A study of learning gain, technological outlook and teacher response to a student active Wii Smart Board project for secondary schools

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Abstract

This paper describes and evaluates a science project where the participants constructed a pointing device using an infrared diode, and then used the device to control a computer using a gaming device - Wiimote and specialized software.

The project was tested on a group of teacher students, a group of science teachers from secondary school, and several secondary school classes. Participants responded to a questionnaire before and after the project, measuring learning gain, associations to science and technology, motivation, satisfaction with the project, and - in the case of teacher students and science teachers, willingness to employ the project in a school. The teachers of the participating school classes gave feedback on pupil assessment afterwards. After a year, a survey on how many of the science teachers from the course who had actually tested the project in their school was conducted.

It was found that both teachers and students were impressed by and engaged by the project. Teachers were excited over how the project covered specific learning goals in technological science. Amongst the pupils the project had a wide appeal and could motivate theoretically weaker students. The learning gain on secondary goals related to the understanding of science showed that the project worked on many levels.

Conclusions are that the project is suited for schools, but requires a small investment in equipment and a modest initial investment in preparation time. The initial investment appears to have been too high especially when combined with some teachers' anxieties of being unable to solve technical hitches on their way. Comprehensive coursing and adequate technical support for teachers in the preparation phase may therefore be necessary prerequisites for successful general implementation in secondary schools.

Introduction

Modern gaming devices such as the Nintendo Wii Remote - Wiimote provide an inexpensive and robust packaging of several useful sensors, with the ability to readily relay information to a computer.

We wanted to conduct a school project where we exploited and adapted the infrared camera of the Wiimote - along with a student built infrared pointer, to create a Wii Smart Board, an inexpensive interactive whiteboard which in many aspects can compete with commercial touch screen interactive whiteboards already employed in some schools.

We wished to evaluate the feasibility and didactical potential of the Wii Smart Board as a secondary school technology and design science project. The project was analysed, identifying which readily available components might be used, and which equipment and construction methods might work the best in schools. A standard format was devised which we believed would receive the widest acceptance in schools, while sufficiently covering key Norwegian curriculum goals.

Our project consisted of two sections. Firstly a short introductory lecture covering the scientific background of the Wii Smart Board was given, including classroom demonstrations. Thereafter, with the help of a laboratory guide, the participants were asked to design, build, test and evaluate their own Wii Smart Board, working in small groups. This section covered topics on design, practical laboratory skills, simple electrical circuits, and complemented some of the theory given in the introductory lecture.

We studied the general reception and learning gains of the project with three different groups, firstly a class of teacher students, then a group of local teachers invited to a course for the project, and finally two 9th grade school classes with pupils aged 14-15 at a trial secondary school. The response of the school pupils was of prime interest and was studied both quantitatively with questionnaire polling and qualitatively through personal observation and through feedback from their two teachers.

Technical background

An interactive whiteboard is a touch sensitive board used in conjunction with a computer and a projector. The image on the computer screen is projected onto the whiteboard, and instead of using an ordinary pointing device like a mouse on the computer, the user works directly on the whiteboard. One may click, double click, drag, draw or write with a finger, virtual pen, stylus, or any other device. Everything may be saved if desired. Any computer function can also be activated directly at the whiteboard.

Commercial whiteboards are however costly, priced well above 1000 euros. A much cheaper alternative is the Wii Smart Board (Lee, n.d.-a), (Lee, n.d.-b)where the touch sensitive screen is replaced by an ordinary white canvas, a Nintendo Wii gaming remote - Wiimote (WiiBrew, n.d.), and an infrared pointing device. A detailed comparison of a Wii Smart Board and a commercial Smart Board can be found in appendix 1. The Wiimote retails for around 60 euros, there are various free software options for the Smart Board. An infrared pointer can be constructed from parts costing a total of around 3 euros. A soldering iron and a hot glue pistol, pliers and a file are required as tools.

The Wiimote includes a charge-coupled device - CCD camera with an infrared pass filter that blocks visible light but is reasonably transparent to near infrared light, such as that emitted by infrared diodes in some remote controls (WiiBrew, n.d.). Since there is relatively low indoor luminance in the near infrared range, the Wiimote is able to detect and separate by contrast low intensity infrared sources like LEDs. We have experimentally determined that of several commercially available wavelengths of near infrared LEDs, Wiimote sensitivity is well suited to wavelengths around 940 nm. A Wiimote with the lid removed is shown in Figure 1.

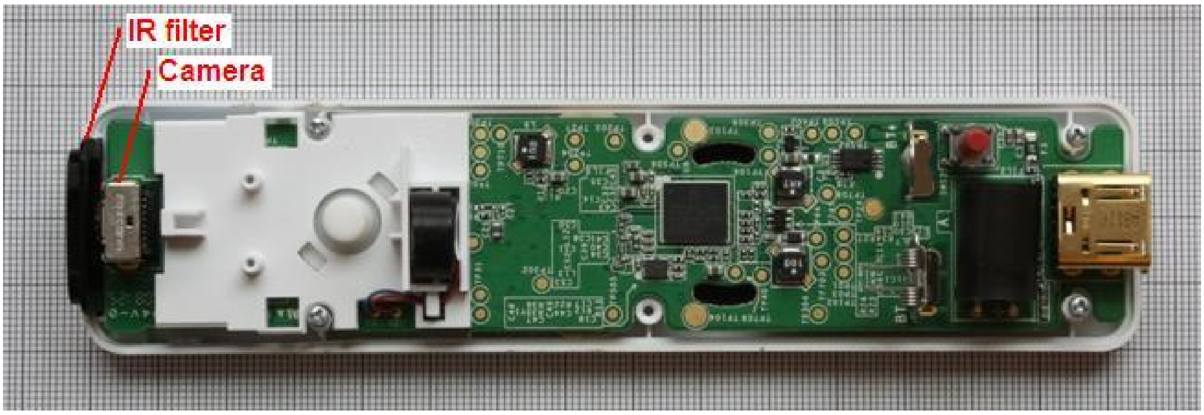

Figure 1: Wiimote with lid removed.

Built in Wiimote software continuously tracks the position relative to the camera of the strongest point sources of near infrared. It reports this information to the computer by Bluetooth.

The Wiimote uses a non-proprietary Bluetooth device to communicate with the main gaming console (WiiBrew, n.d.), thus it may also communicate with any Bluetooth equipped computer. Many laptops have Bluetooth as standard equipment, and any modern computer may be equipped with Bluetooth by plugging in a USB dongle.

The Wii Smart Board specialized software (Lee, n.d.-a) (Smoothboard, n.d.), utilizes the strongest point source information, in this case representing the position of the infrared LED relative to the camera. In order to calculate the position of the infrared source relative to the screen, the Wiimote must be positioned so that the entire screen falls within the IR camera picture. A 4-point calibration is performed. Since the screen itself is a projected image of the desktop, the infrared source can be used as a stylus to control the cursor thus replacing the function of the mouse, performing a similar function as a pointing device on a touch sensitive whiteboard. This setup is known as a Wii Smart Board and illustrated in Figure 2.

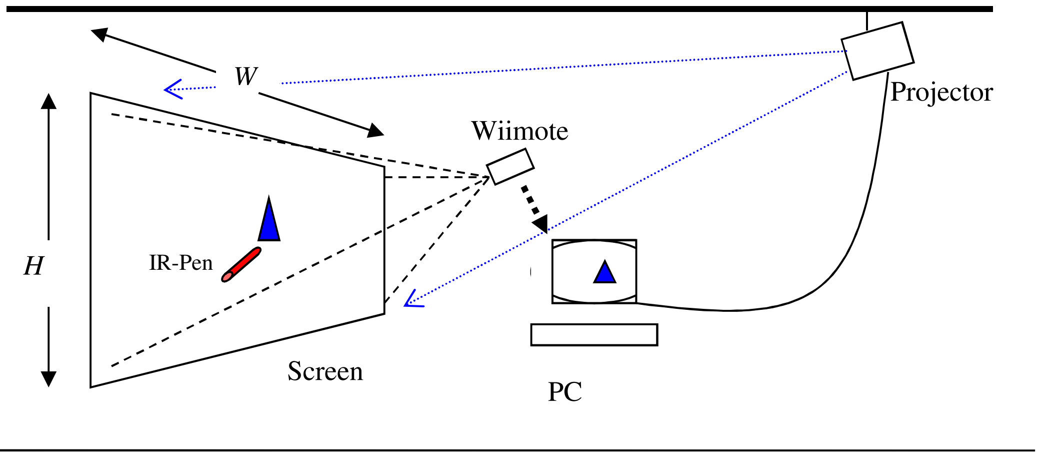

Figure 2: Wii Smart Board.

School project description

The project was initiated with a 30 minute presentation covering the scientific background. The Wii Smart Board was used to control the PowerPoint presentation used, thereby demonstrating its function. The introduction briefly covered the difference between short wave radiation and long wave electromagnetic radiation in terms of energy and chemical and physiological effects. This included the type of microwave signal communication used in the wireless Bluetooth connection that the device has with the computer. Concerning infrared particularly, the difference between long wave infrared used in thermal imaging and near infrared from LEDs and hot sources was explained, and the fact that all objects emit radiation with wavelength and intensity varying with temperature was pointed out. When the audience was teachers or teacher students this was formally related to blackbodies and the Wien and Stefan-Boltzmann laws.

A demonstration was conducted, showing how a mobile phone camera, being sensitive to near infrared, picks up light from the IR-pen that is otherwise invisible to the eye. To demonstrate how the Wiimote camera is similar to a standard digital camera with a filter blocking visible light, an IR pass filter removed from a television remote control was placed in front of a web-camera so that the effect could be observed. Typical indoor sources for near infrared such as direct sunlight were identified. To demonstrate colour temperature an incandescent light bulb and a low energy light bulb of the same rating were shown side by side with and without the filter.

A simple calibration process needed to define the position of the infrared pointer relative to the screen was also demonstrated and explained.

After the presentation the participants designed and constructed an IR-pen, collaborating in groups of around four. The IR-pen was constructed around the housing of a disassembled felt tip pen, soldering a circuit consisting of an IR-LED, wires, springs, a push button switch and a single AAA battery. A file was available to make an opening for the switch in the felt pen housing. The wires had to be cut, stripped and soldered taking care to connect the diode in the correct polarity. Hot glue was used for non-electrical assembly. A sketch of the assembly and the corresponding circuit diagram is shown in Figure 3.

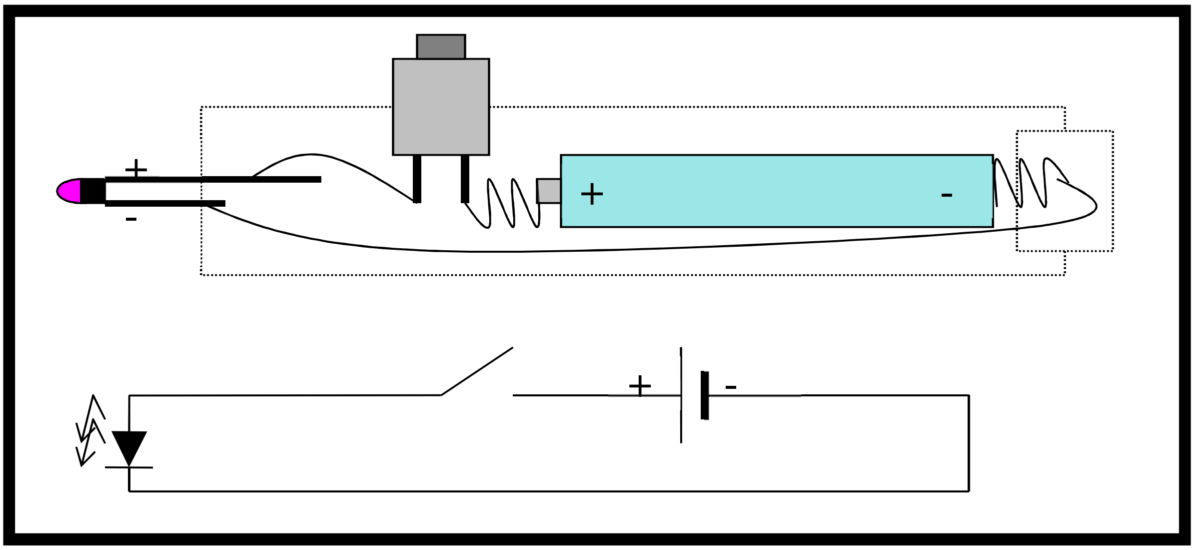

Figure 3: Assembly and circuit diagram of IR-pen.

The participants were given some step by step information on a suggested construction of the IR-pen, as well as being allowed to examine a preconstructed pen. A number of design features had to be addressed, such as where to place the hole for the button switch, the need to replace the battery, and the general robustness and appearance of the assembly. Construction technique, order of construction and quality of build also required their attention. Problem solving techniques were needed to troubleshoot typical problems, such as poor contacts, electrical shorts, incorrect direction of battery relative to the diode, and non-functioning diodes. Testing of the IR-pen could not be achieved visually, since the infrared diode gave no visible sign of function. Instead the participants tested with their mobile phone cameras.

Once working, the infrared pointer could be employed on the screen with the Wii Smart Board software. Participants could learn how the calibrate the program, test the ease of use and feel of the IR-pen and program, test the resolution that was possible to achieve, examine the problems of shadowing the pen from the Wiimote, disturbing the Wiimote and the effect of bright sunlight. Participants finishing the pen earlier had more time to investigate these questions, allowing a degree of differentiation. Pupils wrote a school report for the project.

In addition to this IR-pen the science teachers and teacher students also built another by modifying a key ring flashlight, replacing the ordinary white light LED with an IR-LED.

Curriculum goals

The technology and design section of the science curriculum goals in Norwegian Secondary School (Utdanningsdirektoratet, n.d.) for 5^{th} to 10^{th} grade pupils require them to be able to:

- develop products based on specifications that use electronics, evaluate the design process and assess product functionality and user friendliness
- elaborate on electronic communication systems on the system level and discuss and elaborate on societal challenges in connection with using these
- plan, build and test simple equipment making use of electrical energy, explain how they work and describe the process from idea to the completed product.

These are the primary learning goals closest related to the Wii Smart Board project. Goals in electronics, technology and design are challenging for secondary schools teachers to cover with practical learning projects. The most common related practical learning program is Lego Mindstorms robotics (Utdanningsdirektoratet, n.d.), which is a comprehensive school robotic build and programming project developed and supported by Lego. Lego Mindstorms (LEGO, n.d.)is a significant time consuming undertaking, and many school cannot afford sufficient equipment to allow small groups and individual participation. The degree of computing skills required of the teacher is very similar to Wii Smart Board, consisting of installation and Bluetooth connection. The Wii Smart Board is low cost by comparison and allowing smaller groups and potentially greater individual participation.

Secondary learning goals addressed by the Wii Smart Board project are scientific, including those of electromagnetic radiation, and simple electrical circuits. The participants also learn the practical skills of soldering and stripping electrical wires. Specifically pupils are required to be able to:

- Experiment with magnetism and electricity and describe and explain the results.
- Experiment with light, vision and colour and explain the results.
- Explain how electromagnetic radiation from space can be interpreted and give information about space.
- Use the terms current, voltage, resistance and induction in experiments with electrical circuits.

Research methodology

We developed the concept, tested components and produced a prototype laboratory guide and tested these on teacher students and teachers. Based on their feedback a laboratory guide for pupils was created. Each participant in each group responded to an anonymous questionnaire before and after the project. The first questionnaire tested prior factual knowledge as well as opinions towards technology and science. The second questionnaire retested the knowledge and opinions and gave feedback on the participants overall experience with the project.

The questionnaire used before the project consisted of 13 questions. The one used after the project included the same 13 initial questions but also 6 additional questions for pupils, and 11 additional questions for science teachers and teacher students. Details can be found in appendix 2. 12 questions were used for measuring learning gain, consisting of 8 multi-choice questions with only one correct answer and 4 open ended questions.

For multi-choice questions the score was set to 100 % for a correct answer and 0 % for a wrong answer, i.e. wrong box checked, multiple boxes checked or no box checked. Score on open ended questions was on a scale ranging from 0 % to 100 %. Details can be found in appendix 3.Since a sufficient number of computers not were available at the lab, a paper questionnaire form was used. Later the authors used the learning platform Fronter's test tool to register the responses electronically. The responses were then exported to a spreadsheet where the percentage of correct answers was calculated.

Certain goals of any general practical work are not directly tested quantifiably. Goals in scientific methodology may include training of laboratory skills, practical trouble shooting with hypothetical testing, learning objectivity and rationality and connecting theory with practice. There are also goals in motivation - making science and technology more interesting and accessible, as well as activating constructively pupils who are hyperactive. Some of this data was acquired through our own observations. We also interviewed the teachers of the two school classes to acquire qualitative data on observations of individual pupils, general feedback on the classes' response in relation to normal response. We also wished to learn more about the teachers' personal opinion about the project after they had tried it out.

Since the initial response from teachers attending our course was generally positive we were keen to ascertain the likelihood of the them actually implicating the project or an adapted version of it in their schools, and find the projects key positive and negative attributes in their opinion. They were therefor asked by email to give feedback.

Initial findings in learning gain

How well the students learnt the theoretical, secondary goals was tested with a multi-choice questionnaire given immediately before the project began - Pre-Test %, and followed by the same questions given after the project was completed - Post-test %.

The normalized learning gain <g> factor is defined by Hake (Hake, 1998) as:

$$< g >= \frac{(post\ \ test - pre\ test)}{(100\,\% - pre\ test)}$$

This gain is normalized and shows how much of the material not already known by the student that was learnt. This learning assessment is less sensitive to issues such as prior knowledge and use of multi-choice. Hake defines low <g> as values between 0 and 0,3 and found that most traditional courses in his survey fell into this category. Some highly interactive courses fell into the medium category with values between 0,3 and 0,7. Average gains higher than this are not expected. Despite being normalized the expected learning gain is of course dependent on the accessibility of the material from the students' current level of understanding, how it is taught and the time used to teach it. With a small sample size, a short project and lacking a control group the gains acquired are only indicative.

Learning gain for pupils is shown in Table 1. The pupils showed a positive gain on all questions, with an average gain of 0,25 which is respectable gain for of a traditional teaching course (Hake, 1998), (Keiner & Burns, 2010). It should be noted that the scores and gain on question 2 and the control question 13 differ considerably, even though the two questions were identical, differing only in formulation. Question 13, which also was the last theoretical question showed a lower score and also a lower gain. A possible explanation is questionnaire fatigue. The questionnaire was anonymous and cannot be considered to have the motivational level of a test. The effort of reading and thinking about the questions may quickly outweigh an initial motivation to answer the questions diligently. This factor further alienates the results from the questionnaires with the typical gain noted by Hake which is based on normal examinations of students motivated to achieve a good personal score.

The post-test sample size was notably smaller than the pre-test sample size - 40/59. The post test was conducted by the teachers who attributed the general high absentee rate for the post test to school holidays. They suspected no bias in these absentees.

The school classes were post tested several weeks after the course thereby showing long term memory. No extra tuition on these themes was given in this interim. Given that the lecturing time was only 30 minutes, and the topics covered considerable and difficult these tentative results seems to indicate that the scientific teaching goals are well complemented by the practical work. The construction of the IR-pen seems to have involved the pupils in the theoretical framework of the Wii Smart Board. It is likely that further theoretical summary taught after the project would have further increased the learning gain although this was not tested.

Learning gains for teacher students and participating teachers (small sample size) are also shown in Table 1. They showed a significantly higher gain than the pupils. The post test was run the same day however, thereby showing short term memory. A higher learning incentive may also be partly responsible. Disappointingly, the pre-test knowledge of the teacher students was lower than that of the pupils.

The subject of question 9, infrared refection, was not included in the lecture, so this question is omitted from the results.

		Pre-test	Post-test	
	P	N = 59	N = 40	
	S	N = 23	N = 22	
	T	N = 12	N = 12	
Question		%	%	**<g>**
2: How do you think a remote control transfers signals through the room?	**P**	73	88	0,56
	S	27	74	0,64
	T	100	100	-
3: How do you think a Bluetooth transfers signals through space?	**P**	19	53	0,42
	S	36	30	-0,09
	T	25	83	0,77
4: What is infrared radiation (IR)?	**P**	75	90	0,60
	S	73	100	1,00
	T	83	100	1,00
5 Are there several types or categories of infrared radiation?	**P**	37	55	0,29
	S	32	70	0,56
	T	58	100	1,00
6: Is infrared radiation stemming from people identical to that stemming from a fireplace?	**P**	54	63	0,20
	S	23	70	0,61
	T	54	58	0,09
7: Why do incandescent bulbs emit radiation a digital camera can see, but not fluorescent tubes or low energy light bulbs?	**P**	3	20	0,18
	S	8	48	0,43
	T	38	54	0,26
8: Does infrared radiation penetrate all the same substances as visible light?	**P**	44	50	0,11
	S	45	39	-0,11
	T	42	58	0,28
10: What is the main difference between microwaves, infrared and ultraviolet radiation?	**P**	26	41	0,20
	S	29	66	0,52
	T	83	83	0,00
11: What is solder used for?	**P**	59	63	0,10
	S	22	67	0,58
	T	92	88	-0,50
12: Draw an electrical serial connection with a battery, a switch and a bulb	**P**	31	38	0,10
	S	68	78	0,31
	T	58	92	0,81
13: Do you know how a remote control transfers signals through the room?	**P**	66	73	0,21
	S	32	70	0,56
	T	67	100	1,00
Average	**P**	**44**	**58**	**0,25**
	S	**36**	**65**	**0,45**
	T	**64**	**83**	**0,53**

Table 1: Learning gain for pupils (P), Teacher students (S) and teachers (T).

Pupil, student and teacher feedback

Based on question 16 in the post-test questionnaire we conclude that the project was positively received by all groups. Over 87% considered it more fun/engaging than average, and 49% gave it 5 or 6 out of 6. This is shown in Figure 4. A teacher in the school classes that employed the project, reported in an interview that unsettled pupils and pupils with theoretical learning difficulties were among those who enjoyed the project.

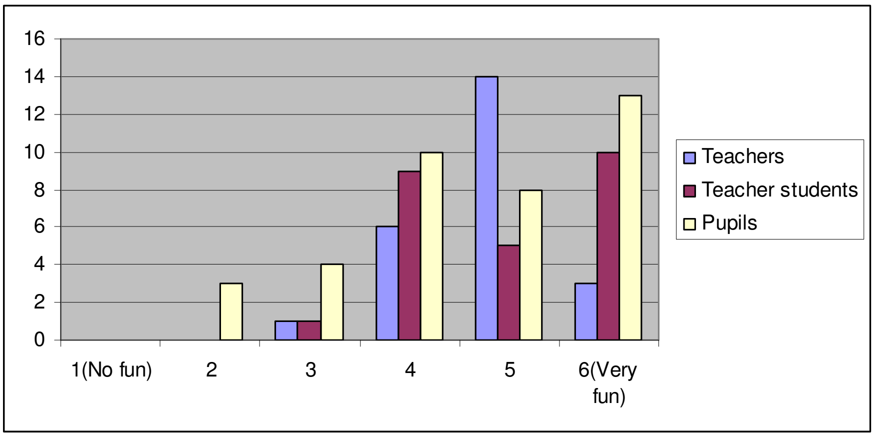

Figure 4: Responses to question "How fun/engaging was it to make an infrared pen and Smart Board?"

Only 5% of the pupils said they didn't know about Nintendo Wii prior to the project whereas 65% had actually played using Nintendo Wii themselves. Figure 5 indicates that the pupils achieved no significant change in their curiosity as to how technological science works, but the majority were initially interested. Some may have felt that the project satisfied their curiosity, but it does not seem to have inspired those few initially uninterested.

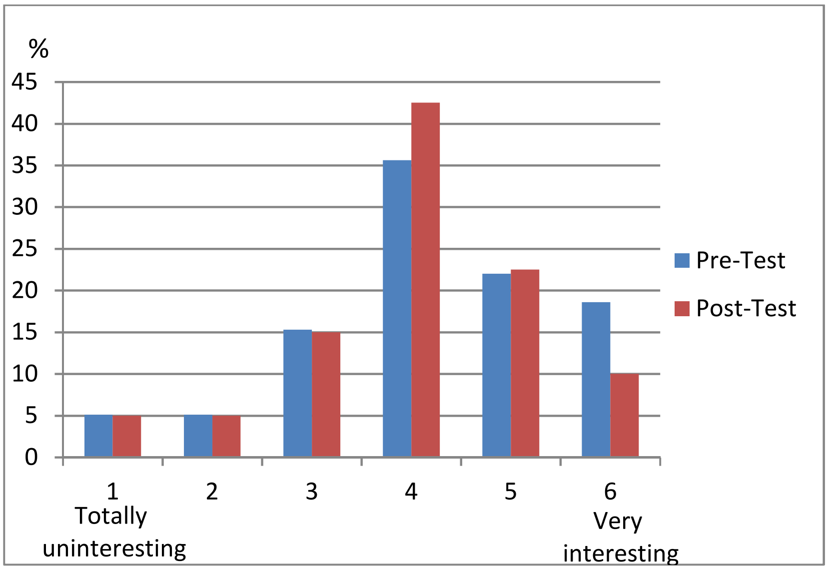

Figure 5: Pupil responses to question "Remote controls, mobile telephones and wireless internet use wireless communication. How interesting is it to know how they transfer signals we cannot see?"

Difficulties

We observed that most participants succeeded in building the IR-pen. Some needed several attempts to make it work, though. Common difficulties were bad soldering and reversed LED polarity. On a single occasion a LED did not work.

For teachers trying to run the software on their own computers we found that the major bottleneck was installing a driver for Bluetooth that was compatible with Nintendo Wii. Also, early free versions of the Wii Smart Board program did not work on Windows versions newer than XP, but a newer improved version could be purchased cheaply to solve this problem.

Not all driver software installed for the computers Bluetooth device is directly compatible with the Wiimote device so sometimes a new Bluetooth driver must be installed.

We've also discovered that the Wii Smart Board software does not run on computers with newer versions of Windows. A more advanced, commercial program, Smoothboard (Smoothboard, n.d.) can however be used instead. It works on both Windows 7 and Mac. The cost is around 20 euros including some user support.

Teacher assessment of pupils

In order to assess the less quantifiable aspects of the project's primary goals in practical technology and design the two teachers whose classes participated in our study were asked to assess the project. Table 2 shows the results of a questionnaire which consisted of a list of general learning goals typical of practical exercises. Each teacher was asked how they prioritized these for the project, awarding each goal low (L), medium (M) or high (H) priority, and asked to rank the degree of learning they thought the pupils achieved for each goal (1 = no learning, 6 = high degree of learning).

General learning goal	**Priority (L, M, H)**	**Pupils' degree of learning (1-6)**
Give training in laboratory/field skills.	M/H	5/6
Give training in design and functionality.	M/M	4/4
Give training in practical problem solving.	H/M	5/3
Give an insight and training in hypothesis testing and modelling.	M/L	3/3
Develop scientific attitudes such as openness, objectivity, belief in rationality, anti-authoritarianism, precision and documentation.	H/M	5/3
Highlight how theory is supported by experimental evidence.	H/M	4/3
Make science more alive and interesting.	H/H	5/5
Expand the pupil's insight in the nature of research and advertise for a carrier in research.	H/M	4/4
Constructively activate and motivate pupils who are hyperactive or prefer practical work.	H/H	5/6
Confirm, verify and repeat knowledge.	M/H	4/5
Deepen knowledge and make in concrete.	H/H	5/5
Introduce new terminology, models and theories.	M/H	4/ 5

Table 2: Priority and assessment of pupils' achievement for practical learning goals

On a scale from 1 (Very unlikely) to 6 (Very likely) the teachers were also asked to specify how likely it was that they would run the project again and how likely it was that they would recommend it to other science teachers. The results are shown in Table 3.

How likely is it that you will repeat this laboratory project?	4/5
How likely is it that you will recommend this laboratory project to other science teachers?	5/6 (have already done this)

Table 3: Likelihood of repeating project and recommending it to other teachers.

One of these teachers participated in a recorded telephone interview about the project. He spoke for his colleague also where possible In the interview the following major points were noted:

- The teachers thought it was positive for the pupils to work practically and the project was “spot on” to the curriculums learning goals.
- The time use was effective for both theory and practice.
- Certain pupils considered weaker in theoretical work succeeded very well with the project, while certain pupils considered to be theoretically strong became frustrated by not managing the practical work.
- The pupils had only a little relevant theoretical background prior to the project, but the introductory lecture did help to some extent. As preliminary work they had gone through the components, process, specifications, materials, designs and concepts.
- Pupils were evaluated on how the IR-pen worked according to specifications, and on a written report.
- Pupils had little opportunity to determine the framework of the project themselves, but it is difficult to see how the degree of framework determination can be increased.
- The degree of (theoretical) learning measured in the aftermath was neither higher or lower than normal teaching.
- In order for other schools to try the project it will probably be necessary with technical support.
- The reason why they will probably not be repeating the course next year is that the school received sets for Lego Mindstorms robotics and will probably be running a project based on this instead of the Wii Smart Board project.

Post course feedback from all participating teachers

A school project or practical experiment must actually be implemented in some form by a significant number of science teachers in order to be considered educationally effective. Therefore we polled the opinion of the twelve participating science teachers at the end of their half day course as to whether they found the project suitable for teaching, and whether they actually were considering using this project in their teaching. The results are shown in Figure 6 and Figure 7.

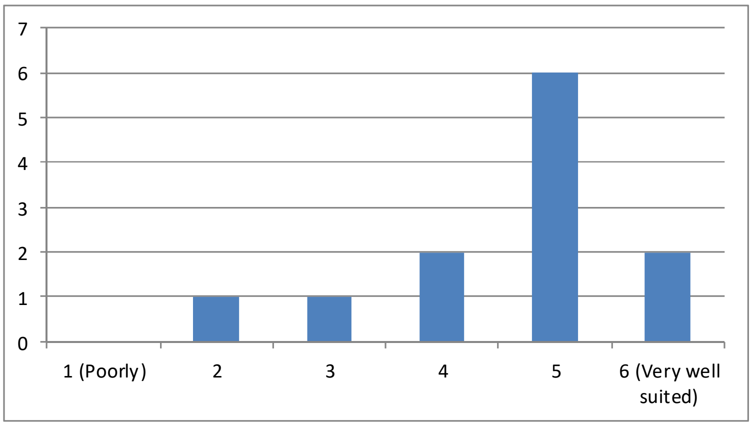

Figure 6: Teacher responses to question "How well suited do you think Wii Smart Board is for an 8th to 10th grade science class?"

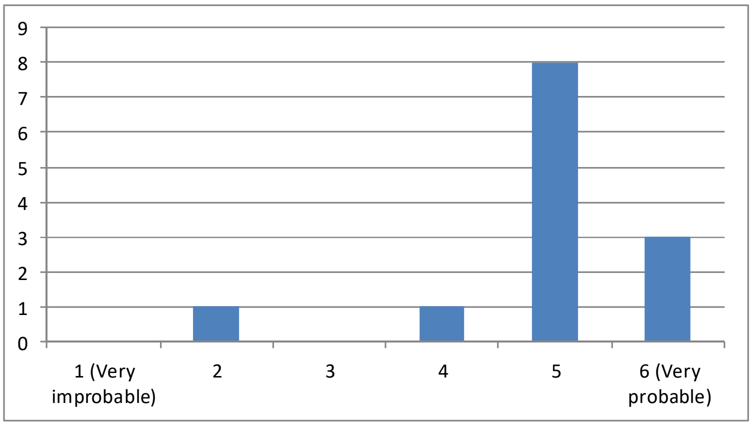

Figure 7: Teacher responses to question "If you taught an 8th to 10th grade science class, how probable is it that you would use Wii Smart Board in a class?"

Responses to why they would consider making a Wii Smart Board in a class were:

- Covers the learning goal on electronic communication processes, etc. that is otherwise difficult to attain.

- To meet the curriculum learning goals.
- Fun task, useful product to use.
- Exciting.
- Cheap. Practice in soldering and following instruction. Collaboration. Understanding a closed circuit.
- Fun. Educational. Covers curriculum learning goals.
- Motivational. Recognition.
- Incredibly fun to create their own Smart Board. It creates curiosity for technology/computing. Students gain a better knowledge of electrical connections and IR radiation
- You go through several elements related to technology and design to make it. Easy to engage students to such a task - they see fast results.
- Covers curriculum learning goals.
- They touch on themes in technology and design. They learn to solder.
- Technology and design in the science curriculum- product oriented.

Responses to why they would not consider making a Wii Smart Board in a class were:

- Some hassle to set up the Wii console, as well as with the placement with respect to finding optimal resolution.
- Requires some training in soldering and costs money.
- Time. Little practical use afterwards due to rigging.
- Price and equipment.
- First need to test the project personally in the classroom.

We conclude that about one third of the participants were unlikely to implement this project in reality, while the remaining two thirds appeared to be highly motivated. There were few concrete negative feedbacks. Where mentioned they included time, cost and the participant's insecurity about implementation. Another participant found the cost reasonable and a positive aspect. The ability of the project to cover key curriculum goals in technology and design was a clear positive recognition amongst the participants. Motivation, enjoyment and secondary goals in electronics and practical soldering skills were also mentioned.

Poll of participating science teachers 16 months after course

There is often a dispartity between a teachers postive impression right after a sucessful course and the pratical reality they meet when returning to school. There may also be anxieties about going ahead alone. We therefore polled the teachers who had attendened the course on whether they had implemented it in their school, and if not, why. The responses are shown in Table 4.

Successfully completed project without assistance	1
Successfully completed project with some minor backup assistance	2
Attempted project but failed due to technical difficulties	1
Have not attempted project with a school class.	5
Have not replied	3

Table 4: Teacher responses to poll on whether they have implemented the Wii Smart Board project in their school.

The technical difficulty met by the one participant who failed was installing the Wii Smart Board program on a Windows 7 operating system. At the time the windows 7 operating system was relatively recently introduced to the market. We advised using a commericial version of the Wii Smart Board program which was compatible with Windows 7 and offered email support and an improved interface. The program, Smoothboard (Smoothboard, n.d.), costs around 30 USD per liscence in 2010. The free version was tried with temporary success, but was user was not willing to buy the liscence, and became frustrated with the commersial interrupts of the free version.

Of the five particpants who did not attempt the project one gave a reason that the school had employed commercial interactive whiteboards and therefore it was not necessary. Another cited the time required in preparations and insecurities as the reason.

Conclusions

We conclude that the technical implementation of the Wii Smart Board project is feasible for school teachers who already have some basic interest in IT and are familiar with downloading and installing software. Both teachers and students are impressed by and engaged by the project. Teachers are particularly impressed by how the project covers learning goals in technology and science. The end product, an inexpensive interactive whiteboard is also a motivation factor. Teacher feedback indicates that the primary learning goals in technology and design and practical science are achieved fairly effectively. Quantitative learning gain on secondary goals related to the understanding of the science shows that the project works on many levels. The project engages most pupils and falls within their sphere of interest. Although being generally enjoyed the project by itself appears to have little obvious impact on general interest of pupils towards the science behind technology.

Despite the projects feasibility, low cost and apparent popularity with the teachers, it has not been widely implemented. The sample size is however too small to draw generalized conclusions. The program is robust enough for schools, but requires a small investment in equipment a modest initial investment in time. This could be beyond the threshold of many teachers. It is likely that this situation is compounded if some teachers have insecurities related to a successful implementation of the project. For many teachers the scientific background necessary to fully understand how the Wii Smart Board functions seems to be deficient, even though the themes should be within the standard science curriculum. A significant insecurity is also likely to be connected to an experience that school computing systems are poorly maintained and/or have restrictions on downloading of programs and drivers. Different versions of operating systems and problems of installing a successful driver for the Wiimote seem to have caused bottlenecks despite that the Wiimote is a highly commercial standard product. Access to internal computer expertise or external helpline support may be an important prerequisite for teacher participation. Comprehensive coursing is also a prerequisite and a half day course may not be sufficient in light of these tentative findings.

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Appendix 1 - Comparison of a Wii Smart Board and a commercial Smart Board

One motivation for teachers to run the Wii Smart Board project may be that the Smart Board is useful in daily school teaching afterward, with the educationally rewarding aspect that pupils learn about and have constructed equipment that the teacher actually uses in regular teaching. The primary learning goal also requires the pupils to evaluate the products functionality and user friendliness. We therefore have examined how the Wii Smart Board compares to a commercial Smart Board. Both equipment are robust, require a simple installation of software and simple calibration. The commercial Smart Board uses 4 pens with different colours, which must touch a screen to write or register, while the Wii Smart Board functions much closer to a conventional mouse and therefore is immediately more intuitive to the user. The major advantage of the commercial touch screen is a slightly better resolution and software, and that the user does not have to worry about blocking the signal from the pen to the Wiimote. Furthermore the Wiimote needs to be placed securely where it will not be disturbed accidentally. A fixed roof installation together with the projector is advisable. The Wiimote and IR-pen require occasional battery replacement and can be thrown off by strong sources of near infrared, such as direct sunlight and incandescent light bulbs. The major advantage of the Wii Smart Board is price, around euro 80 euros against the commercial Smart Board costing around 1500 euros. Wii Smart Board is also portable as it is not dependant on a touch screen. It can therefore be used in all classrooms that have video projectors. Generally Wii Smart Board is preferable where use in is occasional or where a portable system is needed. The commercial interactive whiteboard is more suited to comprehensive use where the high cost is better justified.

Appendix 2 - Questionnaires

Questions answered both before and after project

Question	Alternatives for multi-choice questions
1: Remote controls, mobile telephones and w wireless Internet uses wireless communication. How interesting is it to know how they transfer signals we cannot see?	Scale from 1 (Completely uninteresting) to 6 (Very interesting)
2: How do you think a remote control transfers signals through the room?	Through microwave pulses Through infrared pulses Through ultrasound pulses Through light pulses too weak to see Don't knows
3: How do you think a Bluetooth transfers signals through space?	Through microwave pulses Through infrared pulses Through ultrasound pulses Through the Internet Don't knows
4: What is infrared radiation (IR)?	A particular kind of sound humans can't hear A particular kind of light humans can't see Electronic pulses Don't know
5: Are there several types or categories of infra-red radiation?	Yes No Don't know
6: Is infrared radiation stemming from people identical to that stemming from a fireplace?	Yes No Don't know
7: Why do incandescent bulbs emit radiation a digital camera can see, but not fluorescent tubes or low energy light bulbs?	
8: Does infrared radiation penetrate all the same substances as visible light?	Yes No Don't know
9: Can infrared light be reflected? (Not taught or demonstrated)	Yes No Don't know
10: What is the main difference between micro-waves, infrared and ultraviolet radiation?	
11: What is solder used for?	

12: Draw an electrical serial connection with a battery, a switch and a bulb	
13: Do you know how a remote control transfers signals through the room?	Don't knows Through light pulses too weak to see Through infrared pulses Through microwave pulses Through ultrasound pulses

Questions answered after project only

Questions marked [p] were answered by pupils only, questions marked [t/ts] were answered by teachers and teacher students only.

Question	**Alternatives for checkbox questions**
14: How many times had you used a Nintendo Wii before today?	Did not know about it Never, but knew about it 1 - 5 times More than 5 times
15: How are your computer skills? (You may check multiple boxes)	Can use a word processor, (for instance Word) Can find, download and install software Know some programming
16 [p]: How fun/engaging was it to make an infrared pen and Smart Board	Scale from 1 (Absolutely not fun/engaging) to 6 (Very fun/engaging)
16 [t/ts]: How fun/engaging was the project?	Scale from 1 (Absolutely not fun/engaging) to 6 (Very fun/engaging)
17: Mention some limitations with Wii Smart Board How can design of infrared pen and positioning of Wii remote help Wii Smart Board to become better	
18 [t/ts]: Mention some advantages / disadvantages by using Wii Smart Board compared to a commercial Smart Board in school?	
19 [t/ts]: What do you think the advantages / disadvantages of the pupils creating and soldering their own infrared pen instead of just replacing the diode in a key chain flashlight	
20 [t/ts]: How well suited do you think a Wii Smart Board is for a science class in secondary school	Scale from 1 (Poorly) to 6 (Very well suited)
21 [t/ts]: If you taught science in secondary school, how probable is it that you would use Wii Smart Board in a class?	Scale from 1 (Very improbable) to 6 (Very probable)
22 [t/ts]: Reasons you can't imagine using Wii Smart Board in a class	

23 [t/ts]: Reasons you can imagine using Wii Smart Board in a class	
24 [t/ts]: Other comments	

Appendix 3 - Score calculation on open ended questions

7: Why do incandescent bulbs emit radiation a digital camera can see, but not fluorescent tubes or low energy light bulbs?	
Correct explanation based on heat, temperature or colour temperature	100 %
Explanation mentioning amount of infrared emitted	50 %
Explanation based on different wavelengths or frequency	50 %
Other explanations, don’t know or no answer	0 %
10: What is the main difference between microwaves, infrared and ultraviolet radiation?	
Correct explanation based on difference in wavelength, frequency or photon energy, ordering them correctly	100 %
Correct explanation based on difference in wavelength, frequency or photon energy, but with ordering incorrect or missing	90 %
Explanation based on energy, but not mentioning wavelength, frequency or photon energy	50 %
Explanation based on ability to penetrate, or other correct radiation properties	50 %
Other explanations, don’t know or no answer	0 %
11: What is solder used for?	
Correct explanation based on connecting or welding electrical components or wire	100 %
Explanation based on connecting or welding, not making it clear that it is about an electrical circuit	50 %
“For soldering”	50 %
“For gluing” or “for fixing”	30 %
Other explanations, don’t know or no answer	0 %
12: Draw an electrical serial connection with a battery, a switch and a bulb	
Correct drawing	100 %
Drawing without a closed circuit, with several circuits, component excluded from drawing or no drawing	0 %