The Impact of Interactive Touchscreens on Physics Education in Upper Secondary School
– A systematic literature review

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Abstract

Interactive touchscreens such as tablet PCs (TPC) and interactive whiteboards (IWB) are becoming more and more common in classrooms around the world. To date, very little research has been conducted on the impact of the new technology on physics education. This systematic literature review aims to investigate research on what impact tablet PCs and interactive whiteboards might have on the education in upper Secondary School. The review was performed in response to the following questions:

1. What is the influence of IWBs and TPCs on students’ active participation in physics education?
2. How can an IWB or TPC improve students’ learning about physics concepts?
3. How can educational research on touchscreen technology help inform effective teaching strategies in physics education?

To respond to the questions of the study, relevant research about interactive whiteboards and/or tablet PCs was consulted and analysed. Twelve articles were located, mainly through the ERIC and Scopus databases, but also through Google Scholar. The included articles reported empirical research about physics education with interactive whiteboards or tablet PCs. The results from the articles indicate that interactive touchscreens might help improve learners’ active participation in physics education. Interactive whiteboards can, for example, be used to display interactive simulations during group work, something students are found to appreciate and easily engage in. A tablet PC can be used in the same way, but also allows students to receive anonymous support and feedback from the teacher during class which seems to be beneficial for learning. Results show that it is possible to improve students’ understanding of physics concepts by using interactive whiteboards or tablet PCs. However, further research is required to compare results from students using touch technology and students taught in traditional manner to be able to draw any general conclusions about observed learning effects.

Keywords
Interactive whiteboard (IWB), Tablet PC (TPC), Physics education, Multimodal, High school, Engagement
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# Introduction

In this report, a systematic literature review regarding the role and impact of interactive touchscreens in physics education is described. The conducted study is a part of the Upper Secondary School teacher programme at Linköping University.

The world is becoming more and more digitalized and schools are no exception. In Sweden, students in Upper secondary school have their own school-provided computer or tablet. The Swedish National Agency of Education (Skolverket) has even started to look into possibilities for digitalizing national tests. The physics curriculum states that students should receive opportunities to use different computerized equipment as learning tools. In Sweden, it is planned that students in upper secondary school are to each have their own personal computer by 2018 (Skolverket, 2016). Although the most common way to reach that goal is by investing in regular laptops, some schools are investing in tablet PCs instead, mainly due to the lower price.

Tablet PCs (TPCs) allow the user to interact with a computer through touchscreen technology. Therefore, the TPC can be used in a more interactive manner than a regular laptop. For example, the screen can be used for interactive simulations or to perform calculations directly in the computer in a much easier way. Since a TPC often allows the user to interact with a stylus, writing on a TPC is similar to a writing with a regular pen than a PC is. The use of laptops and tablet PCs in education can help to create a student-centred learning environment. The traditional teacher who teaches through lecturing might lose ground to a teaching style more focused on helping the students to navigate through all available information that comes with the modern technology, to create a beneficial learning path. In this regard, there is no longer a knowledge-monopoly for the teacher, almost everything can be found online through the computer, and the teacher becomes more of a facilitator in helping students navigate through all the information. However, the emergence of tablet PCs are a very new technology in general, and in schools specifically. Research investigating the role of tablets is starting to rise, mainly in association with lower age
groups. However, in upper secondary level, very little research has been conducted in this area.

Another tool that many schools have invested in is the interactive whiteboard (IWB). An IWB can be used as a regular whiteboard where the teacher uses a pen and writes down the lecturing notes on the board. The IWB, however, allows the user to save all notes that may have been generated. It can also be used as a projector or it can be used as large interactive screen, which could be useful for running simulations for the class. Overall, an IWB represents a significant financial investment for many schools and there has been very little research conducted on its educational impact. IWBs offer a new possibility to create multimodal learning environments in the classroom. However, many teachers believe that they have not been given the opportunity to learn how to use the IWB, and therefore, often refrain from using it (Somyürek, Atasoy, & Özdemir, 2010).

This report is a systematic review where the databases ERIC, Scopus and Google Scholar were used to locate articles presenting empirical educational research in the area of interactive touchscreens such as interactive whiteboards (e.g. SmartBoards, Activeboards) and tablet PCs. This report focuses on upper secondary level physics education. The aim of the study is to investigate how IWB and TPC touchscreens might impact students’ active participation in physics education, and whether there is an impact on the learning of conceptual knowledge. Active participation, in this report, is defined as participation in the learning or teaching process in an active way. For example, by answering the teacher’s questions, interaction with an IWB, and relevant discussions with the aim of learning. Non-active participation is for example listening to the teacher lecturing or watching a movie without further discussions (Prince, 2004).

To date, empirical research on interactive touchscreens has focused on tablet PCs and IWBs. These devices are also the most common interactive touchscreens used in schools and, therefore, the focus of the current study is on tablet PCs and IWBs.
2  Aim of the study

The objective of the study is to investigate the impact of interactive whiteboards (IWBs) and interactive tablet computers (TPCs) on physics education in upper secondary school. The study aims to answer the following specific questions:

1. What is the influence of IWBs and TPCs on students’ active participation in physics education?
2. How can an IWB or TPC improve students’ learning about physics concepts?
3. How can educational research on touchscreen technology help inform effective teaching strategies in physics education?
3 Background

This section of the report describes definitions of concepts and theories, as well as the theoretical framework relevant to the study. The first subsection consists of a list of definitions of concepts and theories to support the reader through the report. The second subsection describes the theoretical framework on which this study is based upon.

3.1 Definitions

In this subsection, important definitions are presented. The definitions are grouped and presented in the order of hardware-, software-, learning environment- and theoretical framework-related.

**Interactive Whiteboard (IWB)** – A whiteboard where the board is a digital touchscreen connected to a computer (e.g. SMARTboard, Activeboard). The IWB allows users to use either their fingers or a pen to control the whiteboard and control the computer through the interaction with the board (Somyürek et al., 2010).

**Tablet PC (TPC)** - There are two types of Tablet PCs. One is similar to a regular computer but with a touchscreen, where the screen is often rotatable. The user can use a special pen or a finger on the screen to interact with the screen (Amelink, Scales, & Tront, 2012). The other type is a touchscreen that can often be connected to a keyboard (e.g. iPad, Samsung Galaxy Tab). Tablets without keyboard is low-weight and very portable and provides a completely different interface than a regular PC. Since it is controlled by touch it is often intuitive to use. On the other hand, the lack of a mouse and keyboard and lower performance than a regular PC makes some tasks more difficult to perform with a tablet PC (TechTerms, 2011).

**Stylus** – A pen used to interact with a touchscreen. Can be used to imitate *pen on paper or pen on whiteboard* (Amelink et al., 2012).
**Classroom response system (CRS)** – Transmitters that students use to send answers to a receiver, and a computer that runs software that processes the data in real-time. Often used to answer “true/false” or to select an answer from given options (Fies & Marshall, 2006).

**Algodoo** – A software program for a physics simulation, that is compatible with both IWB and computers. The software allows the user to create physics simulations based on Newtonian physics (Karsenti, 2016; Smith, Higgins, Wall, & Miller, 2005).

**Applications (Apps)** – Computer programs developed to help the user control the functions of a computer or a mobile device (Wang, Wu, Chien, Hwang, & Hsu, 2015).

**Simulations** – A computer based imitation of a system or process. Simulations can be used to visualize phenomena that cannot be perceived directly (Moreno & Mayer, 2007).

**Joint workspace** – A learning environment where students share and develop ideas. The IWB and TPC can play a role as physical artefact. However, a joint workspace is not a physical space, but a social realm where collaborative learning is encouraged (Mellingsæter & Bungum, 2015).

**Multimodal learning environment** - Learning environment that uses different modes to represent content. In an interactive multimodal learning environment, actions, such as pressing buttons or touching the screen, determine what happens next (i.e. simulations). A non-interactive multimodal environment could be the viewing of a movie, for example (Gregorcic & Bodin, 2017).

**One-to-One-technology** – Every student has access to his or her own digital tool for use in the classroom (e.g. computer, tablet) (Holen, Hung, & Gourneau, 2017).

**Activity Theory** – A descriptive theoretical framework where cognition is viewed as a process between the individual and his/her surroundings (Engeström, 2001).
**Distributed cognition** – A theoretical framework where cognition is viewed as the interplay between internal and external artefacts (Zhang & Norman, 1994).

**Embody** – A tangible or visible expression of an idea. For example, a physical model of the atom is a way to embody the concept of atoms (Oxford English Dictionary, 2017). In pedagogy, often used in the context of embodied cognition.

**Embodied cognition** - A theory advocating the notion that sensory interactions between humans and their environment shape cognitive processes (Woolfolk, 2016).

**Haptic** – Manual sensing and manipulation, through touch. The ability to sense and manipulate objects in natural and synthetic environments, e.g. IWB or TPC (El Saddik, 2007; El Saddik, Orozco, Eid, & Cha, 2011).

**TPACK/TPCK** – A theoretical framework based on the idea that teachers’ knowledge about content, pedagogy and technology together form a complex relationship (Mishra & Koehler, 2006).

### 3.2 Theoretical framework for the review

In the last decade, integration of technological tools in school teaching has rapidly increased (Smith et al., 2005). Many countries and schools around the globe have invested in Interactive Whiteboards. For example, the UK has invested a huge amount of money on IWBs and almost every classroom has an IWB today (Karsenti, 2016).

Another way schools and countries have introduced new technology in the classroom is through one-to-one systems. A one-to-one system is a school where every student has their own computer or tablet to use during education. Sweden is one example that has a national plan envisioning that every school is eventually one-to-one (Gregorcic, Etkina, & Planinšic, 2014; Skolverket, 2016).
According to the Swedish curriculum, students in upper secondary school should learn about physical models as a simplified view of the reality. Furthermore, the curriculum states that the students should gain an ability to plan, implement and interpret the results from experiments and observations (Skolverket, 2011). Students should also be given an opportunity to use computerized equipment for learning, which in turn, motivates the use of IWB and TPC for students and teachers in upper secondary school.

### 3.2.1 Description of IWB and TPC

An interactive whiteboard is a projection of a computer display on a screen and allowing for touch interaction. The user can control the computer by touch interaction, either with a finger or a pen. Furthermore, the user can highlight text, add annotations and save notes generated on the board allowing the user to print the notes and hand them out to the students. Since the board allows touch interaction, it can also be used for simulations and demonstrations where objects can be moved around on the screen by a finger or a pen (BBC, 2010). Figure 1 illustrates a student using an IWB to drag words into the right spaces to create correct sentences.
A tablet PC is a computer allowing the user to control it through a touch-sensitive screen. There are two kinds of TPCs on the market. One controlled with a keyboard and stylus/mouse (figure 2) and one without mouse or keyboard (figure 3). Since the screen is touch-sensitive, the user can write on the screen with a finger or stylus and move objects around on the screen. Furthermore, many TPCs have built in accelerometers and sound meters, for example. The TPC can therefore be used as a measuring tool for experiments (TechTerms, 2011). However, common TPCs that are found on the market today do not have the same performance as regular laptops of the same price, and therefore, TPCs are relatively uncommon in school.
In the forthcoming subsections, three theoretical frameworks are presented in relation to thinking about TPCs and IWBs in education.

### 3.2.2 Activity Theory

Activity Theory (AT) is a descriptive framework with its origin in Vygotsky’s (1978) theories of social psychology, developed by his students Leontiev and Engeström (Holen et al., 2017). According to AT, cognition is viewed as a process between the individual and his/her surroundings, for example other people or tools. According to AT one can divide the
surroundings into four key components: subject (e.g. the student), object (goal), tools (IWB, TPC) and rules (explicit or implicit) (Holen et al., 2017). While trying to reach a goal in an activity, the person uses, either physical (e.g. computers, tablets) or mental (memorization techniques) tools. Interaction with the surroundings is formed by both formal and informal rules, for example rules about how the work in the classroom is organized.

An activity can be divided into three levels where the highest level is called “activity”. Activity is when one combines efforts to reach the goal of the activity. One analogy that can be used is a football match, “activity” would be everything the team does to win the match. The second level is “action”. Action represents procedures carried out to achieve smaller goals. Using the same analogy, this can be seen as scoring a goal, or winning back the ball. The third level is operations. Operations are automated actions, like passing the ball. Actions become operations when the skills for that action become automatized. However, it is possible for operations to become actions through “de-automatization”. De-automatization can take place when learners need to question their operations (Gregorcic et al., 2014).

3.2.3 Distributed Cognition
Distributed cognition can be seen as a compromise between theories where only external (in the world) or internal (in the mind) information contributes to cognitive processes. Distributed cognition fuses insights from sociology, cognitive science and Vygotsky’s psychology. In distributed cognition, individuals, artefacts and the environment and the relationship between them is seen as paramount. The theory purports that to generate knowledge both internal and external information has to be processed. In the same way, Zhang and Norman (1994) argue that internal and external representations are indispensable. This differs from traditional cognition where representations are viewed in terms of internal processes alone. External objects can only be seen as help in the periphery (Woolfolk, 2016). However, both Roman and Arabic numerals represent the same entities, but Arabic numerals are more effective for multiplication. This is one example indicating that external representation itself influences cognitive behaviours (Zhang & Norman, 1994).

According to Zhang and Norman (1994), the representational system of a distributed cognitive task can be considered as a set. Some members are internal and some external.
The internal representations are for example propositions, productions or mental images. External representations can be physical symbols (e.g. written symbols), external rules or relations embedded in physical configurations (e.g. visual and spatial layouts of diagrams).

### 3.2.4 Embodied Cognition

The classic view of learning in cognitive theory has its focus on inner processes within learners’ minds (Woolfolk, 2016). Today’s research shows that sensorimotor experiences in the world are very important to learning in widely different topics, for example language comprehension and mathematics learning (Ionescu & Vasc, 2014). In this regard, embodied cognition suggests that cognition is not amodal. This means that representations are multimodal and grounded in sensorial modalities in the brain. Another way that embodiment theory differs from classical cognitive theory is that in embodiment theory, emotional and affective processes are seen as contributing to cognition.

In embodied cognition, it is often claimed that cognition has to be situated, which means that cognitive activity takes place in the context of real world environment. However, activities like planning and imaging future events are per definition not situated. Situated cognition has to involve interaction with the aspects that the activity is about (Wilson, 2002). For example, learning how to shoot a football requires training with a football. Furthermore, the internal structure and physical understanding of concepts are parallel to each other. Even abstract concepts, such as general ideas rather than particular events, are rooted in sensory and motoric knowledge (Wilson, 2002). This view is supported by empirical research on cognitive neuropsychology (Gallese & Lakoff, 2005). Gallese and Lakoff argues, with support from neuroscientific evidence, that thinking of the concept “grasping” activates the same nodes in the brain as when the procedure “grasping” is physically performed. Furthermore, studies have shown that abilities that are not traditionally combined with body engagement do benefit from bodily movement. For example, reading ability is improved by writing training, which is explained by the sensory experiences of writing. Similar effects can be seen in topics like mathematics and conceptual knowledge in physics (Ionescu & Vasc, 2014).
The described theoretical frameworks all state that learning and cognition are benefitted from interaction with the environment. Therefore, the described frameworks support the use of interactive touchscreens in education. And according to TPCK, the teacher’s technological knowledge is important when designing the teaching, for example when choosing the most effective illustration or choosing simulations (Mishra & Koehler, 2006).

3.2.5 The use of Interactive whiteboards in education

A number of international studies have shown that both teachers and students are positive to the interactive whiteboard (Balta & Duran, 2015; Gregorcic et al., 2014; Smith et al., 2005). For example, in a study conducted by Beeland (2002), students felt more concentrated on the lesson’s content when the IWB is used. The study was conducted at one school that had invested in IWBs and computers and included 197 students and 10 middle-school teachers. The students and teachers answered a survey, and 20 students and the teachers answered a questionnaire. Many students stated that visualisation on the board instead of being verbally explained, or read in a book, helped the gained knowledge to persist. However, Balta and Duran (2015) showed that, among Turkish students, the positive view of the IWB decreased as the students get older. Moreover, studies have also shown that teachers do not get the time and education they need to be able to use the IWB in an efficient way, which may explain why there are teachers who do not use the interactive whiteboard as part of teaching practice (Smith et al., 2005).

Some teachers have pointed out that the flexibility that comes with the IWB is positive for their teaching (Smith et al., 2005). In this regard, the IWB makes it easier to adjust the level of the lessons to fit different needs in the classroom. The possibility to save and share the lessons have also been reported as something that teachers find useful and might lead to less time spent on planning the lessons since one can draw from existing materials. A further benefit reported by teachers, is the possibility to create multimodal learning environments. The possibility to include images, animations and movies in teaching should, according to a number of studies, have a positive impact on students’ learning since the students get an inner representation of the topic (Smith et al., 2005). It is also possible to use a hands-on approach and allow students to see and “feel” physics phenomena through
the touchscreen, which could be beneficial for learning from an embodied cognition, distributed cognition and activity theory perspective (Smith et al., 2005).

One frequently raised concern is the lack of proper education and instructions on how to use the IWB. If the teachers do not get to learn which features an IWB provides and how to use them, it will be impossible for the teacher to use the IWB in a meaningful way (Karsenti, 2016). According to several studies, teachers that were early to adopt the new technology tended to be the teachers who already were confident with using ICT. The teachers who stated that they used ICT in their regular teaching were more likely to learn on their own by experimenting and trying, while the teachers who did not use ICT in their regular teaching needed clear guidance and support on how to use the IWBs features (Gray, Hagger-Vaughan, Pilkington, & Tomkins, 2005; Waight, Chiu, & Whitford, 2014).

Waight et al. (2014) showed, that among science teachers in 24 different high schools in north-eastern USA, it was the physics teachers that used technical tools like the IWB the most. They also showed that the teachers who worked with inquiry approaches were more likely to use technical tools. Among the 154 science teachers who answered a questionnaire that explored, for example, what amount of training the teachers had received, how comfortable they were using the IWB and other tools, the teachers were more comfortable with hardware (e.g. laboratory tools) than software (e.g. simulations). Furthermore, the study showed that one of the most important factors was if the teachers felt comfortable with the tools. This conclusion is supported by a number of studies (e.g. Gregorcic et al., 2014; Smith et al., 2005).

3.2.6 The use of Tablet PCs in education

The Swedish National Agency of Education aims for every student in the Swedish school system to have access to a personal computer or tablet by the end of 2018 (Skolverket, 2016). In Sweden, laptops (i.e. not TPC) are the most common tool in one-to-one schools but in other countries such as Turkey, TPCs are used in almost every classroom (Şimşek & Doğru, 2014).
Studies have revealed some positive impacts of one-to-one technology. One benefit of one-to-one is that every student gets the same access to technical tools, regardless of his/her socio-economic background. However, there are also negative issues that are associated with the technology. For example, social media can be disturbing in classes and distort students’ sleep patterns, which of has an impact on learning (Holen et al., 2017). Holen et al. (2017) also showed that according to answers from the students the new technology did have a positive impact on their engagement with content. However, the teachers’ and parents’ answers did not support that conclusion. Especially the parents believed that the computer made it harder to know how schoolwork was going since the children often turned to help from internet during homework.

The TPC can be used to communicate in real time with the lecturer or other students. Furthermore, the lecturer can observe the students’ work through the lecturers TPC. This means that the lecturer can provide students with real-time formative assessment. Formative assessment is believed to be essential for learning since it provides students with feedback about their learning and knowledge gains. Therefore, the possibility to administer the assessment in real time should make the assessment even more powerful as a tool for learning (Woolfolk, 2016). This is supported by various studies. For instance, a study conducted by Gök (2012), where the students developed their problem solving ability while using a TPC and a software (InkSurvey) to receive direct assessment in an advanced magnetics course at Colorado school of mines. However, when this was tried in a statistics and probability course, no positive effects were found. Rather, it was found that the students’ positive attitude towards the subject decreased during the term (Lauriski-Karriker, Nicoletti, & Moskal, 2012). Another study demonstrated positive effects of removing the fear of writing wrong answers on a chalkboard in front of the class by allowing students to solve the problems on the TPC, which can be directly connected to the teacher’s computer or a projector/IWB. Such use can help students to increase their self-esteem and stimulate discussions in the classroom (Sneller, 2007).

Another impact that one-to-one system might have is a change in the learning environment. For example, teachers have to change their teaching to become more student-centred. With rapid access to Internet, the teacher becomes more of a coach and mentor rather than the
traditional teacher (Grubelnik & Grubelnik, 2016). Also, the study showed that students desire answers immediately and therefore only seek answers without acquiring any deeper understanding. This suggests that the teacher needs to be a review specialist, guide and ICT specialist. Furthermore, laptops and TPCs enable mobile learning. In this regard, teaching does not have to be conducted in a traditional classroom. According to Shamir-Inbal and Blau (2016) the TPC gives much better options for mobile learning, compared to regular laptops. Furthermore, mobile learning can be positive for group discussions. Research has explored that engineering students who use TPCs are more likely to engage in elaborative learning than students who do not. The TPC is also beneficial for organization and peer learning (Amelink et al., 2012).

Both the TPC and IWB allows students to use the touchscreen, individually or in a group, and in that way, use a hands-on approach, which should be positive for the learning process (Cook, Mitchell, & Goldin-Meadow, 2008; Holen et al., 2017; Ionescu & Vasc, 2014).

Overall, it seems that the IWB and TPC share various similar potential benefits, for example, the afforded multimodality and possibilities to interact with simulations through interaction with the touch screen. However, there are, some differences. A teacher can use the IWB in a teacher centred classroom, while the TPC contributes to a student-centred classroom. Additionally, there are some potential drawbacks with the new technology and both the advantages and disadvantages require analysis in the literature.

The use of IWBs and TPCs might be well suited for physics education in upper secondary school. For example, interactive simulations and models are a common way to teach students about abstract physics concepts. Furthermore, physics is a subject associated with many misconceptions among the students, which an IWB and/or TPC can potentially help remediate. However, not much research has been done regarding IWBs and TPCs in physics teaching in general or physics in upper secondary school in particular. Therefore, this study aims to summarize the research done to date.
4 Method

This study was conducted as a systematic literature review. A systematic literature review summarizes the research that already has been conducted and relevant to the questions posed by the study. A systematic literature review should contain a clear search strategy, and distinctly described criteria and methods for searches and selection of articles (Eriksson Barajas, Forsberg, & Wengström, 2013). A systematic literature review should also have clearly defined research questions that the study should aim to answer through analysis of already existing empirical, research. (Eriksson Barajas et al., 2013).

A systematic literature review should contain all conducted research that is relevant to the particular study. However, this might be difficult if there are a lot of investigations done in the area. In that case, the author should adopt criteria to help guide which articles should be included in the analysis. Articles omitted from analysis should also be presented in the report together with a motivation for why they were not considered in response to the posed research questions (Eriksson Barajas et al., 2013, p. 32).

According to Eriksson Barajas et al. (2013), a systematic literature review is conducted by following eight steps:

- Argue for why the study should be conducted
- Formulate answerable questions
- Formulate a plan for the study
- Decide upon search words and search strategies
- Identify and choose literature in the form of peer-reviewed scientific reports
- Critically evaluate, judge quality, and select literature to include
- Analyse and discuss the results contained in the selected articles
- Summarize the findings and deduce conclusions.

Literature search methods for selection of articles and analysis are presented in sections 4.1-4.4 below.
4.1 Methods for searching the literature

*Scopus* and *ERIC* were the primary databases used in this study. *ERIC* is a database containing research only about education. Scopus, on the other hand, provides research on various topics, including educational science and computer science. By consulting the two databases, the risk that relevant researches are missed is minimized. *Google Scholar* was also used to ensure that, as far as possible, every relevant article was found. Some limitations had to be implemented to make sure that the findings were relevant. First of all, only peer-reviewed articles were included. Also, included articles had to be published within the last 15 years (i.e. published from 2002 or later). Since today’s technology is rapidly evolving, the time limit has to be narrow enough to make sure the reported findings are still relevant. However, in the UK for example, a huge investment was made in 2003-2005 and most of the classroom has since then used the same IWB. Therefore, the time limit was deduced to include those years. However, research about tablet PCs and IWBs in physics education has mainly been conducted in the last 10 years.

The searches were conducted by combining search words and Boolean operators. Boolean operators can be used to either narrow down searches or expand upon the hits. The Boolean operators that could be used were *AND*, *OR* and *NOT*. The operator *AND* (X AND Y) was applied to return sources where X and Y are included. This operator is used to limit the searches. Another Boolean operator was *OR*. *OR* returns the sources including either X or Y and is therefore a widening operator. The third operator, *NOT* (X NOT Y), returns the hits including X only. *NOT* is used to limit the searches, for example the search “education NOT pre-school” returns hits about education but not including pre-school (Eriksson Barajas et al., 2013). However, since the searches returned relatively few hits, the *NOT*-operator was not used. Another way to widen the searches is to use truncation. Truncation means that the beginning or end of the word is replaced by the sign “*” and returns all hits with the same beginning or end. For example: the search “Teach*” returns hits including teach, teacher, teaching etc.

In addition to the searches, snowball sampling was used to locate relevant research. *Snowball sampling* is when articles found in references of other articles are included for the analysis (Wohlin, 2014). These articles were subsequently located through *Google Scholar*. 
4.2 Assessing the relevance of the selected literature

This report focuses on studies on education in upper secondary school. However, studies involving secondary school and early university courses were also considered relevant for the study and were therefore included. In this regard, the ages and school forms are not equivalent around the world, and neither is the curriculum. The physics concepts that Swedish students learn in lower secondary school might be taught in upper secondary school in other countries, and vice-versa. Furthermore, in Swedish education, physics in lower secondary school and early university physics courses do not differ too much from the physics in upper secondary school. For example, linear motion is taught in similar ways at introductory university level and in upper secondary school, while Archimedes’ principle is taught at both lower and upper secondary school level. Therefore, studies conducted on those levels were also deemed as relevant. However, physics taught in Primary school and later university courses differ too much from upper secondary and would therefore not be relevant for this study. In sum, it was deemed relevant to include studies on students from 6th grade up to introductory university level, including upper secondary school. Furthermore, studies conducted on physics concepts relevant for these ages should be included, regardless of the age of the participants.

In order to be included for individual analysis, the research articles had to represent studies on interactive whiteboards or tablet PCs and physics education. The studies should contain empirical data, in quantitative and/or qualitative form. Opinion articles were not included in the analysis.

All abstracts from the returned articles were read and those that did not meet the criteria stated above were excluded from the study. If the article was deemed relevant based on the abstract, the entire article was read for further analysis. Following this, a decision was made as to whether the findings were relevant to the research questions and should be included in the study, or not.

4.3 Assessing validity and reliability of the selected articles

Reliability can be defined as a measurement of whether a study would generate a similar result if repeated on a different occasion. Striving for high reliability is desired for all
research since low reliability indicates that the study is more vulnerable to random errors (Eriksson Barajas et al., 2013). Reliability is often described with a number ranging from 0 and 1, called Cronbach’s alpha. Cronbach’s alpha describes to what extent questions that are supposed to measure the same item actually measure the same item. If Cronbach’s alpha is 1, the questions measure exactly the same values. Different research methods require different ways to determine their reliability. For example, a quantitative method needs a high number of participants to be generalizable. However, a study can have a high reliability with a small number of participants if the method is good, for example a study where individual students are interviewed might have a high reliability even though the participant number is low. By the same token, a qualitative study is not always generalizable by virtue of its design, since it is often of a descriptive and context-bound interpretation of a particular learning situation.

Validity is a measure of whether a study investigates what it is intended to investigate (Eriksson Barajas et al., 2013). In quantitative terms, this means that there should be no systematic error or bias from the researcher. Also, the measuring instrument should include relevant questions for the study, which should be answered with an appropriate method. To pursue validity of a study, the researcher can consult experts while designing a questionnaire and/or do a concept analysis.

A study can have a high reliability and low validity, but it can also have high validity and low reliability (Trochim, 2006). For instance, a study conducted on a group can, despite a wide variance of answers, return a correct answer on a group level. Therefore, the study may demonstrate a good validity in a group perspective, but the results could be inconsistent. A study with high reliability but low validity measures the same construct over and over again, but there could be situations that does not measure what it is supposed to measure. By analogy, the reliability is high if an instrument is designed to measure weight exactly constantly. However, if the aim of the study is to investigate the length of the participants, the validity is low.
4.4 Methods for analysing selected literature

This study is conducted as a systematic literature review. In a systematic review, analyses and synthesis of qualitative and quantitative studies is performed upon a previously decided selection of articles (Eriksson Barajas et al., 2013). Each article is analysed individually, and the findings from the different articles are then compared to each other. The comparison and discussion of the findings in the articles included for the synthesis is made in the light of the theoretical background and the aim of the study.
5 Results and Synthesis the Literature Search

This section describes the findings from the systematic literature search. The search strings used and the number of hits that each string returned is presented in subsection 5.1. Subsection 5.2 presents the articles revealed in the searches that were excluded from the analysis. The included articles are presented in subsection 5.3, table 11. The content of each article is presented in section 5.4.

5.1 Summary of the literature searches

In this subsection, the search-strings together with the number of relative hits are presented. Search 1 to 4 and 8 concerned IWBs and search 5 to 7 focused on TPCs. Table 1 presents a search in Scopus regarding IWBs.

Table 1. Result of search 1 conducted in Scopus.

<table>
<thead>
<tr>
<th>Keywords, operators, limiters</th>
<th>Number of hits</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Interactive Whiteboard” AND “physics”</td>
<td>17</td>
</tr>
<tr>
<td>AND “education”</td>
<td>14</td>
</tr>
<tr>
<td>AND “high school”</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 2 presents search number 2, conducted in Scopus regarding IWBs.

Table 2. Result of search 2 conducted in Scopus.

<table>
<thead>
<tr>
<th>Keywords, operators, limiters</th>
<th>Number of hits</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Interactive Whiteboard” AND “physics”</td>
<td>17</td>
</tr>
<tr>
<td>AND “students”</td>
<td>14</td>
</tr>
<tr>
<td>Exclude topics: Medicine, Multidisciplinary, Psychology</td>
<td>11</td>
</tr>
</tbody>
</table>

Table 3 presents search number 3, conducted in Scopus regarding IWBs.

Table 3. Result of search 3 conducted in Scopus.

<table>
<thead>
<tr>
<th>Keywords, operators, limiters</th>
<th>Number of hits</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Interactive Whiteboard” AND “physics”</td>
<td>17</td>
</tr>
<tr>
<td>AND educat*</td>
<td>14</td>
</tr>
<tr>
<td>Exclude topics: Computer science, Medicine</td>
<td>9</td>
</tr>
</tbody>
</table>

Table 4 presents search number 4, conducted in ERIC regarding IWBs.
Table 4. Result of search 4 conducted in ERIC

<table>
<thead>
<tr>
<th>Keywords, operators, limiters</th>
<th>Number of hits</th>
</tr>
</thead>
<tbody>
<tr>
<td>“interactive whiteboard” AND physics</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 5 presents search number 5, conducted in Scopus regarding Tablet PCs.

Table 5. Result of search 5 conducted in Scopus.

<table>
<thead>
<tr>
<th>Keywords, operators, limiters</th>
<th>Number of hits</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Tablet PC” AND physics</td>
<td>29</td>
</tr>
<tr>
<td>AND Educat*</td>
<td>24</td>
</tr>
<tr>
<td>AND “high school”</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 6 presents search number 6, conducted in Scopus regarding tablet PCs.

Table 6. Result of search 6 conducted in Scopus.

<table>
<thead>
<tr>
<th>Keywords, operators, limiters</th>
<th>Number of hits</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Tablet PC” AND physics</td>
<td>29</td>
</tr>
<tr>
<td>AND Educat*</td>
<td>24</td>
</tr>
<tr>
<td>AND “interactive”</td>
<td>12</td>
</tr>
<tr>
<td>Limit to doc.type: article</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 7 presents search number 7, conducted in ERIC regarding TPC.

Table 7. Result of search 7 conducted in ERIC.

<table>
<thead>
<tr>
<th>Keywords, operators, limiters</th>
<th>Number of hits</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Tablet pc” AND “physics”</td>
<td>10</td>
</tr>
<tr>
<td>AND learn*</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 8 presents search number 8, conducted in Scopus regarding IWBs.

Table 8. Result of search 8 conducted in Scopus.

<table>
<thead>
<tr>
<th>Keywords, operators, limiters</th>
<th>Number of hits</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Interactive whiteboard” AND physics AND teaching</td>
<td>3</td>
</tr>
</tbody>
</table>

The searches returned 21 unique hits. Most of the articles appeared as duplicates in at least one search. Therefore, the number of hits in table 1-8 is 48 but the presented articles found from searches 1-8 in table 10-11 only is 24, including the findings from snowball sampling.

Table 9 presents the articles found in the references from other articles and reason for inclusion.

Table 9. Articles found through snowball sampling.

<table>
<thead>
<tr>
<th>Title</th>
<th>Author(s) (year)</th>
<th>Reason for inclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhancing Student Performance Using Tablet Computers.</td>
<td>Enriquez, A.G. (2010)</td>
<td>The study compared the difference in achievement between traditional teaching and teaching with a TPC.</td>
</tr>
<tr>
<td>Interactive Whiteboard (IWB) and Classroom Response System (CRS): how can teachers integrate</td>
<td>Bonanno, A., Bozzo, G., Napoli, F., &amp; Sapia, P. (2014)</td>
<td>The study investigated the impact of IWBs on students’ conceptual knowledge.</td>
</tr>
</tbody>
</table>
these resources in physics experimental activities?

5.2 Excluded articles from the systematic review

In table 10, the excluded articles are presented together with the reason for exclusion.

Table 10. Articles excluded from the analysis and reason for exclusion

<table>
<thead>
<tr>
<th>Title</th>
<th>From search no.:</th>
<th>Authors and year</th>
<th>Reason for exclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kahoot, a new and cheap way to get classroom-response instead of using clickers</td>
<td>2</td>
<td>Cutri, R., Marim, L.R., Cordeiro, J.R., Gil, H.A.C., &amp; Guerald, C.C.T (2016)</td>
<td>The study is not about IWBs or TPCs.</td>
</tr>
<tr>
<td>Interactive whiteboard teaching and online learning cryogenics</td>
<td>2</td>
<td>Serban, A., Nastase, G., Draomir, G., &amp; Brezeanu, A.I. (2016)</td>
<td>Cryogenics are not taught in upper secondary school and the study is therefore not conducted on a relevant level.</td>
</tr>
<tr>
<td>The deployment of interactive presentation media in medical physics and biophysics: A novel approach</td>
<td>2</td>
<td>Hofer, E., &amp; Haas, J. (2014)</td>
<td>The study is conducted in a biophysics course on university level and therefore not</td>
</tr>
</tbody>
</table>
to improve quality and dynamics of plenary lectures.

Interactive white boards in preschool and primary education

<table>
<thead>
<tr>
<th>Article</th>
<th>Year</th>
<th>Authors</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drigas, A.S., &amp; Papanastasiou, G. (2014)</td>
<td>2</td>
<td>The study is conducted in preschool and primary school and therefore not on a relevant level.</td>
<td></td>
</tr>
<tr>
<td>Stav, J.B., &amp; Thorseth, T.M. (2008)</td>
<td>2</td>
<td>The article does not present empirical data.</td>
<td></td>
</tr>
<tr>
<td>Reid, A. (2008)</td>
<td>4</td>
<td>The study is not about IWBs or TPCs.</td>
<td></td>
</tr>
<tr>
<td>Gök, T. (2012)</td>
<td>6</td>
<td>The study is conducted in</td>
<td></td>
</tr>
</tbody>
</table>

The physics of the Data Projector

Real-time assessment of problem solving of physics
students using computer-based technology

Teaching and learning with pen-based technology in engineering physics course

Ubiquitous presenter: A tablet PC-based system to support instructors and students

5.3 Included articles in the systematic review

This section identifies the articles included for analysis and synthesis. The included articles present empirical research regarding the impact of tablet PCs or interactive whiteboards on physics education at the previously defined level. The included articles are numbered from 1-12 and listed in Table 11 below. Each article is individually summarised in section 5.4.

Table 11 Presentation of articles included for the analysis. Twelve articles, together with author, source and publishing year, are presented.

<table>
<thead>
<tr>
<th>Article Title (Journal title)</th>
<th>Year: Author(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Enhancing Student Performance Using Tablet Computers (College Teaching)</td>
<td>2010: Enrique, A.</td>
</tr>
<tr>
<td></td>
<td>Title</td>
</tr>
<tr>
<td>---</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>7</td>
<td>Interactive White Board in Physics Teaching; beneficial for physics</td>
</tr>
</tbody>
</table>
8 Interactive Whiteboard (IWB) and Classroom Response System (CRS): how can teachers integrate these resources in physics experimental activities? 
*(GIREP/MPTL International Conference: Teaching/Leaning Physics: integrating research in to practice)*

9 The Contribution of the Interactive Whiteboard in Teaching and Learning Physics *(Romanian Reports in Physics)*

10 Students’ Use of the Interactive Whiteboard During Physics Group Work *(European Journal of Engineering Education)*

11 Engineering Students’ Experiences from Physics Group Work in Learning Labs *(Research in Science & Technological Education)*

12 Effects of Embodied Learning and Digital Platform on the Retention of Physics Content: Centripetal Force *(Frontiers in Psychology)*
5.4 Summary of articles included in the systematic review

This section summarizes the included articles in the same order as presented in table 11.

5.4.1 Enhancing Student Performance Using Tablet Computers

(Enriquez, 2010)

This study took place in a circuits course at Cañada College in the San Francisco Bay Area. Traditional teaching, where the lecturer introduced relevant concepts and demonstrated to students how to solve example problems, was found not to be successful. Therefore, the college designed an Interactive Learning Network (ILN), where TPCs were used to take notes during lectures and lessons and to communicate with other students and the lecturer. The TPCs were intended to give the students a possibility to interact with the lecturer during the lesson and the lecturer could follow the development of individual students’ concept understanding.

To evaluate the implementation of the ILN, two case studies were conducted. In the first study conducted in 2006, 41 participants were a part of an experimental group and 28 in the control group. In the study conducted in 2007, 16 students were included in the experimental group and 46 in the comparison group. The first study, conducted in 2006, used the 2005 students as a control group. The teaching was similar in both terms, and the same homework, quizzes and exams were administered. However, in the experimental group, the quizzes were conducted through the TPC and reviewed in real time instead of pen and paper. Furthermore, the experimental group could receive feedback and help from the lecturer was offered anonymously through the TPC.

In 2007, the second case study was undertaken. In this study, two sections of Circuits courses were studied. One at Cañada College and one at San Francisco State University (SFSU) and both courses were taught by the same lecturer. The SFSU-group was chosen as the comparison group. The difference between the groups was that at Cañada College, the students used the TPC to take notes, solve problems, and interact with the lecturer. The SFSU course was one week shorter than Cañada College, but over the 15 weeks that both courses covered, the content was the same. Therefore, the last week of the Cañada College course was not included in the tests. A diagnostic test before the start of the
intervention showed no significant difference between the two student groups, even though SFSU is a university and Cañada College a community college.

In both studies, only the experimental group used TPCs, the students used software for instant surveys and an electronic whiteboard feature allowing all students to participate. Through the software, the lecturer could observe the students from his/her TPC and individual guidance could be provided. In Study 2, the lecturer used a TPC instead of a blackboard in both classes. With the TPC, the lecturer could add and save handwritten annotations and problem solutions and upload them.

The impact of the ILN was measured by comparing the performance during the courses. In each course, data was collected from 15 homework sets, 4 quizzes, 4 tests and a final examination, which all featured as regular parts of the course. In Study 1 the tests and homework were slightly different between the groups, but in Study 2, they were identical. Study 2 repeated the diagnostic test as a post-test administered one week before the final exam.

The results showed that the groups who used ILN and TPC performed significantly better, than the control groups. The students mention the possibility to receive immediate assessment, for example while “stuck” in trying to solve task, as one of the most important benefits of the TPC. The students who used the TPCs were more successful in completing homework assignments and were better prepared for quizzes, which might also be due to the guidance from the lecturer. Another advantage of the TPC was the possibility to receive help anonymously. Also, the lecturer had the possibility to monitor students’ work and progress, which led to increased focus on the lessons.

The students from the 2006 experimental group filled in a survey about their attitude towards the TPC and the ILN. The results showed overwhelmingly positive results. The “Help request” feature received most positive answers and control features were viewed as least positive. For instance, the locking of student computers and application control, i.e. that students could not install apps, were not appreciated. According to the surveys, the TPCs helped to improve the performances of the students and increased the instructors’ teaching efficiency. In the open-ended questions, the students mentioned increased attentiveness
and focus during lectures, real-time assessment, immediate feedback, increased one-on-one time, and ease of communication, with the instructor, and, when needed, quick assistance as the instructor could assist the student through the TPC.

This study suggests that the software used together with the TPC, which allowed the instructor to provide immediate feedback, is one of the most important components for increasing students’ performance. According to the study, one of the positive effects of the ILN and TPC is that the students in the experimental group gained confidence and were more successful in completing homework assignments, and came better prepared for quizzes. Furthermore, the improved performance in the experimental group could also be influenced by the increased focus and attentiveness observed during class. The increased focus and attention were a result of the instructor’s use of survey questions and the knowledge that he/she observed student progress through the monitoring feature where the lecturer could monitor the students’ TPC on the lecturers’ TPC. The monitoring feature was also useful since it allowed the lecturer to identify common misconceptions early in the learning process. The students also found the “Help Request” feature useful since it allowed them to receive feedback anonymously.

5.4.2 Investigation of Learning Behaviors and Achievement of Vocational High School Students Using an Ubiquitous Physics Tablet PC App
(Purba & Hwang, 2017)

The authors of this article developed an app for mobile devices (TPC and smart phones) with the purpose to help students learn about the principles behind a simple pendulum. The app is called “Ubiquitous-Physics” (U-Physics). The TPC and smartphone were used as a pendulum and the app used the sensors on the devices to collect data about acceleration and velocity during the pendulum swing and automatically generate graphical representations of the data.

The aim of the study was to investigate the relationship between learning behaviours and learning achievements among students who use U-Physics to learn the concepts behind a simple pendulum. In particular, the researchers raised the following questions:
1. What are the relationships between interpreting graphs, applying formulas, pair coherence, learning gains, and post-test scores?
2. What is the relationship between learning behavior and learning achievement?

The study consisted of three experiments. The first experiment studied the effect of the mass of the pendulum on the period. This was conducted with three different masses, namely, the TPC’s mass, a TPC and a mobile phone and a TPC’s mass and two mobile phones. In the second experiment, the students studied the effect of different rope lengths on the pendulum system. The last experiment determined the effect of the start angle of the pendulum, from 15° to 45°. The study lasted for 3 weeks and included 36 first year students from a vocational high school. The students were randomly divided into 18 groups. Each group had a smartphone and were familiar with its use.

The study commenced with a pre-test consisting of 10 multiple-choice questions and two open ended questions. After finishing the experiments, the students completed a post-test. The tests consisted of questions about, for example, period definition and effects of mass on the period of a simple pendulum. Eight students were randomly selected for interviews to be able to provide a deeper understanding of the findings. The study was completed in 4 weeks and Pearson correlation analysis was employed to examine the correlations of the students’ learning behaviours and students’ achievement. Examples of what the researchers defined as learning behaviour are interpreting graphs and interacting with their working partners during the activity. Achievement is defined as the test-score.

The study found a 33.68% improvement in students’ achievement when comparing the pre- and post-test. Furthermore, a significant correlation between interpreting graphs and applying formulae was found. Post-test gains were also observed, and students who could interpret the data tended to apply the correct formula. Students with high post-test scores demonstrated high gains between post- and pre-test scores. Furthermore, a negative correlation was found between ability to interpret graphs and pair coherence, which indicates that students who were good at interpreting graphs could not reach consensus with other students. According to the findings, the students felt that it was important that their belief was correct and therefore it was difficult to reach consensus. Students with a
high pre-test score were not likely to adopt other students’ opinion and boys were more unlikely to change their mind. According to the researcher, this might be due to a lack of experience of group-work where students were tasked with reaching consensus as part of their day-to-day education. Furthermore, the students could not reach a conclusion if they were on the right track without the help from a teacher or expert. This means that the teacher’s participation is important for the sharing process.

The findings indicate that the ability to interpret graphs can help students to learn physics and, according to the findings, U-Physics and the TPC might be beneficial for students’ learning. However, the U-Physics app was not explicitly evaluated and there was no control group to compare the revealed gains against. This means that it is difficult to generalise the findings from this study and it is challenging to draw any conclusions of the TPCs’ or software’s impact.

5.4.3 Designing Applications for Physics Learning: Facilitating High School Students’ Conceptual Understanding by Using Tablet PCs

(Wang et al., 2015)

This article describes a study where 61 11th grade students in a public high school in Taiwan participated in instructional activities in physics education using applications (Apps) on TPCs. The chosen school is highly ranked in Taiwan with teachers that were willing to adopt new teaching methods in their classes. The research took on an embodied perspective and accordingly, it was hypothesised that the TPC could be beneficial for students’ conceptual knowledge since its mobility, embedded sensors and the possibility to engage haptic manipulation. Since a TPC is light weight it can be used outside the classroom and gives the teacher a possibility to contextualize science teaching by moving the teaching out in the real world. Today, most TPCs have an integrated gyroscope, accelerometers and gravity sensors, which can be used as measuring tools in physics class. According to embodied cognition, the possibility of haptic manipulation could be beneficial for conceptual learning of physics. Furthermore, the interface is intuitive and easy to use and the TPC supports multiple data inputs. The aim of the study was to explore if the TPC might improve students’ concept knowledge about collisions between objects.
The researchers designed two apps in Adobe Flash. The first app visualized projectile motion. The students created the objects and set their initial speed. When the objects were released, the objects started to move according to the laws of physics. Tilting the TPC changed the magnitude and direction of gravity, which lead to the observation that objects started falling in a new direction.

Just like the first app, the second started with an empty canvas where the students could create objects and set the initial conditions, such as speed and mass of the objects. This app focused on collisions and let the user choose between the modes “Collision” and “Bouncing”. In “Collision”, the objects stop upon collision, which gives the user the possibility to estimate the time before the collision. In “Bouncing”, the objects keep moving after the collision, allowing the user to observe what happens with the objects after the collision (i.e. what direction and velocity will they move in?).

A concept test about collisions was designed with the help of a physics professor and two high school teachers to ensure the validity of the items. The study followed after a pilot study to ensure a high validity and reliability by evaluating the pilot study. A lesson plan was created for a 100-minute lesson where the students worked in groups with the apps to answer a number of physics questions, e.g. “Under what conditions can two cannonballs that are projected horizontally (along the X-axis) collide before landing on the ground?”, “Do the changes in external forces affect the time of motion before their collision?”, and “If the external forces acting on the cannonballs are changing after they are projected, under what conditions can the two cannonballs collide before landing on the ground?”. The test was administered before and after the lesson and the lesson was videotaped. The answers on the questionnaire were analysed using Bloom’s taxonomy. Bloom’s taxonomy allows test items to be categorized into four cognitive levels: Remembering (recognizing a concept), Understanding (e.g. explaining the concepts), Applying (using concepts in a new condition and making predictions), and Analysing (breaking a process down into physics variables).

The results of the study showed that there was a small improvement in students’ understanding of basic concepts, such as perpendicular components of motion. However, the scores in the pre-test were high (85% correct), therefore, only a relatively small
improvement was possible before reaching the maximum score of the test. On the advanced concepts, there was a greater improvement. The results also showed that the cognitive levels of Analysing and Understanding were significantly improved. However, the levels of Remembering and Applying did not improve very much. This might be due to the design of the apps, where those cognitive levels were not in focus. Another possible explanation is that the pre-test showed high results and therefore there might be a ceiling effect.

The study suggests that TPCs and apps might be beneficial for concept learning in physics education together with well-designed applications. In this experiment, the software and TPC allowed touch interaction and easy manipulation of the variables, such as mass and velocity. One possible reason why the TPC could a better tool than a regular computer is that the TPC helps create a multimodal learning environment, since it allows multi-touch and haptic manipulation, which from an embodied perspective, could benefit learning, since more senses are involved in accessing the learning process. However, it cannot be concluded whether it is more beneficial than other teaching methods since there was no comparative group in this study.

5.4.4 Doing Science by Waving Hands: Talk, symbiotic gesture, and interaction with digital content as resources in student inquiry
(Gregorcic, Planinsic, & Etkina, 2017)

This study investigated how students would engage in collaborative inquiry while interacting with a simulation in the exploration of Kepler’s laws. Kepler’s laws are three laws that Johannes Kepler (1571-1630) deduced to describe planetary motion around the sun. The laws are:

1. The orbit of a planet around a star is an ellipse with the sun in one of the foci.
2. A line segment joining a planet and the Sun sweeps out equal areas during equal intervals of time.
3. The square of the orbital period of a planet is proportional to the cube of the semi-major axis of its orbit.

The focus of the study was on students’ use of talk and hand gestures to interact with other
students and with the IWB. The IWB was in centre of the activity since the simulation was
done on the board and the discussions between the students took place around the board
and focused on the content on the IWB. The researchers studied small groups interacting
with and around an IWB, while using *Algodoo* software. The software started with a yellow
object (a star) in the centre and the students could create new objects by drawing them on
the board with a stylus. If the new object was not given any velocity, it would be dragged
into the star by the gravitational force. The students gave the objects a velocity by
“throwing” them in the desired velocity and direction. If the object was given too high or low
velocity, it would not end up orbiting the star.

The research questions that the study posed were (p.3):

- What meaning-making resources (or a combination thereof) do students use in the
  interactive whiteboard-based learning environment?
- How do students employ the available meaning-making resources to engage in
discourse that resembles scientific practices?

Based on these questions, the study aimed to investigate how the scientific discourse among
the students emerged in an inquiry- and collaborative-based learning environment
supported with interactive technology (IWB). The topic for the study was astronomy focused
on Kepler’s Laws.

The participants of the study were students in a secondary school in Slovenia, where
students of 14-19 years old attended. All participants in the study were in their second year
of high school (15 to 16 years old.) All students had regular physics lessons for 3 years and
were familiar with Newton’s law of gravitation before the study commenced. Some students
were familiar with Kepler’s laws but in the Slovenian curriculum, teaching Kepler’s laws is
not compulsory. Furthermore, all the students were familiar with the fundamental functions
of an IWB.

The sessions started with an *Algodoo* “scene” containing only a circular yellow object on a
dark background. The researcher presented students with the task to “Explore the motion of
smaller objects in the vicinity of this massive central object”. The researcher also provided
the students with some instructions about how they could use the software, such as creating and positioning new objects on the interactive screen. To be able to analyse the discussions and the students’ gestures, the sessions were videotaped and the discussions from the films were transcribed. From the films, screenshots were taken and connected with the transcript, and the gestures were analysed from the screenshot and transcript. For example, arrows were drawn to show the motion of hand gestures and accompanied with the transcripts. One instance is when one group started to discover that the objects were not orbiting the sun in a circular-shaped orbit, even though it looked like that. One student says, “It looks like it is going in a circle. It’s just that this one [pointing to the sun] is not in the middle”, “see how it goes [moving his hand]...” (p. 7). By tracking the gestures and combining them with the transcripts, the role of gestures and talk in the learning process could be analysed.

All groups started to interact with the IWB immediately after been given the task. A stylus was used to control the IWB features and the stylus was spontaneously passed between the members of the group while manipulating and creating content on the IWB.

All groups started by creating a planet and letting it get dragged into the sun by its gravitation. However, every group soon came up with the idea to assign velocity to the planet so as to make it orbit the sun. The students introduced a tracer to visualise the orbit. In general, the participants were very active with gestures while interacting with the IWB and the gestures were used to establish the shared attention in the collaborative formulation. Furthermore, the gestures helped the participants to express their ideas when they could not be explained by the students in words. All three groups came up with a qualitative description of all three of Kepler’s Laws.

It is clear that the participants in the study took advantage of the environment and used gestures and the interactive nature of the IWB to explore Kepler’s laws. The discussions and interactions emerged without specific prompting. The researches see the gesturing as a first means to express conceptual and procedural ideas, by using “this” and “that”, the students freed up cognitive resources that otherwise would be needed to explain through pure physics language. In this case, they could express their observations in a fluent way and more focus is therefore placed on the concept and understanding, instead of trying to interpret advanced, scientific, language. According to the authors,
attaching a word to an already known concept should be easy. If the students are familiar with a phenomenon, it is easier for them to accept a formula that describes it. In this experiment, all groups came up with a qualitative description of all three laws. Therefore, it then becomes possible for the teacher to introduce a formula that maps to the students’ experiences from the simulation.

5.4.5 A New Way of Using the Interactive Whiteboard in a High School Physics Classroom: A Case Study (Gregorcic, Etkina, & Planinsic, 2017)

This report describes a case study where two teachers in a high school in Slovenia were taught how to use an IWB and the Algodoo software. After their education, the teachers implemented their new knowledge into their teaching by using the IWB and Algodoo for a simulation regarding Kepler’s laws. However, only one teacher is part of the described report. In a Slovenian high school, students are 14-19 years old. In general, the physics teachers in this high school were negative to the IWB and what it might contribute to the education. Instead, most of the teachers (and students) used the IWB as regular whiteboard. The students shared this view. For the study, one teacher who was not used to the IWB and one who already used it in his teaching, were included. However, in the article, only the teacher who did not use the IWB in her regular teaching was reported.

In the study, an Algodoo simulation was introduced in the teachers’ physics lesson. The simulation commenced with a blank black board with only a yellow object on the screen (the Sun). The user could create small objects by drawing them on the board and by throwing them in the correct direction and velocity, where the object will orbit the sun. If the objects were not assigned any or too high velocity, the object would not orbit the Sun. With this simulation, the students were intended to discover Kepler’s laws. The simulation allowed the students to physically interact with the board, and the simulation aimed to work as a bridge between playful out-of-school settings and the established high school physics settings. Since the teacher felt uncomfortable with the IWB and Algodoo software, the researchers trained her in the technology to make her feel more confident before implementation of the simulation in the classroom.
Two classes of 26 and 28 students participated in the study. One group (consisting of 4 students) from each class were selected for a group interview a week after the lesson. Two of the students in the first group used the IWB during the lesson and the other two students did not. Three of the students in the second group had been active with the IWB, while the last student did not use it.

The first lesson commenced with the teacher repeating Newton’s law of gravitation and the students writing it down. Next, the teacher introduced the new topic and the simulation and used the IWB to send a planetary object into an orbit around the Sun. After the teacher’s demonstration, students who volunteered, received the opportunity to repeat what the teacher did and send their objects into orbit around the sun. Meanwhile, the other students were sharing their advice and ideas. After a short break, the teacher, with the help of the students, consolidated their findings and wrote down a simplified version of the first law (planets’ orbits have elliptical shapes, the foci were not mentioned). The teacher moved on and added tracers for a short while, allowing her to shade the area covered by an imaginary line between the sun and the planet. Together with the students, they found that the area covered was the same when an equal time passed (the second law). The last 15 minutes of the lesson was similar to a regular lesson. The teacher derived the third law from Newton’s second law for circular motion and Newton’s gravitational law. The students helped by providing relevant equations. Also, the teacher added that the Sun is placed as of the foci to the first law.

During the first implementation, the authors revealed some issues around the lesson and the teacher’s use of the simulation. One problem was that the teacher did not have enough knowledge about how to use the IWB. The teacher did not try out the students’ suggestions that could have lead the lesson astray, and in the second part of the lesson, none of the students got to use the IWB. Furthermore, some students did not have the confidence to approach the board, which the researcher believed concerned the teacher’s tense relationship with the software. This observation was also brought up in the interviews with the students who said that one could tell that the teacher was uncertain and that this led to the students doing less than the teacher had planned.
In the interview, some of the students said that they find it stressful to stand at the IWB in front of the whole class. They also felt at risk of failing the task in front of the class. The main reason for this stress seemed to be related to students’ confidence in their ability to do what they are asked to. However, every student in the interviews had their own personal touchscreen device and therefore, they did feel comfortable using the touch technology.

The lessons engaged the students, and the authors see a potential of the activity to serve as a complement to regular physics teaching, by providing an embodied way to learn about Kepler’s laws. Furthermore, in physics practices, it is common to observe phenomena, followed by attempting to describe what is happening. By using this activity, this practice can be taught, instead of as in traditional physics experiments in school where the point is often to merely confirm the textbook text and formulae. However, the teacher needs to be confident with the software and IWB, otherwise the activity will not reach its pedagogical potential.

5.4.6 Evaluating and Developing Physics in Teaching Material with Algodoo in Virtual Environment: Archimedes’ Principle

(Çelik, Sari, & Harwanto, 2015)

Thirty-seven pre-service physics teachers participated in this study designed to investigate the role of computer-based learning experiences and simulation on physics teaching. The researchers used an IWB and the Algodoo software to visualize a chosen phenomenon by a simulation. The topic of choice was Archimedes’ Principle. Archimedes’ Principle is a part of 10th grade physics in the Turkish curriculum. The simulation provided a demonstration of fluid dynamics and the user could change the density of the materials by pressing a button on the screen. The user started with an empty board and had to draw their own bucket, fill it with water and create smaller objects that were supposed to be dropped into the liquid. However, no liquid other than water could be chosen and the density of the water was constant.
The study was conducted as a case study and included both qualitative and quantitative methods. The quantitative data was collected through a questionnaire consisting of 28 Likert scale questions that investigated if the software and/or the IWB increased the motivation, worked properly and were using the screen space in a satisfying way. A Likert scale survey employs statements that are answered in terms of a scale from 1 to 5, where “1” corresponds to strongly disagreeing with the statement and “5” corresponds to strongly agreeing. The qualitative data was gathered by two open-ended questions about the use of *Algodo* in physics education. The open-ended questions consisted of one question asking about the advantages and one about the disadvantages.

The simulation allowed users to easily change the density of the material to any desired value. Furthermore, the user could create their own buckets and solid objects by drawing them on the screen. Participants’ answers in the questionnaire showed that the simulation was good enough to be used in education, since it provided a good visualization and was easy to use. The answers revealed high scores on “remarkable”, which indicates that the participants appreciated the simulation, and “encouraging creativity and developing logical thinking”. The open-ended questions showed that 29% of the users believed that the simulation increased the understanding of physics and 28% of the participants claimed that the demonstration provided a good visualisation of Archimedes’ principle. However, 26% reported that it was a problem to use a simulation in a foreign language (English). The second most salient disadvantage was the opinion that the simulation did not represent the phenomena in a satisfying way and that the preparation time was too long. Those opinions both had a response rate of 18%.

Findings of the study suggest that a simulation can be useful when introducing Archimedes’ principle. The simulation in the study was easy to use and was relevant for the subject. Furthermore, the study indicated that the simulation could increase the students’ understanding about physics with a visualisation of Archimedes’ principle.
5.4.7 Interactive White Board in Physics Teaching; beneficial for physics achievement
(Van Veen, 2012)

This study was conducted as an individual crossover intervention study in a Dutch high
school. The aim of the research was to answer the following questions:

1. Does the use of IWBs in teaching physics influence physics achievement of students
   in the 9th grade?
2. Which teaching strategies with IWBs are appreciated most by students?
3. What should a good lesson plan for teaching physics with IWBs include?
4. Does the use of IWBs in teaching physics influence girls’ achievement differently than
   boys?
5. How did the IWB influence the researcher? (Van Veen, 2012, p.1)

The study was conducted with 56 students divided into two classes that consisted of 29 and
27 students, respectively. One class participated as a control group and received traditional
physics education while the other class participated as an experimental group and received
an intervention consisting of teaching that also incorporated IWB functions. While the
control group conducted quizzes on worksheets, the experimental group used a voting
system on the IWB. In addition, when the control group’s whiteboard notes were erased, the
experimental group had the possibility to go back and consult previous notes. Furthermore,
the teacher used the IWB to summarise the students’ notes instead of the teacher
summarising by himself, which was the case in the control group. After the first intervention,
the control group was assigned as the experimental group and vice versa. Both groups
received the same amount of teaching hours and the concepts were taught in the same
order. The subjects that were taught were mechanics and electricity, two topics in physics
that are associated with multiple misconceptions. Both groups filled out identical pre- and
post-tests on both subjects. An example of a question from the mechanical pre-test was,
“Draw the v, t graph of the movement of the space probe in the diagram below. Also, give a
short explanation why you draw it like that” (p. 108, author’s translation). An example of a
question of the electricity pre-test is, “Here you see a battery with a light bulb. What does
the battery supply so that the bulb shines?” During the intervention, the lessons were
videotaped to make sure that the teaching matched the intentions. After the intervention,
the students filled out a questionnaire with both Likert-scale and open questions, for
example, “During the lessons with IWB, I learned more!” and “During the lessons without
IWB I had to do more self-studying to understand physics. Does this statement apply to you or doesn’t it? Explain” (p. 66).

The lessons in the intervention consisted of traditional teaching where the teacher explained and the students took notes. The treatment difference between the groups was that the control group did not use the technical features of the IWB, but only to write down the lecture notes. The experimental group used the IWB to view animations and movies, and do quizzes in real time and to summarize the students’ notes. The control group performed the same activities without using the IWB, and responded to the quizzes on paper worksheets. Each intervention consisted of 7 lessons, and after the first intervention there was a 6-week break to reduce any effects from the first intervention to the second.

The results from the tests showed that there was a significant difference between the groups on the electricity test, but not on the mechanics test. Furthermore, the questionnaire revealed that the students were very positive to the IWB in general, and they were confident that the IWB helped them to understand physics. For instance, the question “Are there advantages of using the IWB in class?” received 49 positive and 1 negative responses. One quote from those questions is “The IWB provides an image with the concept, which makes it easier to remember the concept.” (p. 51). According to the answers, the possibility to show pictures and animations was appreciated by the students. The function that allowed the students to vote for what they believed were correct answers to given problems, also gave the teacher a possibility to give formative feedback in real time. The study found no significant differences in learning gains between boys and girls.

The researchers found that the students became more engaged from time to time and the researchers suggest that this finding is linked to the use of images and the voting system. From the observed lessons, they also saw that the lessons needed to follow a high pace so that the students do not lose their focus.

The findings of this paper indicate that the IWB helped the students to improve their understanding of electricity better by letting the teacher visualise the topics in a more accurate way than on a regular whiteboard. Furthermore, results also suggest that the IWB
induces an increase in students’ active participation in the lessons, and students are very positive to the use of the IWB in the classroom. However, it is clear that the lessons need to maintain a high tempo, otherwise the students’ activity will decrease.

5.4.8 Interactive Whiteboard (IWB) and Classroom Response System (CRS): how can teachers integrate these resources in physics experimental activities? (Bonanno, Bozzo, Napoli, & Sapia, 2014)

The report describes a study with pre-service primary school science education students to investigate the results of an “experimental learning path”. The researchers aimed to see how performing real experiments and data analyses influenced the students’ perception of linear motion and linear acceleration concepts. The experiments in step 4 were conducted in reality and the video analyses and the simulations (step 3) were done on the IWB. The participants were 67 future primary school teachers and the study was conducted through 3 activity sessions that consisted of about 3 hours each.

The study was performed as 8 steps (Bonanno et al., 2014, p. 2):

1. Open response pre-test (40 minutes);
2. Multi-choice pre-test through Classroom Response System (40 minutes);
3. Introduction of concepts related to linear motions, using different animations (40 minutes);
4. Real experiment about linear motions (60 minutes);
5. Video analysis of a walking student and a free falling object (180 minutes);
6. In-depth activities through CRS (60 minutes);
7. Multi-choice post-test through Classroom Response System (40 minutes);
8. Open response post-test (40 minutes)

The pre-tests were based on an experiment where a steel ball was dropped onto a ramp (composed of an inclined part followed by a horizontal part) and the students were asked a number of questions about the experiment. Step 1 of the learning path was an open response test and step 2 was a multiple-choice test, conducted with CRS. The students were given a question, for example, “Which is the graphic that represents the relationship between velocity and time for an object that accelerates for two seconds, then moves with constant speed for one second and finally decelerates for three seconds?” (p. 9). The
students used a clicker to choose between 4 different graphs (and a “I don’t know” option). The pre-tests showed that the students had a lack of knowledge of the concepts and accompanying scientific language. The same procedures were repeated as step 7 and 8 to evaluate the learning.

In step 3, the students repeated the experiment on the IWB using Algodoo software. The simulation gave the students a possibility to visualize the phenomena the students observed prior to step 1. After the first simulation, the students did two more simulations, found on the Internet, on the topic of linear motion.

Step 4 consisted of 5 pedestrians who were asked to walk with a constant velocity while being videotaped. The students were then required to plot the distance covered versus the time spent. The plotted graphs were intended to help the students understand that the angular coefficient represents the speed of each pedestrian. The pedestrians were filmed and step-5 comprised viewing the videos to analyse the movement of the pedestrians. Furthermore, the students recorded a free-falling object. From each video, the students created a graph for distance versus time and every group’s result was presented on the IWB. The IWB helped to stimulate the discussions, both between the students and between student and teacher.

In step 6, the IWB and CRS were used to investigate students’ comprehension about linear motion. Also, the IWB and CRS were used to analyse if, and in which manner, the technical tools influenced students’ understanding of linear motion. Furthermore, eighteen qualitative and quantitative questions were posed about the graphical representation of different physics quantities (distance vs. time, velocity vs. time and acceleration vs. time).

The responses to the post-test showed that the students’ descriptions of the first experiment changed during the learning path and showed a shift from generic descriptions to explanations in terms of physics quantities and concepts. The results from the multiple-choice tests supported the conclusion that the students’ description of the motion was improved during the learning path. Furthermore, the ability to analyse graphs increased, which was indicated by the in-depth CRS activity and by comparing the pre- and post-test
responses. The authors claim that the IWBs function as a means to store information helped the teachers by stimulating the discussions in the classroom. Through the CRS, the students received immediate feedback and this stimulated peer comparison of the answers.

The research suggests that use of IWBs can be beneficial for physics learning since they provide a new and interactive possibility to analyse graphs and motion. The CRS could also potentially increase students’ understanding since it provides the student with immediate feedback. However, the study was not conducted with a control group and therefore no conclusion can be drawn regarding the effect of the implemented learning path in comparison with traditional teaching in general.

5.4.9 The Contribution of the Interactive Whiteboard in Teaching and Learning Physics
(Stoica, Jipa, Miron, Ferener-Vari, & Toma, 2014)

The aim of the study was to explore if students’ attitudes towards physics education activities changed when an IWB was introduced into the classroom. The IWB was used for three months in the physics classroom before the students answered a questionnaire. Sixty students aged 17-18 participated in the study. The participants generated concept maps and used the IWBs for computer-based experiments, where the data from the experiments were presented in real time, which allowed the students to receive immediate feedback to their actions. The deployed software allowed the user to interact with the board in different ways, for example moving objects or using a “magnifying glass” to visualize phenomena such as magnetic fields.

The IWB allowed students to visualise the graphics from the computer-assisted experiment and to focus on the phenomena that were intended to be studied. The researchers identified the cost of laboratory equipment as an issue for computer-assisted experiments, since every student does not have access to an individual computer. However, the researchers believe that the IWB might be a solution for mentioned issue, since it allows the whole class to participate in the experiment in real time.

The questionnaire consisted of 20 questions and each question was answered on a scale of 1 to 4, where “1” corresponded to strongly disagree and “4” to strongly agree. The study
showed that the students found the IWB to be very popular, and that they desired to use it more often in the classroom.

Overall, the study showed that the participants enjoyed using the IWB and that they would like to use it more often. The result also shows that the students believe that they learn better while using the IWB, but this was not measured directly in the study. According to the study, the IWB helps students to appreciate physics and become more interested in physics education.

5.4.10 Students’ Use of the Interactive Whiteboard During Physics Group Work (Mellingsæter & Bungum, 2015)

The article describes a case study conducted with first year engineering students in Trondheim, Norway. The aim of the study was to investigate how students used an IWB during group work. The researcher takes its stance in Vygotsky’s sociocultural theories, in which meaning making and learning is developed through interaction with peers and cultural tools.

The students were handed a task as part of a university mechanics course with the instruction that they should find a solution through working with the IWB. The tasks were 3-4 physics problems strongly linked to the curriculum, and included for example, “Estimate the moment of inertia of a human body along a vertical axis through the centre of the head, when standing straight with the arms stretched out and the legs together? […]” (Mellingsæter & Bungum, 2015, p. 120). The university had some concerns that the students solved assigned group tasks individually, and not as a group. Therefore, this task was designed so that the students had to work together.

In the beginning of the term, the students were shown an instruction video of how to use the IWB. This was followed by meeting once a week for 3 hours in the learning labs (group rooms where the IWB was placed). The project was conducted for 11 weeks. Two teachers were present at the group work sessions, and both had been involved in designing the task and had experience in ICT.
The researcher was present at all sessions and observed the groups. Furthermore, the researcher gained some information about the students’ and the teachers’ impressions through informal conversations. One of the groups, consisting of 5 male students, had their group work videotaped by the researcher. The group was chosen on the basis that it seemed to be representative of the whole student group regarding age and engagement. Only 10% of the students in the physics course were female and, according to the author, can the group be seen as typically representative regarding gender too in this context.

Due to lack of space in the room, the camera faced away from the IWB and toward the students. The researcher analysed student dialogue and students’ facial expressions. In total, 23 hours of group work was filmed. The sequences where the students interacted with the IWB were extracted and analysed. In total, video material of 12 hours was analysed. From the data, the researcher identified four different processes in which students used the IWB. In the exploratory process, the IWB was used as part of an inquiry approach toward the problem. The explanatory component comprised of a student demonstrating his/her idea of how to solve the problem on the IWB to other students. The clarifying process was when the students questioned and criticized what they had written on the IWB as a collective, which also resulted in adjustments on the board. The final process was termed the insertion process, and comprised a student copying his/her notes from the notebook onto the IWB so that the other students could see them.

The researchers reached the conclusion that the IWB supports students’ collaborative learning since it engages students’ mutual exploration and explanations, and helps create a learning environment where students share and develop ideas together. The IWB provided an opportunity to share the arguments and solutions of the physics problems to everyone in the group so that every student could follow the process. However, no conclusions of the effects of the IWB contra a regular whiteboard can be drawn from this study.

5.4.11 Engineering Students’ Experiences from Physics Group Work in Learning Labs
(Mellingsæter, 2014)

The aim of this study was to investigate students’ experiences of learning labs. A learning lab is a small room with an IWB where students are intended to cooperate to complete their
assigned tasks. The study was conducted with first year engineering students in a university in Norway, who attended an introductory physics course. The researchers wanted to find which aspects are most important in students’ experiences of learning labs and how those aspects relate to the emergence of a joint workspace. A joint workspace is an environment where collaborative learning is stimulated, and the students share and develops ideas.

The students attended the learning lab once a week during one term to solve assignments, handed from the university, together. The assignments consisted of calculation problems in classical mechanics.

A focus group that consisted of 5 male students was selected. The focus group was interviewed immediately after the last session and was asked questions about their experiences. The interview was conducted with the whole group present, and the posed questions were open-ended and led to discussion and students being allowed to elaborate on each other’s thoughts (e.g. the students were asked about their overall impression of working in a group as opposed to working alone). After transcription, sections in the interview were coded to mark what the quotes were about. Furthermore, data was also collected from video recordings and field observations. The field observations were used as background information to make sure that the video-recorded material was representative of what happened in the other groups. The focus group interview helped to make it possible to investigate the reasons for the observations made in the video material.

Analysis of the video recordings revealed that the use of the IWB decreased during the term. The students worked more and more in silence and used the IWB only to insert the solutions. This might be explained by the notion that new technology is exciting. However, in the early part of the term, more time is spent on inquiry and conceptual discussions. In the interviews, the students explained that their focus was on getting good grades, but also to “show off” how clever they are compared to their peers, by solving difficult tasks by themselves. The students described a conflict between personal and common goals, in terms of finishing in time, attaining good grades and making sure the whole group understands the solution.
The participants expressed some doubts about working in groups. For example, one student felt that he was slower than the others, and therefore skipped some problems to work on the ones that the rest of the group had not yet reached. Another opinion was that it would be more effective to solve the problems alone. These answers might be reasons why the collaboration around the IWB decreased. One student said in the interview that the group work functioned much better in the beginning when they were explaining the concepts and solutions to each other. Another explanation from the interview was that the students recently had lectures on the same topics, sometimes even the same day. The decreased elaboration and conceptual discussions might be caused by a lack of knowledge about the necessary concepts. This is supported by the fact that the subject of the course in the beginning was linear motion and acceleration, which is a part of the curriculum in Norwegian upper secondary school and the students should therefore have had some knowledge about basic concepts. Later in the course, subjects such as thermodynamics were covered, which the students had not studied before.

In general, the students were positive to the learning labs. They indicated that the IWB is fun to use and might help in their learning since the solutions become visible for the whole group, which might work as a counterweight to the fact that some students did not follow the task at the same speed. However, one student said, “There’s nothing special about it [the IWB] that makes it: “Ooh, like, we learn much more”. No, it’s just fun!” (Mellingsæter, 2014, p. 29).

An implication from the study is that a careful consideration has to be made regarding the timing between lectures and exercises in order to create a joint workplace. The students pointed out a close temporal proximity between lectures and exercises, which would counteract the creation of a joint workspace. Furthermore, since the students experienced a conflict between personal and common goals, students’ awareness about shared and personal goals must be increased.
5.4.12 Effects of Embodied Learning and Digital Platform on the Retention of Physics Content: Centripetal Force

(Johnson-Glenberg, Megowan-Romanowicz, Birchfield, & Savio-Ramos, 2016)

This research explored what effect an embodied learning approach had on students’ misconceptions regarding centripetal force. To do so, the researchers used different ICT-platforms that occur in different frequencies in American schools. The platforms consisted of a SMALLab, an IWB and a traditional desktop. SMALLab is a room-sized, interactive projection on the floor. When it comes to centripetal force, there are misconceptions that are very common. In this article, the focus is on two of them. Firstly, many students believe that an object released from the centripetal force continues its circular motion. Second, there is a belief that a longer radius infers a greater centripetal force.

From the introductory psychology research pool at a large university, 105 participants were recruited. The participants were recruited from the psychology student pool where the median number of high school and college physics courses was 1 and 0, respectively. The study was designed to investigate the effects of different levels of embodiment on the three interactive platforms. For example, on the desktop, low embodiment could be to control the speed of a moving body (called a “bob”) by controlling a slider on the screen, from left to right, with the mouse. High embodiment would be to control the bob with the mouse by moving the mouse in circles. However, the IWB and SMALLabs allowed more embodiments. Every condition was introduced by a pre-test followed by an instructional video. After that, there was an instructional intervention (lesson), where the participant interacted with one of the experimenters. Thereafter, a post-test was administered the same day, and about a week after the lesson there was a follow up test. The participants were randomly assigned to a certain condition (e.g. low-embodiment IWB or high-embodiment desktop).

In the SMALLabs high embodiment lesson, the students spun a bob with their arms. To vary the radius, the length of the physical string attached to the bob was adjusted. The mass corresponded to the number of weights and the velocity depended on the velocity at which the participant spun the bob. In the low embodiment lesson, the participants controlled the variables through sliders in the projection. The adjustable string provided the participants a possibility to investigate if a bigger radius corresponded to more centripetal force. In
another part of the experiment, the participant was required to release the bob to hit a target on the floor. In this way, the researchers could investigate what happens with the bob when released from the centripetal force.

Through an IWB, the participants used a tracking pen to control the simulation. In the high-embodied condition, the participants started the movement of the bob by creating a circular motion with the pen. By moving the pen, the user could control the velocity directly, and by releasing a button on the pen, the bob was released. In the low-embodied condition, sliders were used to control every variable. To release the bob, the participants pressed a release-button. The desktop experiment was similar to that conducted on the IWB. However, when the participants on the IWB used an interactive pen, the participants on the computer used the mouse.

A test to investigate the learning effects was designed with help from two high school physics teachers. The test was conducted by the participants on three different occasions; before the experiment, immediately after, and one approximately one week after finishing the experiment. The tests consisted of 20 items and all three tests were identical (except one item that was only in the post-test and the delayed test and therefore not included in the analyses). The first 13 questions were part of a declarative knowledge test carried out using a computer. The last questions were answered with pen and paper and was a generative knowledge test that allowed the students to form their own explanations. For example, one question was to draw how the bob would move when released from the centripetal force.

In the pre-test, there was no significant difference between the participants in different conditions. The post-test showed a significant improvement in all conditions. However, there was no a significant difference between the conditions in the declarative post-test or the delayed test. The generative test showed that all conditions had similar scores on the post-test, but the participants in the high-embodied conditions retained more of their knowledge about centripetal force than the low embodied condition. Furthermore, there was no significant difference in the results between the different conditions according to the test conducted immediately after the experiment, but in the follow up test, a significant
difference occurred. The participants who learned through the high-embodied condition showed an advantage on the recall of generative physics information one week after the study.

Results suggest that learning through high-embodied conditions is associated with increased knowledge retention. This might be because of the use of more senses, which according to the theory of embodied cognition, could influence the acquisition of new knowledge, and to strengthen or “cohere” new knowledge to existing knowledge. The use of high-embodied conditions can be used to enhance delayed learning gains and overcome incorrect mental models. Therefore, the researchers suggest that teachers design their physics teaching to increase the level of embodiment where possible.

6 Discussion

The results of the literature study and the methods to identify and analyse the literature are discussed in this section. The results are discussed by returning to the research questions stated in section 2.

6.1 Discussion of the reviewed findings

6.1.1 What is the influence of the IWB and TPCs on the students’ active participation in physics education?

The use of IWBs differs greatly between teachers. The use of IWBs can be divided into three different levels of interactivity: Non-interactive (e.g. use of the IWB as a regular whiteboard and/or projector), teacher-interactive (the teacher uses the interactive features of the IWB during interactive demonstrations, for example), and student-interactive (the students use the interactive features, such as simulations).

The non-interactive use of the IWB has not been examined in this study since, to the knowledge of the author, there is no research done on the topic. However, the possibility to save the lessons on the teacher’s computer might save time for the teachers, which could lead to more time for the teacher to dedicate to fostering engagement with the students and their physics learning. A common negative opinion that teachers reveal in the reviewed
studies is the lack of education for the teachers regarding the IWB and its features. If the teachers do not feel comfortable with the IWB, it is not hard to believe that the IWB is associated with a negative impact on their teaching. However, to date, there is not enough data to reach any conclusion about this level of interactivity’s impact on the students’ activity.

The teacher-interactive level allows the teacher to display pictures and movies on the IWB. It can also be used to show demonstrations and conduct quizzes (Çelik et al., 2015; Van Veen, 2012). The findings show that students perceive the IWB to be beneficial for their learning, and that the students become more active during the physics classes when the IWB was used in this way, compared to a non-interactive usage. Celik, Sari and Harwanto (2015) showed that demonstrations on the IWB could provide a good visualization of physical phenomena (i.e. Archimedes’ principle) and increase students’ understanding of physics concepts. However, the same study showed that teachers flagged preparation time as a problem for the use of IWB in their teaching and that the simulations cannot represent physical phenomena in their entirety. Van Veen (2012) revealed that the use of the IWB through quizzes and displaying movies and pictures, did engage the students and that students’ learning improved in comparison with the control group.

A number of the studies investigated the role of the IWB in student-interactive activities. Allowing the students to engage in an interactive simulation where Kepler’s Laws were meant to be discovered, activated students’ inquiry and induced discussion immediately (Gregorcic, Etkina, et al., 2017; Gregorcic, Planinsic, et al., 2017). According to Embodied Learning Theory and Activity Theory, these kinds of hands-on activities help the students to improve their learning of physical concepts.

Mellingsæter and Bungum (2015) followed students who used the IWB in their group projects. They found that the IWB was used to assist in cooperative learning and that students used the IWB to visualize and explain their ideas to each other. However, it was found that the IWB was used less and less as the term progressed (Mellingsæter, 2014). It is plausible that the positive effects of the IWB on group work depended on the fact that the technology was new.
It is clear that the interactive features of the IWB enable possibilities to create embodied learning environments, which could be beneficial for learning and engagement in physics education. It is also clear that the use of an IWB might support the gestures as a tool for the learning process. However, it is not realistic to believe that the most embodied activities (e.g., simulations in SMALLabs or inquiry-based simulations on the IWB) can replace traditional teaching; but it can be seen as a positive complement.

The studies also show some benefits of TPCs. In this regard, TPCs allow for immediate feedback, both from the lecturer and the computer. For example, the real-time created graphs are believed to have a positive impact on students’ learning in terms of conceptual understanding (Purba & Hwang, 2017).

The interactive features of the TPC could allow the teacher to monitor the student’s work from his/her computer. Doing so removes the fear of revealing the misconceptions to the teacher, but still allows the student to present his/her solution. The TPC also provides the student the possibility to ask questions and receive help from the teacher anonymously. According to Enriquez (2010), this feature encourages students to ask questions earlier in the process, which gives them an opportunity to keep up with the process and overcome obstacles that might have held the control group back.

In one study, where the students used the TPC to interact with a simulation of centripetal force, results showed a positive impact on the students’ conceptual understanding when it came to advanced concepts. Bloom’s cognitive levels of analysing and understanding were improved the most (Wang et al., 2015). With activity theory or embodied learning theory as a theoretical framework, the use of TPCs is beneficial for improving students’ conceptual knowledge.
6.1.2 How can an IWB or TPC improve students’ learning about concepts in physics?

The reviewed research shows that both the TPC and IWB can help improve students’ knowledge about physical concepts. However, it cannot be concluded from this study that the use of IWB or TPC is always better than traditional teaching, or that any overarching generalisations can be deduced in this regard.

At least three of the studies indicated more improvement in student groups that were using an IWB or TPC than groups who were taught in a traditional manner (Enriquez, 2010; Johnson-Glenberg et al., 2016; Van Veen, 2012). Johnson-Glenberg et al. (2016) showed that the students’ who participated in a high embodied condition during the learning process, retained the knowledge better than the students who used low-embodied conditions. The theoretical background and theoretical framework underpinning this review supports these results, and a multimodal approach should help the student to keep the knowledge that s/he learned. However, the studies are conducted with small sample sizes, which prevents any general conclusions to be reached.

A number of studies have showed that interactive touchscreens might help students to understand and remediate misconceptions of physical concepts, such as linear acceleration, centripetal force and collisions (Bonanno et al., 2014; Johnson-Glenberg et al., 2016; Wang et al., 2015).

The possibility of real-time formative assessment through TPCs was shown to have positive effects on learning (Enriquez, 2010). One of the possible reasons mentioned by the study was that the students could ask questions anonymously and therefore, the questions were asked in an earlier stage of the learning process. This might be due to an atmosphere where students feel afraid of asking questions in class. However, it is not clear that this would be the case in other schools or countries.
6.1.3 How can educational research on touchscreen technology help inform effective strategies in physics education?

Interactive touch technology provides the teacher with novel opportunities in physics education. According to the reviewed studies, the possibility to provide instant assessment is appreciated by students and might improve their performance since it allows the teacher to detect misunderstandings and correct them immediately (Enriquez, 2010; Van Veen, 2012). Both TPCs and IWBs can be used to create a learning environment where an instant, formative assessment is present. Software is available for the teacher to construct questions and obtain students’ responses in real time. In this way, the teacher can identify and discuss misunderstandings immediately. The TPC provides the students and teacher a new possibility to interact with each other through digital technology. In this way, students can ask questions and receive help anonymously. From the results, it seems that this opportunity induces students to ask questions in the learning process, questions that if were not asked would impede the learning process.

According to the described research results and based on the provided theoretical background of Embodied Learning Theory, Activity Theory and Distributed Cognition, body movement and combined sensorimotor interaction helps to reinforce learning. Therefore, activities that include physical interaction with the screen could be effective for improving learning. Also, the interactive touch afforded by IWBs engages students’ in learning physics. However, those activities take a lot of time to plan and prepare to make sure it becomes meaningful. Most of the activities used in the studies included in this review (e.g. Gregorcic, Planinsic, & Etkina, 2013; Gregorcic, Planinsic, et al., 2017; Johnson-Glenberg et al., 2016), used an inquiry-based approach which takes a lot of time. Therefore, they cannot easily replace the ordinary, less interactive education.

The teacher should provide a lot of interaction with accompanying direct assessment in his/her teaching, such as through real-time quizzes. In this way, teachers can help avoid misunderstandings being propagated and increase students’ engagement (Gregorcic, Etkina, et al., 2017; Gregorcic, Planinsic, et al., 2017; Johnson-Glenberg et al., 2016; Skolverket, 2011). From time to time, interactive touch simulations could be used to allow students to explore physical phenomena. Those activities might be beneficial for learning, since they
engage students. Furthermore, the Swedish curriculum states that students should be given the opportunity to work with computerized tools (Skolverket, 2011).

In summary, factors that teachers should keep in mind while designing teaching that includes the integration of interactive touch screens could include:

1. Take the time to learn how to use IWB/TPC technologies.
2. Use the interactive touch functions in demonstrations and lectures to visualize and simulate physical concepts. By doing that, the lecture can provide the students with a deeper understanding of the concepts.
3. Engage features that allow for real-time interaction with the students and use the technology for instant formative assessment.
4. Use the IWB to create a collaborative learning space and spend time designing meaningful tasks that maximize the benefits of the technology.

6.2 Discussion of methods used to locate the reviewed literature

In this section, the method of the literature search deployed to locate the studies for this systematic literature review is discussed.

When conducting a systematic literature review, all research that might be relevant for answering the questions posed by the study should be included and synthesized (Eriksson Barajas et al., 2013). It should be stated that other relevant articles might be found if different search strings, different limiters or approaches were adopted. However, there is not much research done in the area of IWBs and TPCs in physics education. The analysed articles were peer-reviewed, published in the last 15 years (2002 or later) and concerned the role of IWBs or TPCs in physics education.

ERIC and Scopus were the databases that were used in this study to conduct searches. Google Scholar was used to find specific articles appearing in the references of other articles. However, some relevant articles might be missed in Google Scholar and/or other databases if the journal sources were not listed in ERIC or Scopus.
6.3 Quality evaluation of the reviewed articles

In the method, some criteria were stated in order to evaluate the articles that were included for analysis. The result of the evaluation is presented in Table 12 below. Column 1 and 3 measures the validity of the study, if the result to those questions is good; the study measures what it is supposed to measure. A clear aim does not require clear research questions since the research question can be subsumed in the aim. However, a clear aim and/or clear research questions are two ways to ensure a high level of validity and is therefore included in the table. Column 2 is about the number of participants. If the intention is to generalize the findings, the number of participants should be as high as possible. In the 4th column the potential degree of reliability and validity are presented.

Table 12. Evaluation of the quality of the 12 articles reviewed in the study.

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<tr>
<td>Enhancing Student Performance Using Tablet Computers (Enriquez, 2010)</td>
<td>Clear aim</td>
<td>Four groups of students (41, 28, 16 and 46, respectively). Conducted in two different years. This gives a high level of reliability.</td>
<td>Two case studies, comparing results on tests and exams. Pre- and post-test in the second study provides high reliability and validity.</td>
<td>Relatively high reliability, high validity.</td>
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<tr>
<td>Investigation of Learning Behaviors and Achievement of Vocational High School Students Using an Ubiquitous Physics Tablet PC App (Purba &amp; Hwang, 2017)</td>
<td>Clear aim and research questions.</td>
<td>Pre- and post-test conducted by 36 students. Eight students randomly selected for interviews.</td>
<td>Pre- and post-test about concepts. 10 multiple-choice and 2 open-ended questions. Interview with 8 of the students to help explain the gathered data. Good validity.</td>
<td>High reliability, high validity.</td>
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<tr>
<td>Designing Applications for Physics Learning Facilitating High School Students’ Conceptual</td>
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<tr>
<th>Title</th>
<th>Aim and Research Questions</th>
<th>Participants</th>
<th>Methods</th>
<th>Validity/Reliability</th>
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<tr>
<td>Understanding by Using Tablet PCs (Wang et al., 2015)</td>
<td>professor and two high school teachers were included to ensure the reliability and validity. No control group.</td>
<td></td>
<td>Observing sessions, analysing video recordings of the sessions and analysing the multimodal transcripts of the sessions. Since a number of methods to collect data is used, the validity is increased. This is called triangulation and is a common way to ensure validity in qualitative research (Carter, Bryant-Lukosius, DiCenso, Blythe, &amp; Neville, 2014)</td>
<td>High validity, low reliability.</td>
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<tr>
<td>Doing science by waving hands: Talk, symbiotic gesture, and interaction with digital content as resources in student inquiry (Gregorcic, Planinsic, et al., 2017)</td>
<td>Clear aim and well-formulated research questions. The study does not claim to be generalizable.</td>
<td>9 students.</td>
<td>Following a pilot study. Video recordings of 2 lessons and follow up interviews. Discussions with the teacher were audio recorded. Systematic methods in response to the aim.</td>
<td>High validity, low reliability.</td>
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<tr>
<td>A New Way of Using the Interactive Whiteboard in a High School Physics Classroom: A Case Study (Gregorcic, Etkina, et al., 2017)</td>
<td>Clear aim, no explicit research questions.</td>
<td>54 students and 2 teachers. Students were divided into 2 classes, with 26 and 28 in each. One group (consisting of 3 and 4 students) from each class participated in semi-structured interviews.</td>
<td>Following a pilot study. Video recordings of 2 lessons and follow up interviews. Discussions with the teacher were audio recorded. Systematic methods in response to the aim.</td>
<td>High validity, high reliability.</td>
</tr>
<tr>
<td>Evaluating and Developing Physics Teaching Material with</td>
<td>Clear aim. No clear research questions.</td>
<td>37 students responded to a questionnaire. This Questionnaire, including both multiple-choice and</td>
<td></td>
<td>High validity, fairly low reliability.</td>
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<tr>
<td>Study Title</td>
<td>Methodology</td>
<td>Participants</td>
<td>Assessments</td>
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<td>Algodoo in Virtual Environment: Achimedes’ Principle (Çelik et al., 2015)</td>
<td>Gives a fairly low reliability.</td>
<td></td>
<td>Open-ended questions, to find the teachers perceptions about the software.</td>
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<tr>
<td>Interactive White Board in Physics Teaching; beneficial for physics achievement? (Van Veen, 2012)</td>
<td>Clear aim and well-formulated research questions.</td>
<td>56 six students in 2 classes. Two interventions conducted with one class as control group.</td>
<td>Pre- and post-test for each topic/intervention. Low Cronbach’s alpha on the pre-test in electricity.</td>
<td>High validity, relatively high reliability.</td>
</tr>
<tr>
<td>Interactive Whiteboard (IWB) and Classroom Response System (CRS): how can teachers integrate these resources in physics experimental activities? (Bonanno et al., 2014)</td>
<td>Clear aim and well-formulated research questions.</td>
<td>67 students answering pre- and post-test about conceptual knowledge.</td>
<td>Pre- and post-test including both multiple-choice and open-ended questions. Observations from the sessions.</td>
<td>High validity, high reliability.</td>
</tr>
<tr>
<td>The Contribution of the Interactive Whiteboard in Teaching and Learning Physics (Stoica et al., 2014)</td>
<td>Clear aim, no research question.</td>
<td>60 students responded to a questionnaire. Low number of participants indicates a potential low reliability.</td>
<td>Questionnaire with multiple-choice questions.</td>
<td>High validity, fairly low reliability.</td>
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<tr>
<td>Students’ use of the interactive whiteboard during physics group work (Mellingsæter &amp; Bungum, 2015)</td>
<td>Clear aim, no research questions.</td>
<td>5 students were video recorded during their group work for one term. The researchers viewed the clips multiple times categorizing to describe the content. Some clips were viewed separately to ensure the reliability</td>
<td>Video recordings from group work sessions. Notes from observations of the group work.</td>
<td>High validity, fairly high reliability.</td>
</tr>
<tr>
<td>Engineering students’</td>
<td>Clear aim and well-formulated research questions.</td>
<td>5 students</td>
<td>Video recordings</td>
<td>High validity, fairly high reliability.</td>
</tr>
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experiences from physics group work in learning labs (Mellingsæter, 2014) formulated research questions.

video recorded during their group work for a term. After the last session, the students were interviewed. Two researchers viewed the clips separately to ensure the reliability from the interpretations and findings.

analysed by two researches separately. A focus group interview, were conducted after the last session. High level of reliability and validity.

analysed by two researchers separately. A focus group interview, were conducted after the last session. High level of reliability and validity.

Effects of Embodied Learning and Digital Platform on the Retention of Physics Content: Centripetal Force (Johnson-Glenberg et al., 2016)

Clear aim and clear hypotheses.

109 participants divided into 6 groups. Fairly high reliability.

Pre- and post-test including both multiple-choice and open-ended questions to investigate the participants conceptual knowledge.

High validity, fairly high reliability.

If the findings from the studies are to be generalizable, the included articles should display a high validity and reliability. Studies with a large sample sizes often have a higher level of reliability than similar studies with smaller sample sizes, and are more generalizable (Eriksson Barajas et al., 2013). However, studies with small sample sizes can provide the researchers with relevant and interesting results if the used method is valid and measuring what it intends to measure. For example, questionnaires should have a large sample size to be able to generalize the results. On the other hand, in-depth and descriptive research methods, such as qualitative interviews and video recorded sessions, can return meaningful results with small samples (Eriksson Barajas et al., 2013; Trochim, 2006).

The study conducted by Enriquez (2010) was undertaken in a community college and a university in USA and was repeated twice. TPCs were introduced in physics classes at Cañada College and a system where the students could interact with the teaching material and the lecturer was designed. The results from the tests and exams were compared with a control
group that had not used the TPC and the interaction system. The findings showed a significant improvement. The use of control groups and replication of the study provides a high level of reliability and validity, and the quality of the research results can be seen as high. However, it is not obvious that the results can be generalized in other parts of the US or the world, since different lecturers teach in different ways and different student cultures might react differently to the implementation of the TPC.

The study by Purba and Hwang (2017) was conducted on 36 students in vocational high school and aimed to investigate the relationships between learning behaviours and learning achievement among the students. A pre-test and post-test were conducted to ascertain students’ conceptual knowledge about a simple pendulum. Eight students were interviewed to provide the researcher with a deeper understanding of the data. The study was not about the app or TPC explicitly and it did not contain a control group. However, the results infer that the features that the application and TPC provides might have a positive effect on the learning. The results would be potentially more reliable if the sample size was bigger and if the study was conducted at different high schools.

Wang, Wu, Chien, Hwang, and Hsu (2015) designed two applications for a TPC and allowed 61 students in a public senior high school to use them to improve their conceptual understanding about projectile motion. The data was collected through a pre-test and a post-test. However, no control group was used. The authors came to the conclusion that the applications helped the students to improve their knowledge about projectile motion. Since there was no control group, no conclusion about the usage of the apps versus traditional teaching can be made. Therefore, the results can probably not be generalized without further research.

Gregorcic, Planinsic, and Etkina (2017) endeavoured to explore how students would react when an inquiry-based activity with an IWB was introduced. By videotaping the sessions and analysing the body movement and interaction, the researchers could find interesting patterns in the interaction with and around the IWB.
Gregorcic, Etkina, and Planinsic (2017) trained a teacher in IWB-based materials that was about to be implemented in the education as an intervention. The teacher training was audio recorded. Two lessons with the new material were video recorded and analysed. After the lessons, two groups of students were selected for follow-up interviews. The interviews were audio recorded. The study followed after a pilot study. The study can be considered to have a high level of validity since it used adequate research methods and the study followed a pilot study, allowing the researchers to make sure that the study measures what it intends to measure.

Çelik, Sari, and Harwanto (2015) investigated pre-service physics teachers’ perception of computer-based learning through an IWB. 37 students participated in a questionnaire and the results suggested that using a simulation program on the IWB might be beneficial for students’ understanding. However, the low number of participants and the fact that all students were at the same university, possibly even same class, makes the results difficult to generalize.

Van Veen (2012) performed a study for his thesis where two classes were used as both an experimental group and control group. The study was divided into two parts, where mechanics and electricity were the subjects of teaching. In the first part, one of the classes used the IWB features and the other class was taught in a traditional manner. In the next phase, the control group became the experimental group and vice-versa. Between the phases, a 6 week break was implemented to minimize the effects from intervention 1 to intervention 2. Data were collected through pre- and post-tests, questionnaires and the lessons were videotaped. From the videos, the researcher evaluated the lessons and analysed students’ engagement. The study has high reliability and validity in respect of other teacher constructed classroom tests. However, Cronbach’s alpha on the electronics pre-test was low. This is explained by the fact that the students had not studied electronics before and the test could therefore only test the students’ general conceptions. The study would have been more generalizable if it was repeated at different schools with different teachers.

In the study conducted by Bonanno, Bozzo, Napoli, and Sapia (2014), a learning path was constructed to help students understand the basic physical phenomenon of linear motion.
The data was collected through open response pre- and post-test and multiple-choice pre- and post-tests through the Classroom Response System (CRS). The study was conducted with 67 teacher-students who were about to teach physics in primary school. The researchers observed the activities during the sessions. The results showed that the learning path with the IWB and CRS, helped the students to improve their abilities around graphical representation and analysis of physical quantities. However, no control group was used and therefore no comparison with traditional teaching or other teaching methods can be made.

Stoica, Paragina, Paragina, Miron, and Jipa (2011) investigated the effects of an IWB on students’ attitudes towards physics education. The study consisted of 3 months of physics teaching using the IWB where 60 students participated. After the training, the students responded to a questionnaire about their engagement in physics class. The findings showed a positive effect on the engagement. The study investigated what it intended to investigate. Nevertheless, the study was conducted on a relative small sample of students.

Mellingsæter and Bungum (2015) followed a group of engineering students at a Norwegian university during group work with an IWB. One researcher followed the group-work sessions and observed the groups. The researched also conducted informal conversations with both teachers and students. From both the observations and conversations, notes were taken to serve as background material. One of the groups was video filmed and the movies were analysed. This research method provides valuable in-depth knowledge about the interaction between students and the IWB with respect to the students’ attitudes towards the IWB as a tool for group work.

Mellingsæter (2014) investigated students experience from group-work with the IWB. The study was conducted at a university in Norway and the participants were engineering students in a basic physics course. One group was chosen for the study and their sessions in the “learning lab” (a room with a IWB) were filmed during a term. After the last session, the group was interviewed. The method is a good way to obtain in-depth knowledge about the students’ points of view.
Johnson-Glenberg et al. (2016) performed a study to investigate the effects of embodied learning. The 109 participants were divided into 6 different groups and participated in a 50 minutes long lesson on centripetal force with different levels of embodiment and different digital platforms. Before the study, a pre-test was submitted, and the effects of the teaching were measured by a post-test and a follow up-test to investigate the retention and delayed learning gains. The results showed that the students taught with high level of embodiment retained the gained knowledge to a higher amount. The study investigates what it is supposed to investigate, and the reliability is fairly high.

6.4 Conclusions and Implications
The articles included in this analysis provide evidence that the possibility to use TPCs for delivering immediate feedback anonymously has a positive impact on students’ learning in physics education (Enriquez, 2010). Furthermore, the in-built sensors of the TPC can be used for experiments, which can help students’ learning (Purba & Hwang, 2017). TPCs can also be used for interactive simulations. According to Wang et al. (2015), interactive simulations could increase students’ learning more greatly than using a computer that not allows touch interaction. A number of the included articles investigated the use of interactive simulations on the IWB. The study conducted by Gregoric, Planinsic and Etkina (2017) shows that IWB simulations allows for a more informal talk which could help students to focus on the physics concepts instead of trying to apply formal scientific language, which could increase understanding related to Kepler’s laws. A further study conducted by the same researchers strengthens those implications (Gregoric, Etkina, et al., 2017), by showing that the students engaged in investigation of Kepler’s laws through an Algodoo-simulation. An interactive simulation helps the students to gain knowledge and active participation during learning. However, the teacher needs to have enough knowledge of how to use the software and hardware, otherwise the positive effects of the simulation can easily be extinguished. The IWB can also be used to show demonstrations and visualize physical phenomena (in this case Archimedes’ principle) (Çelik et al., 2015). The IWB also provides the user with a possibility to analyse graphs and motion, which combined with CRS, helped students to understand linear motion and acceleration (Bonanno et al., 2014). Learning through high-embodied
conditions (e.g. interactive simulations on IWBs or TPCs) allows the students to retain their knowledge (Johnson-Glenberg et al., 2016).

Van Veen (2012) concluded that the use of the IWB reinforced students’ understanding through visualisation of phenomena. Furthermore, using an IWB increased the students’ active participation. An increasing level of active participation is also associated with other studies (Stoica et al., 2014). According to the study conducted by Stoica et al. (2014), the students’ felt that physics education became more interesting when the IWB was used. Furthermore, the IWB can help create a joint workplace, which should be beneficial for students’ learning (Mellingsæter & Bungum, 2015). However, students in group work felt that their personal goals and the common goals were in conflict and the use of the IWB decreased during the term (Mellingsæter, 2014).

Some salient conclusions can be drawn from this literature review. For instance, students seem to be generally positive toward use of the IWB. They tend to use the IWB in an interactive way when receiving the opportunity. The IWB is therefore suitable for interactive simulations or as a tool to encourage engagement and collaboration during group work. Similar conclusions can be drawn about the use of TPCs in physics education. Furthermore, another conclusion that can be made about TPCs is that they can be used to create interactive learning environments where students can interact with each other and the lecturer in real time. In this way, students can easily pose questions with confidence and misconceptions and reasoning difficulties can be dealt with earlier in the learning process.

The teacher, who anticipates designing their teaching using these technical tools, should use the opportunity of interaction when using the IWB. The literature advocates that students should not use the IWB for hands-on simulations every lesson, but that IWB technology can also be used as a CRS or to demonstrate various physical phenomena.

6.5 Future research directions
The articles included in the analysis displayed a general focus toward the advantages and positive effects of IWBs and TPCs. Therefore, studies that investigate and identify potential
problems associated with implementing the technology should also be considered. Furthermore, studies with larger samples of participants would allow more general conclusions. In general, the included articles lacked a control group, which makes it difficult to draw any general conclusions of effects of the IWBs or TPCs on the learning compared to traditional teaching. For example, it would be interesting with larger studies comparing test results from students who were taught with and without IWB technology.

A large proportion of the research indicates that teachers feel like they do not possess the adequate skills for using IWB and TPC technology to complement their teaching. In this regard, more research on how these technical tools can be effectively integrated into regular physics teaching would be welcomed. It would also be interesting to investigate how, or to what extent, the tools are used in regular upper secondary school-classrooms.
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7.1 Acknowledgement of source for figures

A student using an IWB (Figure 1). By Laurie Sullivan - DSC01784, CC BY 2.0. Retrieved on December 10 from Wikimedia commons: https://commons.wikimedia.org/w/index.php?curid=62727253

TPC with rotatable screen (Figure 2). By Janto Dreijer - Self-photographed, Public Domain. Retrieved on December 14 from Wikimedia commons: https://commons.wikimedia.org/w/index.php?curid=867335

TPC without keyboard (Figure 3). By 彭家杰 - Own work, CC BY-SA 3.0. Retrieved on December 14 from Wikimedia commons: https://commons.wikimedia.org/w/index.php?curid=36912702