Interactive learning environments:
The effects of interactivity in online learning environments

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Abstract
We live in an era where interactivity is gradually becoming more available, yet our schools are not catching up to this trend, instead we are faced with passive learning environments where active construction of knowledge is limited. In this study we looked at the constructivist approach to learning and compared it to the objectivist approach that is commonly used in most schools of today. We looked at other successful interactive learning environment and how they may look like. We developed a passive educational video and a prototype of an interactive learning environment, where the interactive environment worked as a supplement to the educational video. We further conducted a quantitative test through a questionnaire on these environments to see if the learning outcome of the interactive learning environment outperformed the learners of the educational video. The data we collected did not show any significant difference between passive and interactive learning, it did, however, show some interesting trends such as younger participants in general performed better than older participants in our interactive learning environment.

Keywords: e-learning, interactivity, constructivism, education

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1. Introduction

In our younger days we gain experience from playing with friends at home or in the kindergarten, we go on trips, explore, play in the sandbox, touch, listen and experiment with our environment. Doing this enabled us to find creative ways of solving problems as they arise, we learn what is right and what is wrong from our mistakes and successes. As we grow older our ways of learning transforms into a more passive state, our educational form changes, we get accustomed to sit down and listen to the teachers’ lectures or reading books. Most schools were not designed to help students develop as creative thinkers, educators and parents generally see activities as “play” and separate it from learning (Resnick, 2007).

Most of us can relate to having learned something through taking on a problem and experiment with it until we get a eureka moment when we really get it. When we learn something this way it tends to get glued to our brain much more than surface knowledge we typically achieve from passive learning. Even if we can recite what we have been taught from a book or a teacher does not mean that we have built a good understanding of the subject. In fact, it has been concluded that 80-90% of a test group of college students who could solve algebra problems failed to explain the underlying concepts of ninth grade algebra and why it works (Ramsden, 1988).

New technologies on the web, and the expansion of interactive devices such as tablets and laptops, open up new possibilities for schools and their way of teaching. Foremost, the new technologies make it possible for schools to create learning environments that uses a constructivist approach in learning, i.e., moving away from the passive form of learning into a more interactive way of learning that involves an active construction of knowledge (Savery & Duffy, 1995). The utilization of these technologies have already existed on higher education for a while where courses are being taught through the web. These web based learning environments are often referred to as e-learning or a Virtual Learning Environment (Brown, 2008). These environments distribute learning material to students and offer many benefits, among them are the benefits of availability at any time, and time efficiencies for teachers (Schell & Janicki, 2013). Recently e-learning environments also include social interactions between students and teachers, this have already seen many successes (Wang et al., 2009). However, the presence of interactive learning material on e-learning environments is still very small compared to traditional learning material (Tavangarian et al., 2004).

The lack of interactive material in these environments raises the question on how efficient interactive learning is compared to passive learning. Is it worth the time, effort and money to develop interactive learning environments? Further, is interactive learning a good approach to make learners get a deeper understanding of the underlying concepts of the area they are studying?

To examine how effective interactive learning is compared to passive learning, and to get an understanding of the time that is required to develop an interactive learning environment, we developed an interactive learning prototype and an educational video. The educational video was made to demonstrate passive learning while the prototype was supposed to complement the video. Both the prototype and the video teach the students about basic digital animation concepts. The prototype, however, give the learner an opportunity to work and play with the different animation concepts taught in the video.
1.1 Problem formulation
- How do interactive learning environments affect learning compared to passive learning environments?
- What differences can be found in learning outcomes from different learning environments?

1.2 Purpose
The purpose of this study is to generate more knowledge about differences in interactive and passive learning environments. We intend to generate this knowledge by doing the following:

- Compare interactive and passive approaches by developing an interactive learning prototype and a video (supporting passive learning) teaching the same subject
- Testing the interactive learning prototype and the video with different test subjects to identify differences in their learning
- Discussing where interactive learning could be an effective complement to passive learning

We contribute to the field of interactive learning with an increased understanding of interactive versus passive learning environments. The results of this study are also of value for practitioners building interactive e-learning systems.

1.3 Limitation
The underlying theories of this research covers a lot of the cognitive and mental workings of the human brain, we will not cover those parts in-depth in this study, instead, we chose to focus on how we as humans learn in general and on the different learning approaches that use these theories in the design of an interactive learning environment.

We will further talk about e-learning which has a lot of aspects associated with it that we cannot cover. Thus our prototype lacks many of the features that a typical e-learning platform offers the students, such as social interactions. The reason that we chose to make this limitation is so that we can look at the interactive part of e-learning as separate as possible.
2. Theory

In this chapter the focus is on the underlying theories for how construction of knowledge works (Savery & Duffy, 1995), the related theories used in learning and how interactive learning environments could result in an active construction of knowledge (Jonassen & Rohrer-Murphy, 1999). We compare learning theories in both passive and interactive learning environments and how they affect the learner. Moreover, we will talk about how an interactive learning environment can look like and how others use the theories in building their learning environments.

2.1 Learning Approaches

There are a wide variety of different learning approaches available that explain how humans learn when presented with new learning material. Two of the main learning theories on how we gain and construct knowledge are the objectivist and constructivist learning theories.

The objectivist learning theory explains that knowledge is something that is external from the learners, that is, knowledge is transferred from an expert, i.e., a book or a teacher, to the learners (Schell & Janicki, 2013). The learners are therefore not constructing their own knowledge, merely learning from already existing knowledge. In traditional schooling the instructor determines what to learn and how to learn, the communication often goes one way, but the learners have the ability to ask for guidance (ibid). If the learners are able to reflect over the subject that they have studied, i.e., through an exam, then it can be confirmed that they have learnt, however, this do not mean that they’ve built a good understanding of the subject.

Constructivism is a view on how we build an understanding on how things work in our world. It is through our interaction with the environment, through real-life experiences and social interaction that we learn and construct new knowledge. We all come to different understandings based on the content and the experience gained from the activity, since understanding is an individual construction (Savery & Duffy, 1995). Constructivist theory says that the learner should be the constructor of their own knowledge based on prior experiences (ibid), that is, if we have previous experience, we use what we have learnt during that experience to build new knowledge and a deeper understanding.

The majority of the theories about interactive learning are supported by the constructivist view. The constructivist learning theory suggests that active learning environments are better for learning (Hrastinski, 2009). This is because constructivism implies that there is no definite meaning of the world that we try to understand, rather, there is multiple ways to structure the world and make meaning of events (ibid). Since we all have different views of how the world works, we use this view to interpret the information that we are trying to learn (Arseneau & Rodenburg, 1998), that is why it is better to have learning material to interact with so that the learner can receive the material in a way that naturally fits the learners way of constructing knowledge.

Most of the learning we practice in school is supported by objectivism learning, it is distributed in the same form to all learners. Higher education most commonly uses an objectivist approach instead of a constructivist approach. Schell and Janicki (2013) explains
that this is not because schools favors objectivism, it is rather a question of financial restraints and it being more cost efficient, especially when one teacher have to teach a large group of students. However, new technology such as portable devices is opening up for new methods that allow schools to easier adopt the constructivist view when forming courses or lectures, that is, implementing much more dynamical learning material for the learners to interact with, which allows learners to learn in a way that is more suitable for them.

Resnick (2007) argues that we need to make school more like kindergarten, and that the kindergarten approach suits the needs of this century. He puts much weight on creativity and says that we need to help learners develop as creative thinkers due the demands of our century where being creative is the key to success. Digital tools of today can play a big role in education, if they are properly designed they can extend the kindergarten approach and continue to develop us as creative thinkers (Resnick, 2007). Not only would we learn how to be more creative, but interactive learning environments can also help students do critical thinking (Wang et al., 2009).

Another relevant theory is the activity theory, Jonassen and Rohrer-Murphy (1999) propose that activity theory can be used as a powerful framework for designing constructivist learning environments. Activity theory has its focus on human interaction during activity and how the human consciousness works during this activity. Jonassen and Rohrer-Murphy (1999) describes an activity system that explains how activity is a conscious action, and that a conscious action can get practiced until it becomes an automatic process which requires less conscious effort, or what they call an “operation” (Jonassen & Rohrer-Murphy, 1999). In short, activity theory says that activities promotes conscious learning, i.e., we are more aware of what we learn during activity, it give us a better understanding of the subject and we can more easily construct new knowledge. Wilson (2004) also confirms this by saying:

“Learning can be seen as change through activity. Activity mediates learning. Designs may apply an instructional strategy or model. But it is the activity of the learners that most directly determines learning”. (p. 199)

Since constructivist learning environments are also activity-oriented, these theories complement each other very well.

One known approach to learning, widely used and developed by Barrows (2006), is the famous problem-based learning (PBL) model, it was first used as a learning model for medical schools in the 1970’s and have since been adopted to a wide variety of areas (Savery & Duffy, 1995). PBL aims to develop learners thinking and reasoning skills, it is more aimed at collaborative learning and explains the significance of social environments and collaboration as a key for constructing knowledge, for example when a group of medical students would take on a problem and solve it using the available resources. PBL uses the philosophical view of constructivism, and is, according to Savery and Duffy (1995), one of the best examples of a constructivist learning environment. We can also see that PBL is directly related with the principles of activity theory, since solving a real-world problem is activity based. However, our study is not aimed at collaborative learning, but we argue that it is worth mentioning because PBL is such a big approach in interactive and activity based learning.
2.2 Interactive Learning Environments

Our main interest is in learning that is happening through digital environments, the main term used for such environment is called e-learning. E-learning stands for electronic-learning and refers to learning happening through electronic media that aims to support the learning process (Tavangarian et al., 2004). The basic concept of e-learning was that it should enhance learning with the use of video and sound, and the focus is aimed at the individual learner (ibid). It is most commonly used in schools that provide distance learning, that is, when learning does not require your physical presence at any predetermined location.

The early adoption of e-learning environments was very passive in nature and did not involve much interaction. Tavangarian et al. (2004) points out that early adoption of e-learning environments and its content was only translated from existing traditional content and therefore the adoption of constructivism could not take place. This is because the translated content lacks all kind of interaction with the user. Content in e-learning environments could therefore be viewed as traditional learning content placed in a digital environment, hence only provide easier access for the learner, but have no major impact on how we construct knowledge. In fact, passive learning on an e-learning platform are proven to cause boredom and disengagement among the learners (Zhang et al., 2004).

E-learning environments used in higher education could also be referred to as a Virtual Learning Environment, or VLE (Brown, 2008). VLE is used for managing online interactions between the student and the educator, and also to manage learning instructions and personalized learning (ibid). VLE often limits the student to static folders with content to be downloaded (Tavangarian et al., 2004). When the content is downloaded, the e-learning environment suddenly becomes a distribution platform. The whole point of e-learning is lost as soon as we move outside the frames of the environment (ibid).

E-learning can, and should be much more than what it currently is. Tavangarian et al. (2004) Suggests that e-learning should be defined as all kind of electronic learning that involves construction of knowledge on the base of the constructivist theory. There have already been several successful developments of interactive learning environments that support the constructivist view. Stephenson et al. (2007) used e-learning with the constructivist approach to train unskilled employees in a highly specialized subject. Their study showed that interactive learning significantly improved the skills of their employees. They conclude that interactivity is a powerful tool in a successful e-learning environment (Stephenson et al., 2007).

Al-Mousawi and Alsumait (2012) used constructivism, based on Piaget’s work on childrens’ mental and cognitive development (Piaget, 1972), when building an interactive e-learning environment for children. With the use of an iPad they developed a tool that helped children between the age four and five to create, share and tell stories with each other’s. Their work showed that it helped children’s development, it improved their general knowledge and essential skills (Al-Mousawi & Alsumait, 2012).

Zhang et al. (2004) developed a prototype, influenced by the constructivist learning theory, called “The virtual mentor”. This system included media in form of instructional videos, lectures and PowerPoint slides created by experts. The learners can interact with this environment, jump between content and ask questions to the virtual mentor as they please.
The learners have full control over their learning pace and can adapt it to fit their own needs. They made this prototype in order to test if distance learning through an e-learning environment is more effective than traditional classroom learning and came to the conclusion that learners in e-learning environments can significantly outperform learners from traditional classrooms (Zhang et al., 2004).

Some good points on why we should put a lot of resources into building interactive e-learning environments are being pointed out by Kalyuga (2007). He says that a good developed e-learning environment will return results in the form of efficient learning, and also reduce the learning time and the mental stress of the learner. Zhang et al. (2004) also made a list that further points out some good reason to why e-learning can be effective compared to passive learning. In this list he compares e-learning to traditional learning and include some pros and cons for both approaches, see table 1 below.

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<tr>
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<th>Traditional Classroom Learning</th>
<th>E-Learning</th>
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<tr>
<td><strong>Advantages</strong></td>
<td>• Immediate feedback</td>
<td>• Learner-centered and self-paced</td>
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<td></td>
<td>• Being familiar to both instructors and students</td>
<td>• Time and location flexibility</td>
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<td>• Motivating students</td>
<td>• Cost-effective for learners</td>
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<td>• Cultivation of asocial community</td>
<td>• Potentially available to global audience</td>
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<td></td>
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<td>• Unlimited access to knowledge</td>
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<td>• Archival capability for knowledge reuse and sharing</td>
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<tr>
<td><strong>Disadvantages</strong></td>
<td>• Instructor-centered</td>
<td>• Lack of immediate feedback in a synchronous e-learning</td>
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<td></td>
<td>• Time and location constraints</td>
<td>• Increased preparation time for the instructor</td>
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<td></td>
<td>• More expensive to deliver</td>
<td>• Not comfortable to some people</td>
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<td>• Potentially more frustration, anxiety, and confusion</td>
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Table 1. Comparison of traditional learning and e-learning (Zhang et al., 2004, p. 76)
3. Method

3.1 Research Approach

The two most common approaches when conducting research are the qualitative and quantitative approaches (Walliman, 2011). In the qualitative research approach the data for the research question is typically gathered through interviews and will thus be in words or letters. A downside to have data in this form is that there is no way to accurately measure it. Since there is no way to accurately measured it, the researcher instead interprets the data through various methods. Qualitative research often provides valuable insights and findings about our society that a quantitative study could not have done (ibid).

The quantitative research approach, which is the other research approach, is about gathering data in form of variables from test subjects. Variables can be defined as measurable value and are usually expressed in numbers. With the use of variables it will be possible to statistically analyse data (Aggarwal & Khurana, 2009). Before conducting a quantitative test, variables of interest are chosen, and a plan on how to convert the test subjects’ actions into these variables is established. A test is then performed in order to gather the data, for example, a questionnaire or by observing the subjects in a controlled environment (Straub et al, 2005). The benefits from doing a quantitative study are that the results to some extent can be proven to be correct or incorrect (Aggarwal & Khurana, 2009). The result can however only say something about the population that the test was conducted on, for instance, if the tests were conducted on children between five and ten years the results could not also be expected to be true for adults.

In order to prove that a result is valid in general, the test group which the test is conducted on has to be representative of a more general population (Walliman, 2011). Through a phenomenon called normal distribution, it is possible to conclude that the results of around thirty people will be very similar to result of infinitely amount of people taking the same test, providing the thirty people represent a normal distribution (Aggarwal & Khurana, 2009). This is very convenient since it provides a way for researchers to study big populations without doing test on tens of thousands of people. However, there are many catches and pitfalls associated with the quantitative research approach, for instance, how can the researcher be sure that the test group represents the population well? Given that the test group is chosen completely at random, the group would give a very close representation of the whole population. However, it is very time consuming and costly process to choose a test group as randomly as possible (Walliman, 2011).

In this study we wanted to look on how passive and interactive learning approaches affect students’ ability to learn a new subject. To answer this question we chose a quantitative research approach, with this approach we can tell if there is a difference in learning as well as how much difference there is, if there is any at all. This approach also fits our research well because we are interested in how much the environments differ. A qualitative approach might have pointed towards a similar result, but it would have been hard to determine how much the environments differ.

To test the difference between interactive and passive learning environments we have created two learning environments, one interactive environment, and one passive
environment. How these are designed and what we took into consideration when creating them will be described later in this chapter.

As we chose the quantitative approach, we needed to gather as much data as possible to get a more accurate result. We needed to evaluate our test and determine if we wanted to do a test on only one test group or if more test groups were more appropriate. In our case, if we were to have only one test group, it would have been hard to make them use both environments and then evaluate what they have learned from these environments because they might have been affected by one of the environments before going to the next environment. Because of this, a more appropriate approach would be to have two test groups and make these groups learn from only one of the environments and compare the differences from these groups (Walliman, 2011). By doing this, and ensuring that we randomly distribute the users among these test groups, we can ensure that we really are testing the effects of our two environments.

3.2 Literature search
We have collected related research findings and theories through Umeå University’s article search service, Google Scholar and ACM Digital Library. We have used keywords such as “interactive learning”, “constructivism” and “e-learning”. As such, most of the literatures we refer to are academic papers, this is advantages because these papers have, before being published, been peer reviewed and controlled to be academically correct. As guidance in method approach and data analysis we have used books more than we have used academic articles.

3.3 Data collection
To collect our empirical data we used two learning environments that we developed, and had participants answer a questionnaire after using these. In this section we will describe how we developed the interactive prototype and video that we used as two different learning environments. We will further describe how and why we designed the questionnaire that was used to collect the data.

3.3.1 Designing the Prototype and Video
Before we could start designing the prototype, we first had to pick a subject that would be taught through the prototype, we decided that the subject should be one that we were both familiar with to make it easier for us to teach and illustrate. We came up with a list of subjects, such as digital animation, space and time, computer science, digital cameras etc. The criteria we had were that the subject should be easy to teach and to illustrate, and it should be a fairly common subject that everyone could relate to and understand. Yet, we did not want to pick a subject that everyone already knew too much about. Considering all of this we chose to make our prototype about the subject “Digital animation”, which has big presence in visual media while it is not a subject taught in school as a core subject. Digital animation is a subject that we have learnt through our academic studies, thus it felt safe to use it as a subject for teaching because we have a good understanding of it and much experience in digital animation environments.
After deciding the subject we started to plan how the prototype should look and work, we had to think about what techniques related to digital animation we wanted to include in the prototype, how we could illustrate these techniques and what challenges in teaching them might present us with. We selected three techniques that are available in a digital animation environment. These three techniques are keyframes, easing and inverse kinematics. Our thoughts behind these tools were that they follow up on each other and cover all the basics to advanced parts of digital animation, each technique, according to us, gets a bit harder to grasp than the previous one.

When designing an interactive learning environment there were several important aspects of design theory we needed to take into account. First we had to understand what we were trying to accomplish and how we could accomplish it. We are not teachers to begin with, nor do we have any predefined knowledge of instructional learning or the knowledge of how to design learning environments. We had to find a framework that support our goal and guided us in the building of our interactive learning prototype.

We looked at Savery and Duffy’s (1995) instructional model for how to design a constructivist learning environment and applied their guidelines in the planning of our interactive prototype. The model explains that the learning environment should be authentic to the environment the learners will be functioning in (Savery & Duffy, 1995). This is also mentioned by Jonassen & Rohrer-Murphy (1999) with their activity theory model for designing a constructivist learning environment which said that the activity system should be authentic and replicate the tools, objects and rules of the real activity. The interface of the prototype should therefore be similar to the interfaces used in real animation tools in order to give the learner an authentic feeling and pre-guidance on how to use such interface. The model also says that it should be as complex as the real environment (Savery & Duffy, 1995), but due to our time restraints we figured that we could only make it as complex as it needed to be, i.e., only covering the techniques we wanted to teach in our prototype, while still designing the interface to look like a real environment for digital animations, if not a somewhat simplified version of it.

3.3.1.1 Developing the video

- The video can be found at this url: [http://learning-survey.herokuapp.com/](http://learning-survey.herokuapp.com/)

The video we made was supposed to work as a substitute to passive learning. The prototype we built would also be using each chapter of the video as an introduction to each chapter in the interactive prototype. Thus, we had to design the video and its instructions to fit the learning stages available in the prototype.

To make the video instructions feel authentic we decided to have one of us talking through each chapter in order to give the learner a feeling of presence from a real instructor. We wrote a manuscript for each chapter and then recorded the instructional voice. We had to re-work the manuscript lines a few times until we felt it was good enough to be used in the video. We then added the voice instructions in the video editing software and started designing the illustrations based on what the instructor explained.
All the graphical content we created was designed to be used in both the video and the interactive prototype. This was necessary in order to make a good transition between the video and the prototype without confusing the learner. We had this in mind when we designed the visuals of the video.

We created three chapters out of the three different techniques that we had chosen. In the first chapter we illustrated what a key frame is, and how it can be used by moving a football around the screen between different keyframes. In the next chapter we illustrated the easing technique, which is used to determine the movement speed and behaviour of an object. We illustrated it through graphs that represented the real tools used in creating easing. In the last chapter we explained the basics of inverse kinematics, which is a technique used to animate a body’s movement. We illustrated it by animating a leg with and without inverse kinematics so that the learner could see the difference and what it does.

Figure 1. A screenshot from the easing chapter of the video.
3.3.1.2 Developing the prototype

The prototype can be found at this url: http://learning-survey.herokuapp.com/module

Before we started sketching on the prototype we had to decide what elements we needed in the prototype that would reflect on the techniques we were going to teach. A list with the needed elements was made after some planning and discussion.

- Previous and Next chapter
- Add and remove Keyframes
- Help button
- Five keyframes, from A to E
- A stop, pause and reverse button
- A timeline from 0 to 6 seconds
- Movable keyframes in the timeline that represent same keyframes on the scene
- A timeline marker

When the elements were decided we started sketching on the interface as a whole, where to place the elements and how the interaction would look like. It was important for us to have a good visual interface, but it would take us a lot of extra time, so we decided to go with an already existing user interface1.

We decided to develop the prototype using JavaScript and html5 canvas technology. The participants could therefore be able to run the prototype inside all of today’s modern browsers. We used this technology because there are direct benefits of being able to run the prototype in a browser, foremost, the prototype becomes easily accessible for all learners and does not require any local installation. It can also be used with any portable devices that support browsers and an internet connection. Because the prototype should be able to show animations, give feedback of the animation on a timeline and explain various animation concepts we chose to use a third party framework called “CreateJS”. CreateJS is a JavaScript library that helped us structure the project and keep the code tidy in order for us to implement all the needed features.

In order to make the prototype complement the video, each chapter of the video was added before each chapter in the prototype, i.e., we added the interactive parts between each chapter of the video. For the keyframe chapter, the prototype would give the learner the possibility to play around with keyframes. We added the functions to add and remove keyframes, and also the possibility to decide the timespan between each keyframe in the timeline. The object they could move around was the same as in the first chapter of the video, a football. In the easing chapter we kept the keyframes features and added options to decide easing between each key frame. They could decide easing by clicking on the graph that illustrated the movement they wanted. When illustrating inverse kinematics in the last chapter we used the same leg as in the video. All the previous features were still available for the learner to use, but this time we wanted them to animate the leg instead. The leg is rigged with inverse kinematics as illustrated in the video.

1 kbsportfolio.com
To conclude, each chapter added a new technique for animation, so the learner could try out everything they tried from the first to the last chapter, by doing so we extended their activity and helped them build new knowledge (Kalyuga, 2007), it also give them the possibility to build knowledge based on their previous experiences (Savery & Duffy, 1995) based on the activity of the early chapters.

![Figure 2. A screen of the first chapter in the prototype](image)

3.3.1.3 Testing the Prototype and Video

Conducting a test on the prototype and video gives the advantage of being able to catch eventual design problems that we might have overlooked. Once the test was launched we could not change anything, doing so would mean that the test would become incorrect.

We started with testing the video for misinformation or other artifacts that would interfere with the teaching or understanding of the video. We tested the video on two people, and those two did not have any negative feedback to give us, we asked them some questions about their understanding of the video. From this we came to the conclusions that no big changes on the video were necessary.

We had two different participants when testing the prototype for the first time and the tests were done with each participant separately. We observed how each of them interacted with the prototype and the controls on the interface. We saw that they sometimes did not use the interface as we intended, and they often forgot about some controls when they continued to the next step of the prototype. Some interactive elements in the prototype were never touched by the participant, as if they did not know they could interact with it.

When they were done we asked them some questions on the things we observed during the test and also gave the participant some room to comment on the prototype in case there were things our observation did not cover. The participants overall experience with the prototype
was good according to them, but they pointed out some things that confused them during the test.

Based on our observations and what the participants said, it was clear that we had to make a few changes in order to make the prototype more understandable and less confusing, this was also necessary because it would increase the grade on how much they would be able to learn from it the interaction with the prototype. Changes can be seen in figure 3 below.

- Voice volume were too low, also very dull, distracted the participant a little bit.
- Instructional voice in the prototype started to fast and did not give the user room to see the interface before being given instructions about how to navigate.
- The transition from video to prototype forgot to mention that the prototype was about to start which caused disorientation when the prototype popped up.
- Some parts of the UI were forgotten during the test.
- The placement of keyframes in the last chapter confused the user.
- The colors of some movable objects were grey, and some movable objects were yellow. All the movable objects should be yellow so that participants would know what could be interacted with in the interface.
- Hover effects on all the movable objects.
- Corresponding hover on the same object in the timeline.

**Figure 3.** Image of prototype after the changes.

After fixing the problems, based on the first tests, we had another participant testing it in order for us to see if the improvements we made worked and if the participant used the prototype’s interface and elements according to how we wanted them to interact with it. In this test the participant did well, from our point of view the participant understood the
elements of the prototype and was not confused with any part of it, the participant interacted with it in a way we saw fitting. When asking the participant how the interaction felt he had no negative comments about it and confirmed that our changes had been to the better. From this we came to the conclusion that the prototype was done and we were ready to deliver it out in order to gather our empirical data.

3.3.2 Designing the Test
The data were collected through a quantitative questionnaire that the participants got forwarded to after completing the video or the interactive prototype. The questionnaire can be found in Appendix A. As our prototype used Swedish to teach, all verbal data gathered from the tests and forums are freely translated to English.

3.3.2.1 Main Test
We followed Williams (2003) guidelines when formulating the questions for the questionnaire. He provide a ten step guide on things to avoid in the questions, we followed the guidelines the best we could. Williams (2003) further suggest using a tool called “Gunning Fog Index” which helps analysing the complexity of questions. We used this tool to check the complexity of our questions. Some of our questions turned out to be too complex and we did our best to change the wording in order to make the questions easier to understand.

We chose to design our questionnaire like a regular school test so that the final data would become a score that represent how much the user has learned. We did this because we are used to having our tests graded with a score, and it is what schools uses to determine how much a student have learned about a subject. The questions had answers that ranged from one to six, all questions could have several correct answers and several incorrect answers. By having several correct and incorrect answers we made it harder for participants in guessing the correct answers. A correct answer would give plus score, while a negative answer would give a negative score, but the score for each question could not go below zero.

3.3.2.2 Test subjects
The tests were conducted online and were accessible at any time. We made our tests available on various forums on the web. The test was posted on Sweclockers.com, a forum for computers in general, on brutalcs.nu, a forum for online gamers, and we also posted the test on Deviantart.com, an online community for art in general. Lastly the test was posted on one of our personal Facebook page. Over the span of five days we had collected enough data (53 answers) to be able to perform an analysis. The reason we consider it to be enough is because with close to 60 participants we had achieved a normal distribution in both test groups.

To do an accurate study, one prerequisite is that the test group is chosen at random so that it is a good representative of the whole population (Aggarwal & Khurana, 2009). To sample a test group at random is called “probability sampling” and is in reality very time consuming and hard to perform. Other ways of sampling the test group are referred to as “non-probability sampling” and this will provide less accurate results (Walliman, 2011). In this study we have performed a non-probability sampling as we choose which forums we posted our tests on. It would have been favourable to perform a probability sampling but that would
mean we would have to find a random system of distributing our test which is not feasible considering our budget and time constraints.

To split the test groups between the video and the prototype we choose to conduct a form of blind test. The reason we choose to conduct a blind test is to make the test group more random. Users that were told about the experiment were only told that it was an introduction to digital animation, and that they will be asked some questions after they had completed the introduction. We programmed the server to send the users to either the video site or the prototype site depending on how many users previously took either of these. The server tried to make the first visitor go to the prototype and second visitor to the video, and third to the prototype again and so on. However, this was not always possible because the prototype is dependent on html5 technologies, not every visitor had a browser compatible with html5 and could therefore not see the interactive prototype, those visitors was therefore redirected to the video instead. When this happened the server later tried to compensate for that by sending more users to the interactive prototype.

3.3.2.3 Evaluating the test

As we had develop question with various degree of difficulty we wanted to make sure that the questions were interpreted as we intended and that there were no big misunderstanding regarding the language. We overlooked the question with our mentor and one of our classmates to check for spelling mistakes, and how well the questions were understood, before we released the test and questionnaire.

3.4 Data analysis

To analyse and get some insights from the dataset that we retrieved from our online questionnaire we needed to run the dataset through some statistical tests. For analysing data there are two different categories of tests to consider, these are parametric and non-parametric. Tests in the parametric category requires the dataset to fulfill more conditions and makes more assumptions about the data-set than non-parametric tests do (Aggarwal & Khurana, 2009), subsequently the most common statistical tests are parametric tests.

Being influenced by Stephenson et al (2007), who had similar data as we had, we decided to use student’s t-test and f-test two sample for means, these are two parametric tests that look for differences between the mean values and variance of two test groups. These tests look for statistical differences in the mean or variance respectively. We choose these tests because they fit well to test if the interactive learning environment did produce better learning outcomes than the passive learning environment. We also included some questions about the test persons, such as age and how much they had perceived that they had learned from the learning environment. With the use of the answers from these questions we calculated the correlation coefficient, which will tell us how much these variable affected the score. By looking at the correlation coefficient we were able to look at the data with a new perspective and find trends we would otherwise not have spotted.
3.5 Research ethics

Ethics refers to conducting research according to few rules that assures that the research participants are not exposed to any harm. Occasionally, some research experiment comes close to the boundaries of what is ethically acceptable and must evaluate their research approaches. An example of an experiment from the past that violated research ethics are Milgram’s study of obedience (McLeod, 2007), in this study the participants were instructed to give electrical shocks to a person and were gradually instructed to increase the power of this shock. The participants were towards the end of the experiment instructed to give an electric shock powerful enough to kill a human being. In reality though, there were no shock. Since the test person were not informed that the shock was fake, and that they were instructed to inflict pain onto another human being, makes this experiment ethically questionable.

We did consider research ethics in our study and we consider our research free from ethical grey zones. The reason we claim this is because the participants in our study did the experiment from their own free will and could at any time stop the experiment if they did not enjoy it. We did perform a blind test and the user was randomly assigned either a video or the interactive prototype and was unaware of the video if they were assigned the interactive prototype and vice versa. However, there is no offending learning material in either the video or prototype.

3.6 Self reflections

Having performed this study, and reflecting back on it, we have come to realize that quantitative studies are often done with much more focus on a smaller subject. One of the reasons for this is that it is much easier to control that the tested variables really are being tested. With the use of a bigger subject, more factors need to be taken into account, and chances are that the variables are not really being tested very well.

Because we had our tests being conducted online we had the luxury of getting more participants than we could have got if we performed the tests in a controlled environment. The negative aspect of this is that we cannot control how the users are interacting and in what environments that they are using their computers in. An approach to get better control of this would have been to invite participants to a controlled environment, by doing this we could get more accurate data as well as be able to interact with the participants afterwards in order to get a deeper understanding.
4. Results and analysis

We collected data from two sample groups and as such we got two datasets. As an introduction to this chapter we would like to present an overview of the data we collected from our tests in table 2. The test questions that generated these results are attached in appendix A, and the full data from participants can be found in appendix B.

<table>
<thead>
<tr>
<th></th>
<th>Active (Interactive Prototype)</th>
<th>Passive (Video)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants</td>
<td>26</td>
<td>27</td>
</tr>
<tr>
<td>Male Participants</td>
<td>22</td>
<td>25</td>
</tr>
<tr>
<td>Female Participants</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Mean Score</td>
<td>2.982 of 6</td>
<td>2.691 of 6</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>1.168</td>
<td>1.423</td>
</tr>
<tr>
<td>Variance</td>
<td>1.356</td>
<td>2.026</td>
</tr>
<tr>
<td>Median (Score)</td>
<td>2.91</td>
<td>2.83</td>
</tr>
</tbody>
</table>

| Mean Age (1-4)\(^1\) | 2.15                          | 2               |
| Mean Gender (1-2)\(^2\) | 1.153                         | 1.074           |
| Mean Perceived Learning(1-6) | 3.730                         | 3.925           |

Table 2. Overview of collected data

Although, we did collect data from 67 participants, only 53 of them are included in the above overview. This is because 15 of the participants either did have previous knowledge about digital animation (found through one of the questions) or incompletely filled in the questionnaire, and thus we did not include them. We reason that if we were to include participants with previous knowledge, the data about how much participants learned would become incorrect. With almost 30 participants in each group we have enough data to get close to a normal distribution in both groups.

Our main variable of interest is the mean score of the two test groups. We designed our test so that the mean score variable became an interval data type. Interval data type means that the gap between a score of 2 and 3 is as big as a gap between 3 and 4. When the data

\(^1\) 1 = Younger than 15 years old; 2 = 16–25 years old; 3 = 26-35 years old; 4 = Older than 35 years old
\(^2\) 1 = Male; 2 = Female
form is in interval type it allows to be analysed through parametric tests which generally gives more accurate test score because less assumptions are made (Aggarwal & Khurana, 2009). We were interested to see if there are any statistical differences between the scores of the two test groups. There are various tests that look for specific differences between two groups, one of them is student’s t-test, which is also referred to as “t-test two sample for means test”. The final calculated value from this test will be a number between 0 and 1, this value is the percentage of likelihood that the two groups are from the same population. A value of 1 will mean that it is exactly the same population and that there are no differences between them (ibid). A low value (closer to zero) will mean that the groups are very unlikely to be from the same population, but since we constructed the test so that both group are the same population we could then conclude that the difference would have to be due to the prototype. We ran a t-test on the mean score, all the questions separately, and all questions together. Table 3 shows the results from these tests.

<table>
<thead>
<tr>
<th></th>
<th>T-Test Two sample for means</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Score</td>
<td>0.418</td>
</tr>
<tr>
<td>Question 1</td>
<td>0.490</td>
</tr>
<tr>
<td>Question 2</td>
<td>0.055</td>
</tr>
<tr>
<td>Question 3</td>
<td>0.831</td>
</tr>
<tr>
<td>Question 4</td>
<td>0.977</td>
</tr>
<tr>
<td>Question 5</td>
<td>0.344</td>
</tr>
<tr>
<td>Question 6</td>
<td>0.767</td>
</tr>
<tr>
<td>All Questions</td>
<td>0.277</td>
</tr>
</tbody>
</table>

**Table 3.** Results of t-tests

A line or critical value that the t-test result has to be lower than to conclude that it is highly unlikely that the groups are from the same population has to be defined so that the score can be interpret better. Across many research fields 0.05 is used as that line or critical value which the score should be lower than to determine that the result is statistically significant (Walliman, 2011). To explain this more clearly, a t-test result of lower than 0.05 means that there is an enough big difference between the groups to conclude that the groups really are different. In our case, the t-test value for mean score is 0.418 which means that there is a 41.8% chance that the prototype test group is the same as the video test group. Although the results hint that the prototype users did better, the value is quite far from 0.05 and we cannot say that it was the prototype that caused this difference. The only test that came close to 0.05 is the test on question 2. This means that it is very likely that the prototype taught the knowledge that was needed to answer question 2 better than the video only.
Although there were no significant statistical differences from the t-test, there exists more ways to test for differences between the groups. Another way to test differences is to look for differences between the variance in the group. A difference in variance between the groups would mean that there were more extreme values in one of the groups. So even if the mean values are similar, the variance can be different. To test for variance differences we ran an f-test two sample for variance test, which is similar to the t-test, will give a value between 0 and 1.

<table>
<thead>
<tr>
<th>Mean Score</th>
<th>F-Test Two sample for variance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.163</td>
</tr>
</tbody>
</table>

Table 4. Result of f-test

Again, the value should be below 0.05, in our case the f-test value was 0.163, and is thus not statistically significant. However, 0.163 is much closer to 0.05 than the t-test score value of 0.418, suggesting that it is more likely that the prototype made the scores of the participant more similar and with less extreme values.

From the questionnaire we also collected variables such as gender, age, and how much the participants perceived that they had learned. These variables may have had an impact on the total score and we are interested in testing how much these variables may have affected the total score. How much the variables relate to each other can be expressed through what is called the correlation coefficient (Aggarwal & Khurana, 2009). The correlation coefficient is a value between 1 and -1 that describe to which degree a variable is related to another variable, a value of 1 describes a positive relation, and an increase in one variable means increase in the other variable as well. A value of -1 has the same strength of relation as 1, but the relation is in the other direction, meaning that an increase in one variable makes the other variable decrease. Values closer to 0 means that the correlation is weaker and that the variables do not affect each other much. The correlation coefficients are presented in Table 5.
<table>
<thead>
<tr>
<th>Correlations</th>
<th>Active (Interactive Prototype)</th>
<th>Passive (Video)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score - Age</td>
<td>-0.221</td>
<td>0.182</td>
</tr>
<tr>
<td>Score - Perceived Learning</td>
<td>0.119</td>
<td>0.231</td>
</tr>
<tr>
<td>Score - Gender</td>
<td>-0.179</td>
<td>0.077</td>
</tr>
</tbody>
</table>

**Table 5.** Correlation coefficients

The correlation between variables did not show any strong connections, it did however outline some interesting trends. The trend that we found most interesting is that the age seems to have an impact on which learning approach taught the most. Participant of younger age learned more from the interactive prototype while older participants learned more from the video. Another interesting trend is how much the participants perceived that they have learned, and what they actually learned did not correlate very well, suggesting that our perception of what we learned does not correctly reflect what we really learn. Correlations in form of scatter plot diagrams with a line showing the correlation are shown below through figures 4-9.

**Figure 4.** Passive score and age correlation

**Figure 5.** Active score and age correlation
Figure 6. Passive score and perceived learning correlation

Figure 7. Active score and perceived learning correlation

Figure 8. Passive score and gender correlation

Figure 9. Active score and age correlation
5. Discussion

Studies from Stephenson (2007), Al-Mousawi and Alsumait (2012), and Zhang (2004) have proved that constructivist approaches similar to ours have outperformed traditional methods of learning. Why did our study turn out different from these studies? One factor that differentiates our study from these researchers’ studies is the time span of the learning. In our study, depending if the users learned from the prototype or the video, the total time of learning varied between only two to four minutes, this short learning period might not be enough to reveal any significant differences between passive learning and interactive learning environments. The structure and design of our interactive prototype could also have been a factor to why there were few differences between the test groups. As an evaluation of the design of the interactive prototype we looked at comments that forum users posted after taking the test. From these comments we could conclude that the most positive feedback came from participants that completed the interactive prototype, participants of the interactive prototype said the following:

“It was very easy to understand what everything did and meant. Especially for me that have problem with concentration and learning difficulties. Keep up the good work!”

“Hehe, this was funny! I am a person that needs to go through things many times before I really get it, but I think I learned a lot from this, I like the practical test (or whatever it's called).”

“Impressive! You did an extremely good work on the guide if you look through a beginner’s perspective, it covered all the basics for making animations.”

These comments suggest that the participants enjoyed using the interactive prototype and that they were learning from it.

According to activity theory (Jonassen & Rohrer-Murphy, 1999), an activity creates conscious actions. Therefore, the learners in our prototype were engaged in an activity that made them conscious about what they were learning. If they would be able to further repeat those actions they would also be able to transform the action into an operation, i.e., being able to build an animation without any conscious action. Since each chapter adds new activities, but also includes the activity from the previous chapter, they could construct new knowledge and understandings of the subject based on their previous experiences in the prototype (Savery & Duffy, 1995). Our interactive prototype gave the learners the ability to construct their own understanding of the subject and also adapt the learning in a way that suited them. If we look at the video, which represents the passive learning environment, the learners only transferred knowledge from an expert (Schell & Janicki, 2013) and could therefore not construct their own understanding of the subject.

When looking at the kindergarten approach in learning (Resnick, 2007) and comparing it to our work, we argue that our prototype could be seen as an extension to the kindergarten approach that promotes creative thinking through the ability to play, build, and learn. It
follows the constructivist view on how we construct knowledge through interactions with the environment (Savery & Duffy, 1995). Although we cannot confirm that the learners did develop any creative thinking around the subject of digital animation. We realized that the questions we developed did not really give us enough information on how well the learner in our prototype could solve problems in a creative way.

We believe that in order to enhance our prototype and engage the users further, we could have implemented activities that guided the users and engaged them in exploring the environment further. We argue that it could have been good if we gave them extra tasks such as “try moving the object in a triangular pattern” and so on. As it is now, we give users freedom to play, but no reason to play. It would have been interesting to have one more test group that were given some extra activities, and then compare their results with our two test groups to see if it affected their learning further.

One of our findings was that the mean score in perceived learning was higher for participants that used the video in comparison to the mean score of the participants that used the interactive prototype, i.e., the participants that saw the video felt as if they had learned more, while their scores in reality were lower than the scores of participants that used the interactive prototype. We reason that this is due to the fact that when we passively learn about a subject, we feel as if we understand it better, but being exposed to practical tasks related to the subject makes us unsure of how much we really understand. We reason that this is because the practical task is a conscious action, it makes us aware of what we are doing (Jonassen & Rohrer-Murphy, 1999), while, for example, reading about the subject does not include any activities and thus not activate much of a conscious actions.

An interesting trend we discovered from the data was that younger participants of the prototype seemed to perform slightly better than the older participants, unfortunately we do not have enough data to study this trend. We do believe this trend can have something to do with how much younger people, from an early age, get exposed to computers and games, i.e., they are more familiar with interactive environments compared to older people. This means that younger learners could possibly benefit more from interactive learning environments, although this requires further studies to confirm.

Referring back to the cost restraints that limit schools to the objectivist learning approach, we argue that this might come to change in the near future. Improved technology at a reduced price may make constructivist models of teaching more cost effective (Schell & Janicki, 2013) which would allow schools to adopt the constructivist approach in learning to more areas of education. If we expand our view upon interactive learning and look at a bigger picture, it is possible that in the future we could replace most of ordinary schoolbooks with tablets.

Tablets offer the possibility to embed interactive learning material as a complement to text or video, similar to how the interactive prototype in our study worked. This could be particularly useful in the more practical subjects, for example, while the teacher explains a scenario or a problem, the students could also try replicating it in the interactive learning environment. Imagine a typical chemistry lab in elementary school, instead of letting the students start with the lab, they could have an interactive chemistry lab on their tablet where they can try mixing chemicals and look at reactions. This would allow the students to play
with the problem and learn from their successes and mistakes before trying it out in a real-life scenario.
6. Conclusion

The purpose of this study was to, a) Compare interactive and passive learning approaches by developing an interactive learning prototype and an educational video that teach the same subject, b) Testing the prototype and video with different test groups to identify differences in their learning outcomes, and c) Discussing where interactive learning could be an effective complement to passive learning. We described how we developed an interactive prototype and video to teach the subject of digital animation and how we tested the difference in the test subjects learning. In the section above we have also further discussed when interactive learning could complement passive learning. By doing this we have also tried to answer our first problem formulation: How do interactive learning environments affect learning compared to passive learning environments?

Our study have further pointed out that, with the setup of two different learning environments in the way we did in this study, there are no significant differences in learning outcomes between a passive and interactive learning environment. To come to this conclusion we developed two representative environments, one for interactive learning and one for passive learning. We then conducted a quantitative test in order to compare the different learning outcomes of the two environments.

We asked the question “what differences can be found in learning outcomes from different learning environments?”. Through a statistical analysis of the data we found some interesting differences. It is important to point out that these differences are not statistically significant, but merely trends in the data. The differences are listed in table 6 below.

<table>
<thead>
<tr>
<th></th>
<th>Interactive Prototype</th>
<th>Video</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score</td>
<td>* Participants had higher overall score with less variance</td>
<td>* Participants had lower overall score with more variance</td>
</tr>
<tr>
<td>Perceived learning</td>
<td>* Participants stated overall lower perceived learning</td>
<td>* Participants stated overall higher perceived learning</td>
</tr>
<tr>
<td></td>
<td>* Stated perceived learning correlated less with the score</td>
<td>* Stated perceived learning correlated more with the score</td>
</tr>
<tr>
<td>Age</td>
<td>* Younger participants performed slightly better</td>
<td>* Older participants performed slightly better</td>
</tr>
</tbody>
</table>

Table 6. Differences in the data

With this thesis we contribute to the practitioners of interactive learning by providing knowledge on how to build interactive learning environments, and to the literature by discussing the effects of interactive learning. We propose future studies that look for further differences in the effects of interactive learning between learners of different ages, mainly how young learners compares towards older learners. We further propose building interactive learning environments to have tasks that promote meaningful activities to see if the learning outcomes increase.
References


Brown, S. (2008), From VLEs to learning webs: the implications of Web 2.0 for learning and teaching, Interactive Learning Environments, 18, 1, 1-10


Appendix A: Test Questions

*Which of these statements are correct? (more than one answer may be correct)*
* Keyframes only moves an object
* Keyframes can change the size of an object
* Keyframes may give an object smooth movement
* Keyframes can rotate an object
* Keyframes can move an object with the help of tweening
* Keyframes may determine an object’s acceleration

*This graph shows an example of an easing curve, what are the characteristics of it? (more than one answer may be correct)*

* Ease in
* Ease in and out
* Ease out
* It gives the object an increase in speed as time passes
* It makes the object lose speed towards the end
* Constant velocity

*When might it be a good idea to use inverse kinematics? (more than one answer may be correct)*
* When you want to animate a yoyo
* When you want to animate a human that runs
* When you want to animate a car that moves
* When you want to animate a bird that flaps with its wings
* When you want to animate a flag that blows in the wind

*Your task is to animate this boll that rolls down from a hill, the animation should look natural, what are you going to need? (more than one answer may be correct)*
* Ease out
* Inverse kinematics to roll the boll
* Two keyframes
* Keyframes with rotation
* Easing in and out
* Three keyframes

The image below shows five kinds of easing curves that are assigned a number. Which order of the curves does the boll in the animation use

* 5 -> 1 -> 2
* 2 -> 3 -> 5
* 2 -> 1 -> 5
* 1 -> 4 -> 1
* 2 -> 4 -> 5
* 5 -> 3 -> 1
The image below describes an animation with easing from key frame A to D, what of the below statements describe the image correctly? (more than one answer may be correct)

* The animation has the same attributes between all keyframes
* The animation has no movement when it is positioned exactly at key frame B
* The animation starts smoothly
* The animation describes a ball that rolls down an hill and then stops
* The animation between key frame B and C has the attribute Ease in and out
* When the animation reaches key frame D, it stops abruptly because the speed of the animation at this time is constant

I am:
* Man
* Women

I have previous knowledge of digital animation:
* Yes
* No

If you answered no on the previous question, how much do you feel that you have learned?
* Very little – 1 <-> 6 – Very Much

Appendix A

30
**Appendix B: Collected data**

Every row represents one user and the abbreviations are as following:

- **ID**: user's id
- **AP**: interactive learning environment (1) or passive learning environment (0)
- **Q1 - Q6**: question 1 - question 6, score between 0-1
- **TTL**: Total score of the users from question 1-6
- **GD**: Gender, Male(1), Female(2)
- **AG**: Age, 1 (less than 15), 2 (15-25), 3 (26-35), 4 (above 35)
- **PK**: Previous knowledge 1(yes) 2(no), all “yes” are removed in this data
- **PL**: Perceived learning, 1-6 where 1 was marked very little and 6 as very much

<table>
<thead>
<tr>
<th>ID</th>
<th>AP</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
<th>Q6</th>
<th>TTL</th>
<th>GD</th>
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<tbody>
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