INTEGRATING COMPUTER SIMULATIONS INTO THE TEACHING OF PHYSICS - AN ACTION RESEARCH APPROACH

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ABSTRACT
This paper describes the use of an action research approach in determining different teaching strategies for the use of computer simulations by physics teachers. Six physics teachers from two different school districts collaborated in two cycles of action research. Three methods of gathering data were employed during each research cycle. This approach facilitated the use of triangulation in determining common results. The first data gathering method focused on journaling - teachers maintained a journal on their thoughts and their reactions while they were implementing the computer simulations. The second methodology was individual interviews during which teachers shared their thoughts, opinions, and observations regarding the implementation of the computer simulations as well as on the use and relative merit of the action research approach. The third method was a general meeting that was held at the end of each cycle of implementation and research to review the participants' experiences. The research suggested that collaboration among physics teachers could be one of the better ways of deciding new strategies for using simulations in the teaching of physics. One of the main findings is that teachers will change their instructional style when working together in practical action research groups.

KEYWORDS
ICT in education, computer simulations, physics, action research

INTRODUCTION

Computers are readily available in today's learning environment (Martin, Austen, Brouwer, & Laue, 1999). Physics teachers can incorporate computer technology in their teaching strategies to aid in the understanding of physics concepts. Many types of software have been developed to teach various concepts in physics (Martin et al. 1999).

With SuperNet (broad band using optical fiber as conductors) coming to Alberta schools, teachers will have at their disposal all the resources available on the servers of Alberta Education (the province's department of education). Physics teachers will be able to download any movie or simulation that is available for teaching purposes.

Physics teachers are members of a relatively small peer group. When the time comes to explore or implement a new teaching strategy, physics teachers often do not have anyone to collaborate with in their own school. Thus, a physics teacher in a school often has to decide in isolation which teaching strategy to use. The teacher might use a strategy that depends on his/her understanding of methodological and epistemological aspects of science and the way they present the material (Brickhouse, 1990; Lederman, 1992; Gustafson & Rowell, 1995; Koudalis & Ogborn, 1995; Laplante, 1997).

Today, excellent computer simulations are available for use in the teaching of physics. A viable strategy for overcoming the isolation factor in the implementation of innovations is for teachers to engage in action research (McNiff, Lomax, & Whitehead, 1996). This paper describes an action research approach to the implementation of computer simulations in the physics classroom

Action research was chosen in part because, according to Waters-Adams and Nias (2003), "the driving force within action research is the participant's desire to discover what their practice is and to see how it can be improved" (p.287).

RESEARCH PURPOSE AND METHOD

Research question and rationale

The central purpose of the research was to explore the implications when physics teachers apply practical action research in determining the use of computer simulations in their teaching practice.

In their quest to constantly improve their teaching practice, teachers relate strongly to the experiences of their colleagues. Action research usually purports to be addressing the improvement of practice (Waters-Adams, S. & Nias, J. 2003). In fact, an important characteristic of the approach is that participants are typically practitioners (teachers in this instance) who will have significant input into the implementation of the research (Bowman et al., 2001). Thus, in using a collaborative approach to research, it was anticipated that teachers' experiences with the integration of computer simulations might provide some insight into how future technological innovations might best be implemented.

The simulations used in this project were part of a suite of Java applets called, a Modular Approach to Physics (MAP). Figure 1 below shows a typical screen from one of the applets.

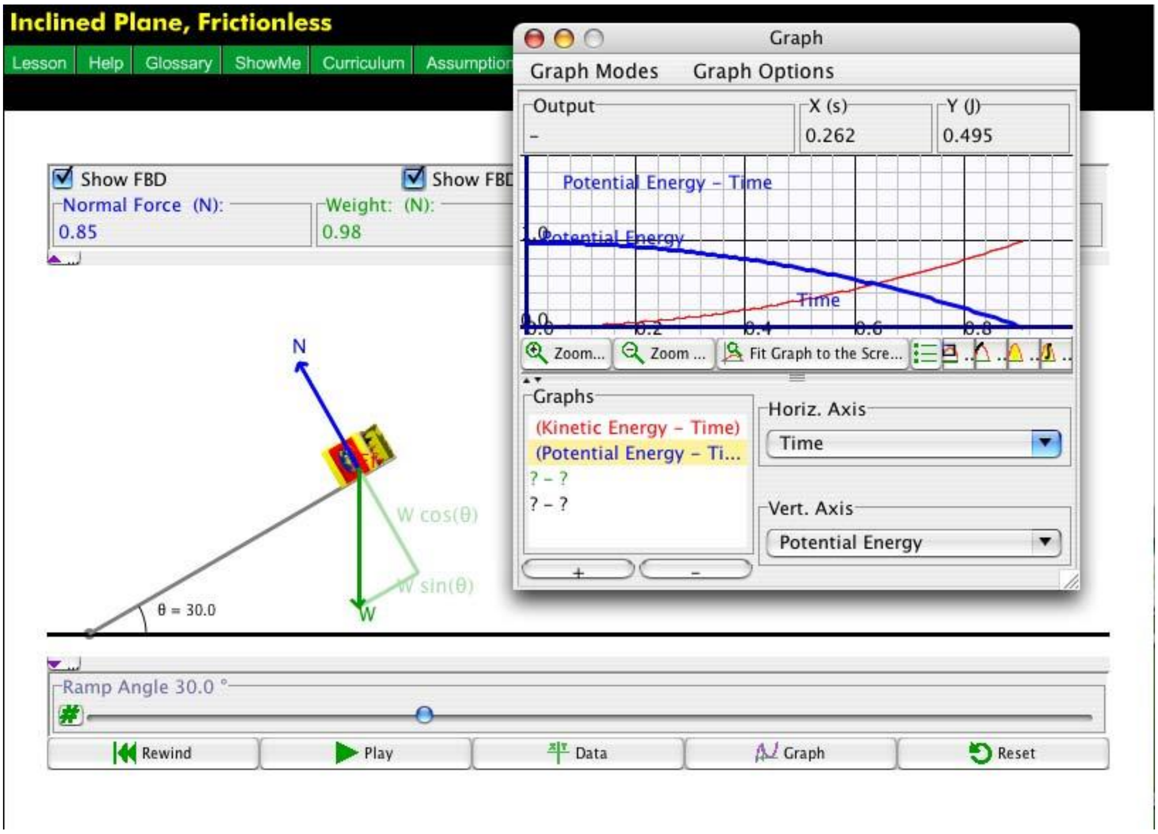

Figure 1. A typical screen from a computer simulation applet

Method

Practical action research occurs when a group of teachers is committed to the same goal (idea). They possess what is called practical judgement whereby they have a disposition toward 'good' action rather than 'correct' action. There seems to be a sense of moral consciousness. They own the idea of improving the teaching strategies that they want to implement. It has been said that practical judgement results in *doing* action (praxis). According to McNiff, Lomax, and Whitehead (1996) "Praxis is informed, committed action that gives rise to knowledge rather than just successful action. It is informed because other people's views are taken into account. It is committed and intentional in term of values that have been examined and can be defended. It leads to knowledge from and about educational practice." (p. 8) As stated by Grundy (1982) "Practical action research seeks to improve practice through the application of the personal wisdom of the participants."(p.357).

One of the authors, three additional teachers from the Edmonton Catholic Schools, and two teachers from the Edmonton Public Schools volunteered to participate in the research. All of the teachers except for one participated in a Physics Summer Institute that focused on the application of a number of key computer simulations in physics teaching. Some of these simulations were used in this practical action research. These simulations can be found on the Alberta Education servers located at (http://www.learnalberta.ca).

Qualitative methods were used to obtain data. According to Wolcott (1988) the strength of qualitative research lies in its triangulation, collecting information in many ways rather then relying solely on one. Therefore, three different ways of collecting data were used. One method used was a general meeting in which everyone attended and discussed the simulations. Another method was the use of interviews in which the author would ask convergent (closed) and divergent (open ended) questions pertaining to the use of the simulations. The last method was the use of journaling in which participants recorded their evaluations, observations, and feelings associated with the action research process.

The research group used the mechanical sequence of steps listed by Kemmis and Wilkinson (1998) which involve a spiral of self-reflective cycles: a) planning a change; b) acting and observing the process and consequences of the change; c) reflecting on these processes and consequences and d) re-planning, and so forth.

During the first meeting, participants reviewed their current practice and considered ways of utilizing the simulations in the teaching of physics. It was also important to establish a feeling of trust among the participants because this facilitated honesty and integrity in the discussions. During the meeting, consensus was used to determine how the simulations would be utilized. After the meeting the teachers implemented the agreed upon practice. Qualitative data was gathered through the use of interviews and personal journals. The author/participant conducted individual interviews with the other participants during each cycle. All discussions held during the meeting and during the interviews were transcribed. The participants were also asked to journal their thoughts on the implementation of the simulations during each cycle. In all, there were two cycles of action research.

During the first cycle, the consensus was that the simulations were to be used as demonstrations. The teacher would project the simulation on a screen and follow the direction of the program. During the viewing, the students participated by providing the answers to the questions in the program. Also, the students and teacher interacted through questioning and by discussing the physics concepts addressed by the program. At the end of the first cycle, the participants met to share their experiences and to decide upon the direction to follow in the second cycle.

It was decided by consensus that, in the second cycle, the simulations would be used as a lab experience. The students would go into a computer lab and follow the instructions in the simulation program. At the end of the lab, they would hand in their work for evaluation. The interviews and journals were repeated as in the first cycle but they were relevant to the decisions agreed upon for the second cycle.

OBSERVATIONS

Cycle 1 – Use of simulations in demonstration mode

Tables 1-3 summarize the findings from the three data gathering processes that constituted the first cycle of the action research project, notably; individual interviews, individual journals, and the general group meeting.

Table 1. Summary of Individual Interview Responses from Cycle 1

Question	Most Frequent Response
1. In what courses did you use the MAP simulations?	Mostly in Physics 20
2. Number of students in each class?	An average of 24
3. Which simulations did you use?	Mostly the vectors and the inclined plane
4. How many times did you use the simulations?	Mostly once in each class.
5. In which location did you use it?	In the classroom
6. How much time did you spend to prepare for the demonstration?	An average of 30 minutes
7. How did you use the simulation (intro, midway or reinforcement)?	Mostly midway with intro and reinforcement coming second.
8. Give me a brief description of how you used it.	They were used midway to confirm and solidify the concept.
9. What strategy did you use during the demonstration?	During the demonstration, "what if " questions were used to interact with the students, which led to the understanding of relationships between the variables.
10. Were the simulations easy to use?	Yes. They were easy and user friendly
11. What was your reaction (+ or -)? Why?	Mostly positive. The negative part was mainly due to the fact that the classroom didn't have the LCD in the room. Therefore it took extra time to prepare for the lesson.
12. What were the students' reactions (+ or -)? Why?	(+) This is cool. The students were engaged. It made them understand the lecture. "What if" questions made them think. Enjoyed the simulations. Motivated them to do more. (-) They felt confused at times due to the fact that the teacher had not presented it in the same manner. In this mode the students wanted to go faster. Some students, because they weren't writing notes, felt that they weren't learning.
13. Would you use it again in the same manner?	The teachers would use them again. Some would use the demonstration as a follow up to the lab, others to enhance their lectures with the visuals and others still to introduce the concept to the students.
14. Any other comments or observations.	The simulations will be used due to the fact that they demonstrate visually hard to explain situations. They are adaptable to the strategy that the teacher wants in his/her practice. At first it takes time to integrate the simulations into the teaching practice.

Table 2. Summary of Individual Journal Entries from Cycle 1

Participant	Summary of Journal Entries
Teacher A	Some typos and some improperly labeled buttons were discovered. Also, not as user friendly as he hoped in some simulations. Due to the fact that no video projector was present in the class, it took him some time to get started. In the frictionless inclined plane simulation, the regular students were more interested at the beginning than the Academic Challenge (AC) students. Regular students were able to better understand due to the visual account of what was happening. The AC students used math to calculate the results but when they did the "what if" questions they found it harder to find the solution mentally. Upon calculation, they found the answer. Overall, the experience with the AC class was more rewarding. It seems that it is the nature of these academic students to actively pursue and welcome enrichment, while the other class looks at it as more work.
Teacher B	He wanted to introduce vectors and displacement. He found that the visual in the displacement simulation worked well. Showed that the net displacement is the same as the saying "as the crow flies"
Teacher C	The inclined plane simulation, worked well, especially graphing the various energy vs. time graphs in real time. With the circular motion simulation, the concept that the students typically have trouble with is that the speed is constant but velocity is not. When the question was asked "What happens if you cut the string?" they could clearly see the effect and therefore understood. The teacher with supporting stories and anecdotes augmented this simulation. A stand-alone video projector had to be brought in to view the simulations on the CD. The collisions simulation also worked well with the "what if ".
Teacher D	The teacher wanted to review vector addition and found the simulation helpful in having the students visually see what happens. The teacher wouldn't have used the simulation if a video projector was not available in the class. He reviewed the graphical and the numerical method of doing the vector addition. Also, for projectiles the students could see what happens during the trajectory of an object. It worked well with "what if" questions. The simulation that uses the normal force and friction force showed well that $F_n = F_g$ but the students were losing concentration. Perhaps this simulation should be used as an assignment. The inclined plane with friction and no friction was the best. It showed very well the relationship among F_g, F_n, and F_f. It kept the attention of the students. They asked many "what if's" and they would visually see the results due to their manipulation of the variables.
Teacher E	The teacher selected simulations that will be very effective as a visual due to the fact that these simulations were going to be used as demonstrations. When he used the displacement simulation, it worked much better than simply explaining with definitions. With the average velocity simulation, he had the students solve a problem manually (pen and paper) and then use the simulation to verify the answer. The students found it helpful to do it in this way. When the reference frames was used, it generated good discussion due to the analogy used. The vector specification simulation was good because it allowed switching back and forth between different systems, providing immediate and effective visualizations of what the teacher and students were discussing. The constructivist approach was used with the vector addition. By trying different ways of manipulating the vectors, the students

	arrived at the conclusion that you have to add vectors using the "tip to tail" method. The friction simulation was good for showing how the pulling force changes as more books are added. Also, the simulation led to a whole discussion of balanced and unbalanced forces, acceleration and Newton's three laws. He will definitely use the above simulations and try some others in the following year.
Teacher F	The friction and projectiles simulations were used. In both cases the lessons were printed and given to the students. While the teacher was running the simulation, the students had to write down the answers to the questions in their lesson. During the presentation, the teacher would enhance the session by questioning and adding to the explanations to what they were witnessing. The students also asked to do "what if " questions during the presentation. In both cases it went well. One student mentioned that if he had these simulations in the first term he would have passed. The simulations showed very well visually what was happening. They will definitely be used again.

After two months, at the end of the first cycle, the participants met to review and discuss what they had accomplished in their practices by using the simulations as demonstrations. Table 3 summarizes participant's experiences as shared at the general meeting.

Table 3. Summary of Experiences Shared at the Cycle 1 General Meeting

Participant	Experience
Teacher A	Lower-end students felt that it helped them whereas higher end students felt that they already had a good idea of the concept and therefore could use their time more efficiently. Labeling of diagrams can create a problem if it differs from the teacher's style. Access to a video projector will influence the use of the simulations. Some students after seeing the demonstration wanted to work on them individually. The teacher is thinking of producing a booklet for the simulations.
Teacher B	In the physics section of Science 20, the displacement simulation was well done. The students could easily understand displacement due to the visuals in the simulation. When adding the vectors, they could easily see that the sum is the same as the crow flies from one point to another. Access to a video projector is very important. It is a time factor to use the simulations but working in collaboration was an absolute slice.
Teacher C	Access to a video projector is an important facet in deciding to use the simulations. The "what if" questions are excellent to develop an inquiring mind for the students. The initial time factor is important but he hasn't regretted it. It is even hard to get teachers in the same school to work together.
Teacher D	The participant could not attend the meeting
Teacher E	Used the simulations as visual aids in his Power Point presentations. He would go to the simulation to demonstrate a concept. Several "what if" questions were answered while presenting the simulation. Ease of access was very important because it determined whether he would show the simulation. His preference was to use it as an introduction to a concept. Participating in this group has encouraged the teacher to review and apply the simulations in his physics course.

Teacher F	The "what if" questions are excellent. The teacher can interact with the students during the demonstration by asking all kinds of inquiring questions. The students can see the results to their questions in real time. When the simulation is well designed, the teacher will use it. Overall the simulations worked well when used in the demonstration mode.

Conclusions from Cycle 1

At the end of the first cycle, participants reflected on their actions and the related consequences. Triangulation of the three information sources led to the following conclusions regarding the use of the computer simulations in a demonstration mode.

1. Ease of access to the hardware is a major concern. Ideally it should be fixed permanently in the classroom so that the teacher is efficient in utilizing the simulations.
2. The simulations are excellent at presenting a physics concept visually.
3. The simulations facilitate "what if" questions when demonstrating a concept.
4. Students will become active learners and critical thinkers in observing the action in real time.
5. The simulations aid in encouraging the constructivist approach.
6. Teacher collaboration facilitated the implementation of the simulations.
7. The simulations can be used as-is or adapted to the particular teacher's method.

Cycle 2 – Use of simulations as laboratory experiments

During the second cycle, the simulations were used as labs. Students were able to work either in pairs or individually on the simulations in the computer lab. Tables 4-6 summarize the findings from the three data gathering processes that constituted the second cycle of the action research project, notably; individual interviews, individual journals, and the general group meeting.

Table 4. Summary of Individual Interview Responses from Cycle 2

Question	Most Frequent Response
1. In what courses did you use the MAP simulations?	Mostly in Physics 20
2. Number of students in each class?	An average of 24
3. Which simulations did you use?	Mostly pendulum and refraction
4. How many times did you use the simulations?	Each simulation was used once in each class.
5. In which location did you use it?	It was used mainly in the computer lab
6. How much time did you spend to prepare for the lab?	Very little
7. How did you use the simulation (intro, midway or reinforcement)?	Mostly introduction and reinforcement.
8. Give a brief description of how you used it.	The simulations were used the way they were designed. In other words, the students followed the lessons as is.
9. What strategy did you use during the lab?	The students went to the lab and followed the instructions in the designed lessons. Some teachers let the students work in pairs so that they could share ideas on the lesson.

10. Were the students on task and were there any questions on the procedures?	The students were mostly on task. If at times they would do something different, the teacher would remind them of their assignment.
11. What was your reaction (+ or -)? Why?	Mostly positive. The simulations worked well.
12. What were the students' reactions (+ or -)? Why?	(+) The students enjoyed the simulations. It was neat to work on them. They were engaged. (-) The symbols at times were confusing. The teacher uses different symbols.
13. Would you use it again in the same manner?	The teachers would use them again.
14. Any other comments or observations.	The simulations will be used again. Some will modify the lesson. The visuals are great for showing concepts.

Table 5. Summary of Individual Journal Entries from Cycle 2

Participant	**Summary of Journal Entries**
Teacher A	The teacher only used one of the simulations entitled Diffraction Grating. Only some of his Physics 20AC students used it as a way of reinforcing what they had learned. He wanted them to get immediate, hands on experience with what happens as you alter individual parameters in the formula. Students were successful in using the simulation. They found it valuable that the colors (wavelength) changed on the screen as they changed some variables.
Teacher B	The teacher in Science 20 didn't want to go too deep into the math of the concepts. He used the simulation of conservation of momentum to help students understand the concept of conservation. The students managed to work through the simulation. The teacher also looked at the centripetal motion simulation but ran out of time to use it with the students in a lab situation. More time is needed to prepare for the application of the simulations.
Teacher C	The inclined plane without friction simulation, worked well enabling the students to get a sense of how to understand and apply forces on a ramp. They worked in the library, mostly in pairs. There was some confusion with the different notation (N instead of F_N). The lesson didn't take a whole class. The projectile motion one ball worked well. Shows well the two types of motion. The vector addition-numerical method simulation shows well visually the addition of the vectors but the use of trigonometry to solve the sum of the vectors was harder. There was confusion with the direction of the vectors (30^0 East of North is the same as 330^0 West of North). The refraction and prism simulations were used. The students found the lesson and simulation to be interesting and fun. It reinforced well what was learned in class. The prism simulation is shorter and perhaps will be used as a demonstration next time. It might do a better job with dispersion of colors.
Teacher D	The teacher used the pendulum simulation as a lab experiment. It worked well. The teacher also looked at the Inverse square Law with planetary motion but it was used as a demonstration. The mechanical waves simulation shows well how the waves behave but it was used as a demonstration.
Teacher E	The teacher used the pendulum simulation as a lab experiment. It worked well. The evaluation of the simulations was shown in the journal of the first cycle.

Teacher F	The students in the lab used the refraction simulation. It reinforced what they learned in the class. The visuals showed when the critical angle occurs. The lesson that comes with the simulation was printed for the students. They had to follow the instructions and fill in the blanks. At the end of the lab, they handed in their work for evaluation. The students were engaged the whole time. Next year, this simulation will be used again.

After approximately two months, at the end of the second cycle, the participants met to review and discuss what they had accomplished in their practices by using the simulations in lab experiment mode. Table 6 summarizes participant's experiences as shared at the general meeting.

Table 6. Summary of Experiences Shared at the Cycle 2 General Meeting

Participant	Experience
Teacher A	The students who had difficulty in understanding Young's experiment were sent to the lab to work on the diffraction simulation. They were told to change the diffraction grating to only two slits and observe what happens when some of the variables are altered. The feedback was positive. It must be noted that this was the AC group, which includes highly motivated students that performed this experiment.
Teacher B	In the physics section of Science 20, the conservation of momentum simulation was used in the lab. The constructivist approach was used. The students were told to manipulate the various sliders in the simulation in order to formulate what conservation of momentum really meant. Afterwards, they had to write a paragraph explaining conservation laws. It worked. The visuals helped to see the effects of changing the variables. It was an effective way to build knowledge.
Teacher C	The teacher used the refraction and prism simulation in the library as an experiment. The students worked in pairs and followed the instructions in the lessons. Next time, the teacher would do the diffraction simulation instead of the prism. The prism duplicated some of the material that was in the refraction. In the other physics class, the teacher had the students do in the lab the Incline Plane without Friction, Projectile Motion with one ball, and Vector addition. The students usually have trouble in breaking gravity into component vectors when dealing with inclined planes. The component vectors in Projectile Motion were well displayed. The Vector addition also showed well how to add vectors. The students were always motivated.
Teacher D	The teacher used the pendulum simulation with a constructivist approach. The students had no prior knowledge of the pendulum concept. They went to the lab and followed the instructions in the lesson. The teacher changed a few minor things in the lab. The following day the teacher reviewed in class the pendulum.
Teacher E	The pendulum simulation was done in the lab. The day before the lab the teacher instructed the students on what to do. He mentioned that it would count for marks, which meant that they would have to stay on task. It was a positive experience. He thought of using the constructivist approach but due to problems in scheduling the lab, he did it as a review

Teacher F	The teacher used the refraction simulation. It was used as a review before an exam. The students were given a hard copy of the lesson before going to the lab. They basically had to follow instruction and answer the questions in the spaces provided. They were always on task. At the end of the lab, they handed in their work for marking. The light pipe (optical fiber) demonstrated well the internal reflection that occurs after the critical angle.

Conclusions from Cycle 2

At the end of the second cycle, participants reflected on their actions and the related consequences. Triangulation of the three information sources led to the following conclusions regarding the use of the computer simulations in a lab experiment mode.

1. Access to the computer lab is a major concern.
2. Students should work mainly in pairs so that they can discuss the lab
3. Marks should be assigned to the lab in order for students to stay on task.
4. Some symbols presented problems. At times, the symbols didn't correspond with the teacher's symbols.
5. The way of describing the direction for vectors was at times confusing.
6. Simulations can be used in either a constructivist or a reinforcement mode.
7. Teacher collaboration facilitated the implementation of the simulations.
8. The simulations can be used as-is or adapted to the particular teacher's method.
9. Some simulations are best used in demonstration mode, others in lab mode.
10. Students can work at their own pace. They can always complete the lab at home.
11. Teachers can easily alter the lesson to apply to their situation.
12. Students are engaged due to the immediate feedback.
13. The cost of doing a lab using simulation is less than using the actual lab equipment.

At the end of the last general meeting, the teachers compared the two cycles. The choice of whether to use the simulations as demonstrations or as a lab depended on the following points:

1. The availability of the lab and the video projector. (In some cases the labs were booked many weeks in advance and therefore it was easier to just do the demonstration in class.)
2. The type of simulation. (Some simulations are brief and could easily be integrated into a Power Point presentation.)
3. The nature of the students in the class (Some students can stay engaged for longer periods of time and concentrate on their work. Others have a short attention span and the pace has to be regulated for them to stay focused.)

IMPLICATIONS

As was stated earlier, the SuperNet is in the process of being constructed in Alberta. All schools will have access to all of the multimedia programs from Alberta Education's servers. Once this innovation becomes a reality throughout the province, all physics classrooms should be equipped with a computer and a video projector for the successful and efficient use of the simulations. It is very important for teachers to have equal access to technological resources (computer labs) in order to use them in their everyday teaching (Sandholtz, Ringstaff, & Dwyer, 1997). Teachers in a large school or in a district should participate in practical action research. In this manner they will collaborate toward achieving the best practices in teaching new concepts. Hannay and Ross (1997) state that for change to occur, factors such as support for collaboration, access to professional learning resources, and leadership for change are important. Through discussion and sharing, teachers will be motivated to change and use new simulations in the classroom. As was seen in this study, the simulations have to be designed in such a way that the teachers can adapt them to their own strategies of teaching. Teachers will use simulations if they are comfortable with them. Woodrow et al. (2000) state that:

> Educational change occurs when the underlying frameworks of established classroom practice are changed. Technology may be the catalyst to produce desired classroom change but technology alone will not effect significant change unless teachers are open to re-examining and challenging their beliefs about what constitutes good teaching and learning, willing to experiment with new teaching practices, and given support during the change process. (p. 38)

According to Rockford in Mills (2000) "Making action research a natural part of the teaching process, in the classroom and the school, is critical to success." and "teachers need to develop the attitude that improvement of the teaching/learning process can and should be addressed with data-based decision making and formalized through action research."(p. 48)

The research reported in this paper suggests that collaboration among physics teachers can be one of the better ways of deciding new strategies for using simulations in the teaching of physics. One of the main findings of this study is that teachers will change their instructional style when working together in practical action research.

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