it would again probably vary between different interpretations as the ones seen from this study. The seeming confusion in relation to the curriculum could be an interesting point to clarify with the upcoming updates of the curriculum as undertaken by the current government (Kunnskapsdepartementet, 2016).

5.3.2 Video format

As previously mentioned the impact on cognitive load from the video format seems an intriguing field, with several studies showing conflicting results, i.e. (Chen & Wu, 2015; Ilioudi et al., 2013; Yang & Tao, 2015), and seems to be in contradiction with the CTML-theory (Mayer, 2002). Additionally, there needs to be a focus on what type of cognitive load is being reduced, as reducing germane load could have a negative effect (Schnotz & Rasch, 2005). In the present study only one format, the whiteboard-imitation (Figure 1 and 2) was used and so the data is of limited value in this field. An interesting way forward could be to construct videos covering the same subject in several different formats, and testing the knowledge-acquisition generated from the videos. Care should be made that the different videos were produced by the same team/person so that differences in the quality of the videos will be minimized. However, this could potentially demand a lot of resources. The study could also investigate how different student types react to different video formats, although Chen & Wu (2015) found no influence from the formats on verbalizers and visualizers learning performances.

5.3.3 Educators uses of IVs

Another interesting field would be how the different methods used by educators for implementing IV's would affect student learning. This study did not examine the learning outcomes for the three classes, only the students' attitudes. Of course one can hypothesize that the C2-students experienced more active learning which is likely to lead to higher learning outcomes for the students (which is well documented in theory) (Freeman et al., 2014; Prince, 2004), but the data in this study neither supports nor disproves this hypothesis. A study that investigated the different approaches impact on learning outcomes would be interesting, for instance comparing the flipped approach with the blended approaches employed by the C2 and C3-teacher.

5.3.4 Macro-level interactivity

Another area of interest is macro-level interactivity, and how it can scaffold student learning. Delen et al. (2014) found in their study of students using IV's with the macro-level elements of: Dialoguing (practice questions) and Searching (supplemental resources) (Delen et al., 2014; Moreno & Mayer, 2007). The students using macro-level interactivity outperformed students viewing the same IV with only micro-level interactivity indicating that it more effectively scaffolded the student learning. However, it remains to be seen which of these elements was most effective in scaffolding the students' learning, something Delen et al. (2014) also notes. A suggestion could be to make three separate videos covering the same theme each incorporating one macro-level interactivity, and one control video using only micro-level interactivity and measuring the learning outcomes.

5.4 Limitations of the study

The study has several limitations that one need to consider when evaluating the results. First of all, there was no measuring of the students learning outcomes, making it impossible to state that one approach was more effective for student learning than the other. On the other hand studies on e-learning often fall into the trap of considering improved results as a direct enhancement, while failing to consider whether the intervention leads to deeper or richer learning (Kirkwood & Price, 2014). However, this study did not research whether the intervention lead to a deeper or richer learning either. Additionally, there was no background data on the student's previous experiences with orbital theory and atomic models in general, and indeed no gauge of their previous experience with e-learning which is an important factor in their reaction to e-learning (Mitra et al., 2010). It could very well be for instance that the C2-students had more experience with orbital theory and e-learning, and therefore found it easier, which might have led to less frustration and a higher self-reporting of enjoyment. In retrospect, a pre-intervention questionnaire should have been utilized to gauge these factors.

Secondly, there is the possibility of data-collector bias (Fraenkel et al., 2012). Although the data-collection and the construction of the questionnaires itself were not conducted by the author but by the teachers participating in the study and my supervisor respectively, the coding of the data was conducted by the author and so could very well be biased. To avoid data-collector bias steps were taken (as described in the methods section), but the possibility remains that the coding of the data was conducted with a bias towards improving the outcomes.

For instance, the C2-students might have been coded more towards the enjoyed scale, or the C1-students might have been coded towards the disliked scale. This could potentially be an important factor to be considered when looking at the results and their suggestions. There is no publication bias for the thesis, as it would have been published in DUO regardless of the results; however, my attitudes and thoughts on how IVs should be used could have influenced my interpretation of the data. Finally, this study is a qualitative study, and so no larger conclusions can be drawn from it (Fraenkel et al., 2012), but it does provide some interesting possible suggestions, which will be shown in section 6.

6 Suggestions from the study

This study set out to research two aspects of using IVs in education. The first was how to design IVs to maximize their learning potential (6.1); the second was to investigate how different educator's use of IVs affected the student's attitudes (6.2). Here the suggestions from the study for the two aspects will be presented.

6.1 Suggestions for design of instructional videos

So how should IVs be designed? The literature is clear on the need for including macro-level interactive elements to scaffold student learning (Delen et al., 2014; Moreno & Mayer, 2007). Since students tend to poorly self-regulate their learning with e-learning (Azevedo & Hadwin, 2005). The suggestion in this thesis is to include the forms of macro-level interactivity known as manipulating, by inserting simulators into the videos and dialoguing by increasing the numbers of feedback macro-level interactivities (Moreno & Mayer, 2007). However, there is no clear data on what type of macro-level interactivity is more effective. The suggestion is mostly made based on practicality. The videos should probably be segmented more, so as to "force" the students to apply the pacing principle (Moreno & Mayer, 2007), possibly by including a more macro-level navigating system, and pre-training should be utilized to train the students in using the micro-level interactive elements (this is, however, not down to the design of the videos). Finally, the extraneous load (the superfluous cognitive load) could be reduced in video 3 by shortening the videos, and the intrinsic load (the inherent cognitive load) could be reduced by separating complex interactive elements (Lee et al., 2006). One should, however, be careful of reducing the germane load (the cognitive load of processing and integrating new knowledge), as it could potentially have an adverse outcome on student learning (Clark & Mayer, 2011; Schunk, 2005).

6.2 Suggestions for the use of instructional videos

As to how the different educator's methods influenced the student's attitudes, the data shows that the blended approach using collaborative problem solving used in the C2 was the one most enjoyed by the students, while the blended approach used by the C3-techer was less enjoyed along with the approach employed by the C1-teacher. However, there are many other factors which could influence the enjoyment, as discussed earlier. So what can we draw from this? Some methods for using IVs promote active learning more effectively than others (Hobbs, 2006; Mitra et al., 2010), and it seems a blended approach utilizing collaborative problem solving is well received by the students. This enjoyment might indicate that they experience more active learning (Jensen et al., 2015; Stowell & Nelson, 2007); although there are too many other factors that it can be stated for certain. So an educator planning to use IVs should probably consider this method for implementing IVs. What can be stated is that educators should choose to utilize pre-training in order to familiarize students with the micro and macro level interactivities (Mayer & Moreno, 2003), making it easier for them to self-regulate their learning.

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