Wii Science: Teaching the laws of nature with physically engaging video game technologies

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INTRODUCTION

The *Wii Science* project is a recently initiated collaborative research project between Stanford University, Södertörn University and two primary schools: Årstadalsskolan in Stockholm, Sweden, and the Nueva New School in Palo Alto, US. It is supported for a total time of 3 years by the Wallenberg Global Learning Network. The primary focus of the project is to introduce science education to learners through the use of a familiar technology: computer and video games.

A great number of educational and edutainment projects have already used video games to teach topics such as physics, math, language, etc., using traditional game or computer controls. Recently, however, commercial games have shifted to incorporate gestures and body motion, as exemplified by a variety of games where the player is required to actually perform real-world physical movements to control the game. This includes an array of dancing games, where the player follow a sequence of instructions by dancing on a sensor mat (e.g. *Dance Dance Revolution*); sports games, where the player performs movements mimicking those required in real games of bowling, boxing, tennis, etc. (e.g. *Wii Sports*); and music games, where the player acts out pieces of music by playing on replicas of real instruments (e.g. *Guitar Hero, Rock Band*). This new focus on physicality in video games has had several benefits, both by making the games more socially engaging for a co-located group of players, and by introducing a degree of physicality to an activity that was previously considered unhealthy and inactive. There is even a popular exercise program, *Wii Fit,* which includes a special sensor board to track the player's movements.

In this project, we are using the popular *Wii game controller,* aka *Wiimote*, manufactured by Nintendo. This piece of commercial hardware has the advantages of being cheap, easy to modify and write software for, and in particular, it includes a very advanced and robust motion sensor (the technical term is accelerometer). However, rather than using the Wiimote as a direct controller for the player's on-screen avatar, as in most popular games, we want to apply the technology to let students explore phenomena related to physics and natural sciences. We will construct software (on a standard personal computer) that collects information from the Wiimote through BlueTooth, and lets students see the sensor readings in real time, as well as letting them perform predictions of what will happen in different situations. For instance, children could explore the laws of acceleration by first using the software to predict what would happen if they dropped a series of objects of different weight out through a window. They would then attach Wiimotes to the actual objects, drop them out the window for real, and see how their predictions matched the actual sensor readings of acceleration and speed. In another example, students could build a miniature roller-coaster track including sections of drops, rises, level passages, etc. They would first predict the performance of a car in the track, using our software to plot it out. Then, they would attach a Wiimote to an actual model of a roller-coaster car and send it through the track, observing in real-time the acceleration and speed of the car as it weaves up and down through the track. With sufficiently portable computer technology, they might even be able to repeat the experiment in a real roller-coaster in a local amusement park!

Thus, by leveraging the sensory capabilities of game controllers that youths already enjoy outside of school, we can introduce physical exploration as a means to engage in learning about phenomena from natural science. Key concepts of physics – work, energy, force, potential energy, kinetic energy, momentum – may be introduced as aspects of the interactive setting that students are exploring. The students will get real-time feedback about how different actions taken with the Wii controller affect various physical measurements. In addition, we can help familiarize students with the practice of scientific experimentation by enabling the use of Wii controllers in students' open-ended exercises. Our goal in this project is to develop robust and deployable materials that will enable educators in a variety of settings to incorporate Wii Science into their programs and curricula.

THEORETICAL AND PEDAGOGICAL BACKGROUND

The field of human-computer interactions is increasingly coming to recognize the importance of the physical and material dimensions of interaction with computational artifacts. The interplay of social and physical interdependencies in interaction is a central theme of much contemporary research of people's interaction with technology. This is most evident in notions of embodied interaction and situated conduct in the works of Dourish

(2001) and Heath and Luff (Heath et al. 2000). Issues of physicality, materiality, embodiment, and social space are also central in research on pervasive computing and tangible interfaces, in which the particular physical manifestation of a computational artifact and its consequences for people's interaction with and through the artifact is commonly brought to discussion (Hornecker et al. 2006; Klemmer et al. 2006). Recent research along these lines suggests a shift away from an information-centric to an action-centric perspective on interaction. This shift has been elaborated in several publications by members of this project during the last year (Fernaeus, Tholander & Jonsson, 2008a, 2008b). These developments indicate how complex cognitive processes are deeply intertwined with and dependent upon our physical bodies and our relations to the material and physical properties of our social world. Thus, new interactive technologies that support mobile, bodily, and social activities beyond the desktop setting enable a shift both in the development of new forms of user interactions, as well as new tools to be used in learning activities.

Learning and tangible artifacts

The theoretical backdrop of our project is in line with the current trend towards conceptualizing cognition and learning as embodied and situated phenomena. This perspective posits that our thinking and knowledge acquisition is intrinsically intertwined and dependent upon the people and artifacts around us and how they mediate the physical world (Lakoff and Johnson, 1999; Säljö, 2000). These perspectives are also central to the research fields of Computer Supported Collaborative Learning (CSCL), which focuses on the role of designed artifacts in people's joint meaning-making (Koschmann, 2002), and secondly, in current work in CSCW and Ubiquitous Computing that attempts to more closely integrate physical and social reality in interaction with software (Dourish, 2001). From our point of view, CSCL research is not only the study of how people interact and learn with designed artifacts, but also the study and design of the situations in which efficient learning is taking place. Learning situated outside a dedicated learning environment such as the school is often referred to as informal learning. Learning then arises from the activities and interests of individuals or groups and may not even be recognized as learning (McGiveney, 1999). Until now, research has paid only limited attention to the artifacts used in informal learning and play situations such as after school clubs and homes, nor has much effort been put into the design of such artifacts. An emerging body of research is concerned with educational research as a process of design (Journal of the Learning Sciences, 2004, Educational Researcher, 2003). Central to this kind of work is that it has transformative agendas, e.g. developing technologies and activities in support of renewed educational situations. Similarly, in research about Interaction Design and Children an important element has been to design new educational technologies together with children in school settings and to study how children use these technologies for their own learning (see Druin, 1999). This work has lead to the development of e.g. story telling tools, digital libraries, and game programming environments.

Approaches to the design of interactive computer based educational material that explicitly takes the embodied and enactive perspectives on thinking and action into consideration are few. One example of such a representation is tangibles, which lets physical, as well as virtual objects, be a part of the computational system. Tangible approaches to interactive learning may make abstract concepts more concrete and easier to manipulate. It is also argued that since tangible objects simultaneously work as input and output devices, they provide a tighter connection between control and the representation of the underlying computation (Ullmer and Ishii, 2001). In the proposed project we take informal learning situations and the artifacts commonly used in those as the starting point for the design of novel technologies for in-school learning.

Bodily engaging technologies

Our choice of video game controllers as an entry point was made to explicitly address how technologies commonly used in everyday play and leisure practices can be incorporated into educational settings. These technologies are pervasive: for instance, over a quarter (29%) of US children have played with console games before the age of 6 (Rideout & Hamel 2006). By integrating elements of video game technologies into our educational curricula, we believe that we can enhance students' interest in their educational activities, materials, and technologies, and, conversely, make them consider the underlying scientific principles that they've learned about whenever they use these video game controllers.

We selected the Nintendo Wii game controller as a platform for our project both because it is very popular with a wide age range of children and because the controller features numerous sensors and actuators that make physics experimentation possible. A main feature of the Wii Remote, or Wiimote, is its motion sensing capability, which allows the user to interact with and manipulate items on screen via movement and pointing through the use of accelerometer and optical sensor technology. This allows the user to make physical actions and gestures with the controller for gameplay, rather than traditional button pushing. Such actions include swinging the controller, making slicing motions, steering, balancing, thrusting, and pointing. The controller features infrared sensing technology, which can be used to track moving objects instrumented with simple infrared LEDs and batteries. The controller also has a built in speaker and basic force feedback. (Morgan, Butler and Power, 2007) The Wiimote uses the Bluetooth protocol to communicate wirelessly with the Wii game station, which makes it easy to adapt the Wiimote to use with any PC with Bluetooth capability, without any hacking or modification of the Wiimote or the PC—an important factor to adoption and accessibility of our project. In addition, the Wiimote has been designed to interface with additional devices (e.g. the Wii Nunchucks) and also to be housed in a variety of shells (e.g. steering wheels, guitars, tennis rackets) that afford different kinds of motions and gameplay—this will make it easier both to augment the Wiimotes and to incorporate the Wiimote into student-designed experimental apparatuses.

There is currently a wide array of projects investigating the use of the Wii: developing the motor skills of preschoolers (Bryant, Akerman and Dresll, 2008), supporting disabled students in education (Pearson and Bailey, 2007), teaching musical rhythm (De Bruyn, Leman, and Moelants, 2008), and, of course, promoting physical activity (Graves, Stratton, Ridgers, & Cable, 2007).

We are also able to leverage existing tools on the software side of our design. Exemplar (Hartmann, Abdulla, Mittal & Klemmer, 2007) is a software program developed at Stanford that allows users to create sensor-based interactions by demonstration. By providing a graphical interface augmented with direct manipulation and pattern recognition, users are able to see live data from sensors connected to a computer, and to create filters and transforms that translate the data into more meaningful continuous and discrete events. This software was originally designed to interface with Stanford's own suite of prototyping sensors, d.tools (Hartmann, Klemmer, Bernstein, Burr, Robinson-Mosher & Gee, 2006), and was tested with college-age students; we intend to modify this software to suit a younger user group and to interface with the Wiimote.

GOALS

The overall goal of the project is to produce a robust, easy-to-use hardware/software system to enhance science learning using existing video game controllers. We would like our system to be readily adopted and deployed, not just by the partner schools but also by other schools and learning institutions – eventually being distributed over the Internet. We intend to evaluate our designed system in an iterative and participatory manner, using a combination of informal, formal, short-term and long-term real-world user studies over a range of different user groups in the participating schools and elsewhere. Our intention is that after the three years of the project it will be possible for schools to continue running the system without our direct intervention. We will also release the finished system as open-source for free download on the Internet. Since the hardware is standardized (Wiimotes, BlueTooth adaptors), we believe it will be possible for schools anywhere to install and use the system with minor technical effort.

In addition to the technical development and user testing, we will also work with important research issues regarding the use of body and movement-based information and communication technologies such as the Wiimote in education. Some of the research questions include:

- To what degree is it necessary or desirable to mimic the visual language and functionality of the ICT in the learning application?
- What lasting insights does the learning program impart to the learners about their everyday interactions with ICT?
- What interface design techniques best convey physical principles to learners?
- What auxiliary materials and technologies best scaffold the use of the Wiimote as a tool for scientific investigation?
- What existing understanding do learners bring to the educational experience based on their prior familiarity with the ICT tool? How does that understanding vary by age? by culture?

We also have a number of *teaching and learning goals:*

1. Enhance interest and engagement in science: We hope to stimulate student interest in scientific and mathematical principles by demonstrating their relevance to the tools and activities they find in their day-to-day lives. We believe that use of existing video-game technologies in the classroom can encourage reflection of educational lessons outside the classroom.
2. Reinforce existing curricula: Our systems are intended to reinforce scientific concepts learned in the classroom, albeit through different learning styles. System use should be integrated with the existing curricula, teaching methods and teaching aids in schools, which both ensures relevance to the recipient schools and lets researchers concentrate on interaction techniques rather than developing new teaching materials and evaluation metrics.
3. Encourage open-ended scientific experimentation: Our systems should also be flexible enough to support students who are interested in using the Wiimote to investigate their own questions about bodily and physical movement. This can enhance student's understandings of science as a process and not just a subject matter.
4. Real-world usage in schools: The prototypes and systems produced in the project should be continuously used in the two partner schools, and by the end of the project they should be robust enough to be continued to use without support from the research team.

EARLY FINDINGS

We are currently in the middle of two studies of the schools involved in the project: The Årstadalsskolan elementary school in Sweden, and the Nueva School in Palo Alto, which caters to Pre-K to 8th grade children.

At Årstadalsskolan, we followed a group of younger children between the ages 6-10, examining how the pedagogical work in the school is organized, how they work with existing technologies, how they work with learning styles, existing pedagogical material etc. This group is not yet explicitly learning about scientific concepts like gravity and acceleration, but are instead working with broader concepts like ”the body”, which is an upcoming theme that we will build upon in our future work. The study shows that the teachers actively works with incorporating support for different learning styles in their pedagogical activities, but that the possibilities for this is restricted by the course material that is available. The specifically state that they lack pedagogical material to support the kinesthetic learning style. Here we thus see an interesting opening for the project to create course material supporting kinesthetic learning activities based on the Wii-controllers.

Similarly, at the Nueva Schol, we have discovered that, for middle school students, it is important not to assume that they will be able to immediately make sense of the data presented. Basedon our observations of students interpreting data from current physics laboratory exercises, we think that it may be important to set the context for the data streams--perhaps by having the interface quiz the students about what the labels of the axes on an accelerometer plot might be, or asking them to sketch out qualitative guesses about what plots they expect – prior to showing students the live data plots.

Furthermore, a first example application have been developed that allows for an exploration of the concept of gravity. In this application you interact with a 3d environment using the Wii-mote and study the effects of your actions under different gravitational forces.

CONCLUSIONS

In the Wii Science project, we will leverage a familiar technology – physical video game controllers – to introduce physical exploration as a means to engage in learning about phenomena from natural science. The students will get real-time feedback about how different actions taken with the Wii controller affect various physical measurements. In addition, we can help familiarize students with the practice of scientific experimentation by enabling the use of Wii controllers in students' open-ended exercises. Our goal is to develop robust and deployable materials that will enable educators in a variety of settings to incorporate our system into school programs and curricula, and to continue using it after the project is over. The project is well aligned with the partner schools' pedagogical approach, which includes social and physical exploration as well as working actively with concepts such as learning styles and tactile and kinesthetic learning. The theoretical foundation draws on current trends in human-computer interaction, where embodiment and physical engagement are becoming a key issue. At the CHI workshop, we hope to share our recent progress in the project, including preliminary studies at the two schools as well as early prototypes.

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