An Interactive Procedural Environment for Learning Electromagnetic Waves and Radioactivity in Secondary School: The RadiationWorld.

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Abstract: This study reports an ongoing research and software development project. The research studies the manipulatable interfaces of computer proceduralisation of a science subject matter, namely the electromagnetic waves and radioactivity, where eighth graders pose many problems. To overcome children's difficulties within electromagnetic waves and radioactivity and to prevent misconceptions from developing, an architecture of an interactive procedural environment is proposed.

Introduction

There is an extensive literature concentrating on students' conceptions (understandings) of scientific phenomena. This is due to the importance of those conceptions in the learning and teaching processes. Children come into class with alternative understandings and as Osborne and Freyberg (1985) point out they are usually strongly held, even if not well known to teachers, and are often significantly different to the views of scientists. On the other hand, these preconceptions are amazingly tenacious and resistant to extinction and teachers often subscribe to the same alternative conceptions as their students (Wandersee, Mintzes and Novak, 1994).

It is also important to note that, while researchers are focusing on the existence and nature of students' understandings of scientific concepts, at the same time, there is an ongoing debate among researchers about how to name this phenomenon. Even though the term misconception is the dominantly used term, as Wandersee, Mintzes, and Novak (1994) list, some researchers prefer terms like; alternative conceptions, mistake, prescientific conceptions, naive beliefs, erroneous ideas, spontaneous reasoning, preconceptions, etc. In this study the originally used term misconception was preferred in describing students' diverse understandings of radioactivity and related topics.

It is evident in the literature that students hold various misconceptions on radioactivity. Millar (1994) cites the findings of various researchers on this issue where Riesch and Westphaul (1975) note a confusion in many pupils' thinking between radioactive forms of transfer and those involving diffusion or movement of the radioactive material itself. Kaszmarek, et.al. (1987) note that many of their samples involving second year medical students consider objects inside a room where X-rays were administered would themselves continue to emit radiation afterwards; and Eijkelhof (1990), on the other hand, showed the presence in many students' reasoning of a largely undifferentiated concept of radiation/ radioactive material (see also Millar, 1994). Alsop (2001), in his study with 30 non-science university undergraduates, investigated the existence of some misconceptions. He also found out that majority of the students have an undifferentiated radiation and radioactive matter concept. Additionally, following misconceptions can be summarized from his study:

- Viewing radioactivity as having a quintessentially eternal and never stopping property.
- The effects of radioactivity were conceptualized in terms of contamination and not irradiation.
- Living things would become radioactive after exposure to radioactivity.

- Radioactivity enters the body through the skin or by inhalation with oxygen
- A germ model of radioactive decay
- The effects of radioactivity described as a type of poisoning or sickness.

In an earlier study, Baslanti (1999) investigated possible misconceptions of 30 high school students during an interview-about-events. Majority of the students thought the followings:

- There is no radioactive element represented in the periodic table.
- A radioactive element poisons someone.
- An atom bomb can be produced by using all elements in the periodic table, because elements are made up of atoms and an atom bomb is the result of destruction of an atom.
- If someone hit on Uranium element found anywhere it will explode.
- All radioactive matters in the world were kept in nuclear power plants.

Further, Aubrecht, Torick and McEnnis (2000) summarize the past research and state that students confuse contamination and irradiation, and that their model of half-life includes halving the mass and volume of the decaying substance. They also state many students' beliefs that nothing is radioactive unless it is exposed to radioactivity. Other interesting misconceptions involve the idea that all radioactivity is man-made (available at http://www.amasci.com/miscon/opphys.html) and statements as follows;

- Radioactivity first appeared during World War II.
- Atoms cannot be changed from one element to another.
- Fission and fusion are the same; fission is more powerful than fusion.
- Neutrons and protons have no internal structure.
- Nuclear power plants produce harmful radioactive waste while other forms of electrical generation do not.
- Radiation causes cancer. Thus, it cannot be used to cure cancer.
- Once a material is radioactive it is radioactive forever (available at http://www.lbl.gov/abc/wallchart/chapters/appendix/appendixg.html).

Overcoming Students' Difficulties through Computer Based Environments

Recent advancements in the field of information and communication technologies enabled learning environments to process, store, retrieve and transmit information in multi-modes as sound, text, graphics and video clips. Increasing complexity of learning environments and the instructional technology allowed to design complex systems based upon a non-linear organization of the information within multiple formats. Visually enriching environments as multimedia and hypermedia are reported to have the potential to motivate learning, to improve understanding and to achieve the highest rates of retention (Levin, 1987). However, research (Kozma, 1991) has shown that simply providing multiple symbol systems for representation of subject matters, for promoting conceptual understanding of a knowledge domain and for enabling multi-sensory experiences does not enhance comprehension and knowledge acquisition. Empirical research has also demonstrated (Clark and Craik, 1992) that assumptions based on integrative effects of representational codes of single media on enhancing learning effectiveness fall short with regard to the conditions necessary for making the characteristics of external representations effective for the construction of individual mental representations. Scanlon and O'Shea (1988) suggesting instructional consequences from their results, concluded that instruction should be developed to provide constraints and to facilitate orderly moves from one inference process, representation or knowledge source to another. Further, Tergan (1997) suggests that "effectiveness of learning with the help of a technology is the result of a complex correlation of constraining conditions on the learner's side, instructional methods to support learners in task appropriate processing, attributes of the learning material and interactivity, and information accessibility of the media used".

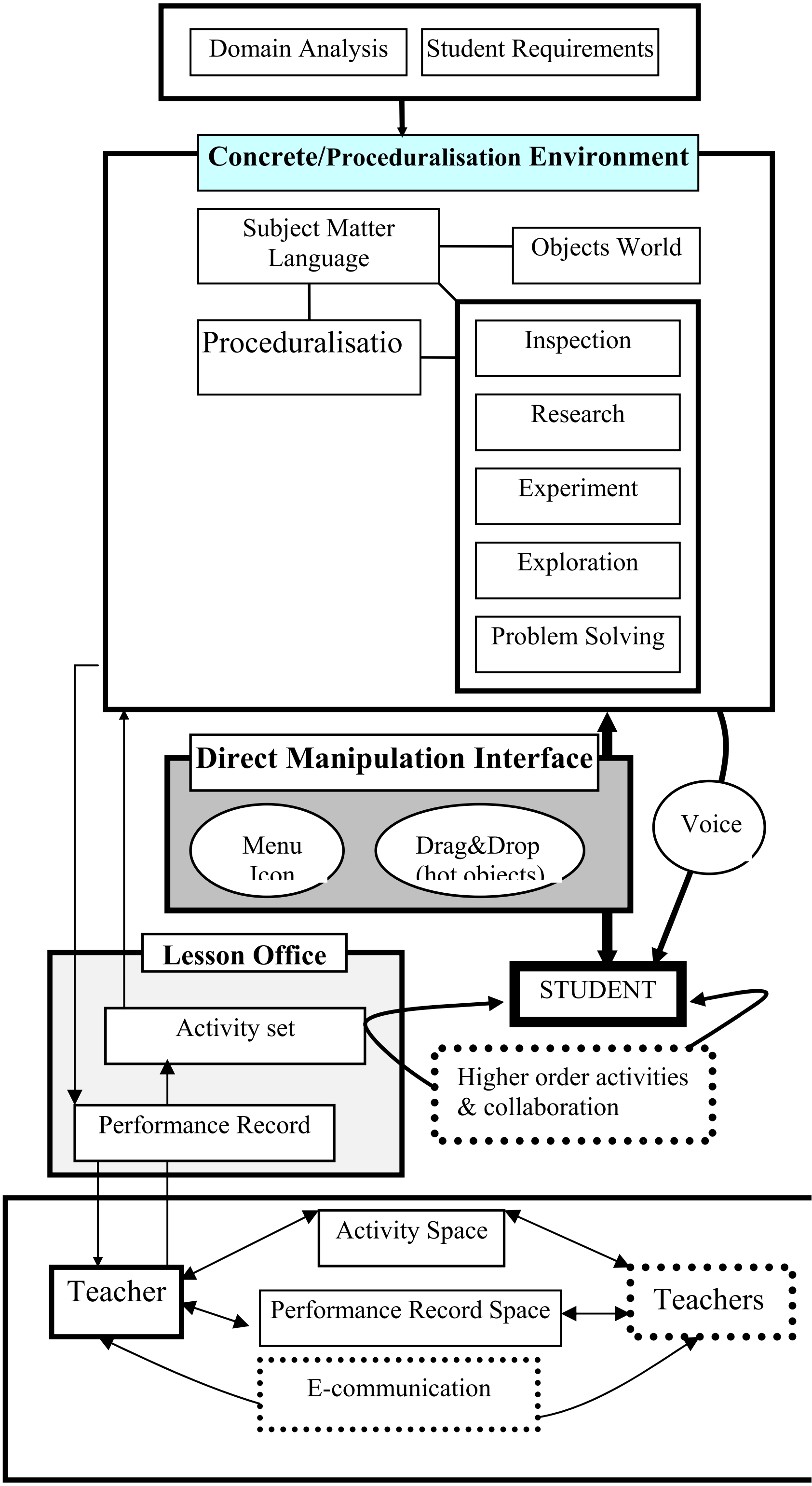
Learning Environment: The RadiationWorld

This study focuses upon the manipulatable interfaces of computer proceduralisation of a science subject matter, namely the electromagnetic waves and radioactivity, where eighth graders pose many problems. To overcome children's difficulties within electromagnetic waves and radioactivity and to prevent misconceptions from developing, a variety of teaching and learning approaches should be supported by learning environments in order to aid the user in proceduralising his/her interaction with the system and eventually be less prone to errors. The environment should regulate the control between the student and the system, accommodate real-life tasks and their solution methods which are rich in feedback and provide interactive illustrations supporting conceptual understanding, learner controlled inspections and problem solving. Collins & Brown (1988) and Thompson (1992) suggest that through the structured procedure capturing systems which offer simple devices, perceptually reflective learning on concrete items can be achieved. Through the students' manipulation and inspection, aspects of the device structure can then be explicitly represented, annotated and become the subject of didactic discussion. On the basis of a firm conceptual understanding the student's actions, as part of a procedure, are to be evaluated and reacted by the computer program to provide feedback about the effects the action would have in the real world. The student then takes successive action and each time explores more information. Further, because developing a firm conceptual understanding of science domain depends heavily upon the constructive work with real world objects in a science community and because the students need building materials, tools, patterns and sound work habits to learn operational relationships, the functional components of such "procedural environment" mainly consist of the followings:

1. A concrete object space whose activity reveal real world facts in order to represent the domain.
2. A student-environment interaction language by which the student can operate an object world in ways that show the effects of their actions and that connect to representations of the object space and its relations at higher levels of abstraction.
3. A curriculum management office (inspired from Draper's lesson office, 1991) to specify and manage the task curriculum and record student performances for further use.
4. User-system interfaces which are needed for students to apply the interaction language and manipulate the object world, and for teachers to specify and customise types of curriculum tasks for the curriculum management office.
5. Mechanisms to check the validity of students' methods, and to provide feedback on the appropriateness of their actions in relation to the presented task.
6. Be able to move its presentation (representation) modes from concrete to symbolic as the learners gain in competence, hence a seamless transition from facts to formalism is enabled.
7. Permit experimentation with concepts and procedures in ways that relate to the pupils' experience, thus supporting guided discovery as well as more directed methods of instruction.
8. The learning to be contextualised and procedural via the types of tasks that are specified within the Curriculum Management Office.
9. Means of communications and web based data manipulation tools for teachers

It is crucial to consider the interface design issues for systems with interactive manipulatives and proceduralisation tools, before considering the architecture of a procedural learning environment for secondary school children's learning of electromagnetic waves and radiation. To develop conceptual understanding of the domain through operations, a software system has to service the learner with operational facilities to undertake tasks. The interface design principles to be adopted were taken from Shneiderman (1992). Although this study is not focused on human-computer interactions, it is necessary to make careful efforts to follow and interpret established guidelines for designing a procedural learning environment (PLE), the RadiationWorld. The architecture of RadiationWorld is shown Figure 1.

Figure 1: Architecture of RadiationWorld



REFERENCES

Alsop , S. (2001) Living with and learning about radioactivity: A comparative conceptual study. *International Journal of Science Education*, 23(3), 263-281.

Aubrecht, G.J., Torick, D.A. and McEnnis, B. (2000). *Student Ideas About Radiation and Radioactivity*. Paper presented at AAPT Meeting, Orlando, FL January 2000.

Baslanti, U. (1999) *Students' Misconceptions about Radioactivity*. Unpublished manuscript. Bogazici University, Istanbul, Turkey.

Clark, R. E. and Craik, T. G. (1992) Research and theory on multimedia learning effects. In Giardina, M. (ed.) *Interactive Multimedia Learning Environments* (NATO ASI Series F: Computer and Systems Sciences V. 93) Berlin, Springer.

Collins, A. and Brown, J. S. (1988) Computer as a tool for learning through reflection. In Mandl, H. & Lesgold, A. (eds) *Learning Issues for ITSs*. Germany, Springer Verlag.

Draper, S. W., Driver, R., Hartley, J. R., Hennessy, S., Mallen, C., Mohamed, R., O'Malley, C., O'Shea. T., Scanlon, E. and Twigger, D. (1991) Design considerations in a project on conceptual change in science. *Computers and Education*, 17(1), 37-41.

Eijkelhof, H. M. C. (1990) *Radiation and Risk in Physics Education* (Utrecht: CD-B Press).

http://www.amasci.com/miscon/opphys.html

http://www.lbl.gov/abc/wallchart/chapters/appendix/appendixg.html

Kaczmarek, R., Bednarek, D.R. and Wong, R. (1987) Misconceptions of medical students about radiological physics. *Health Physics*, 52, 106-107.

Kozma, R. B. (1991) Learning with media. *Review of Educational Research*, 61(2), 179-211.

Levin. R. (1987) On empirically validating functions of pictures in prose. In Willows, D. M. & Houghton, H. A. (eds) *Psychology of Illustrations*, New York, Springer.

Millar, R. (1994). School students' understanding of key ideas about radioactivity and ionizing radiation. *Public Understanding of Science*. 3, 53-70.

Osborne, R. and Freyberg, P. (1985). *Learning in Science: The Implications of Children's Science*. Aucland: Heinemann.

Riesch, W. and Westphal, W. (1975) Modellhafte Schülervorstellungen zur Ausbreitung radioactiver Strahlung. *Der Physikunterricht*. 9(4). 75-85.

Scanlon, E. and O'Shea, T. (1988) Cognitive economy in physics reasoning. In Mandl, H. & Lesgold, A. (eds) *Learning Issues For ITSs*. Germany, Springer Verlag.

Shneiderman, B. (1992) *Designing the User Interface: Strategies for Effective Human-Computer Interaction*. Massachusetts, Addison Wesley.

Tergan, S. (1997) Misleading theoretical assumptions in hypertext/hypermedia research. *Journal of Educational Multimedia and Hypermedia*, 6(3/4), 257-284.

Thompson, P. W. (1992) Notations, conventions and constraints. *Journal for Research in Mathematics Education*, 23(2), 123-147

Wandersee, J.H., Mintzes, J.J. and Novak, J.D. (1994). Research on alternative conceptions in science. In D.L. Gabel (Ed.) *Handbook of Research on Science Teaching and Learning*. Macmillan, New York. pp.177-210.