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INNOVATIVE TEACHING AND LEARNING SCENARIOS USING INTERACTIVE SIMULATIONS

Hildegard Urban-Woldron, *University College of Teacher Training Education Vienna/Krems, Austria*

Abstract
This case study was inspired by publications on the effect of ICT[1] teaching activities in science lessons on pupils' understanding of science ideas and focuses on the pedagogical implementation of digital learning objects in secondary education and the development of guidance strategies. Well-integrated flexible software products available on the internet (focus: hydrostatic pressure and buoyant force) had a positive effect on pupils' motivational and cognitive processes (in grade 6 of an Austrian school). The gains in pupils' learning physics concepts when using digital learning objects seemed to be significantly enhanced, when the teacher actively guided pupils through the problem set assignments including virtual experiments.

1. Introduction and Framework
The mere availability or use of computer doesn't have an impact on pupils' learning, but digital media can contribute to changes in teaching practices and school innovation and specific applications of ICT can positively impact student knowledge, skills and attitudes (Kozma, 1994). In recent years computer based simulations have morphed into an interactive interface for student exploration (Gratch et al., 2008). Learners are able to manipulate the parameters of the virtual environment within the simulation and construct new understanding of the underlying concepts through inferring and predicting possible outcomes.

Yet few discussions focus on the fundamental issue surrounding the implementation of digital learning objects, which is probably one of the most challenging innovations that many teachers have to confront today. The purpose of an educational simulation is to motivate the learner to engage in problem solving, hypothesis testing, experimental learning, schema construction and development of mental models (Lunce, 2006). Because digital media are only as effective as the pedagogical approach in their use, ICT use and pedagogy have to be inextricably linked (Osborne & Hennessy, 2006). Learning with computer simulations is closely related to a specific form of constructivistic learning, namely scientific discovery learning (de Jong & van Joolingen, 1998).

Simulations used in Physics teaching are computer programs that have an implicit model of the behavior of a physical system and that allow students to explore and to visualize graphic representations (Concari, 2006). The ease in performing the investigations and doing problem-solving without equipment constraints are two of the benefits using simulations. Students can (a) interact with the system changing parameters and observing the results of their manipulation, (b) make a great number of simulations in a short time and (c) investigate phenomena which would not be possible to experience in a classroom or laboratory.

De Jong & van Joolingen (1998) present a review of scientific discovery learning within computer-based simulations. Students find it difficult to learn from simulations using discovery methods and need much support to do so successfully. One conclusion they draw is that information and instructional support need to come *while* students are involved in the simulation.

The focus of this study is on the use of virtual experiments which were offered to pupils in addition to traditional classroom experiments in order to relate better to the physical structure behind the experiment and to enhance the development of mental models. The study was performed during physics education of 11–12 year old students (grade 6) with two classes exposed to the use of two virtual experiments embedded in two problem set assignments in a so called "cross-over-design" (see Tab. 3) with different personal guidance by the teacher.

2. Digital learning modules and their integration in the classroom
Modules were selected which were freely available on the internet and which offered a high degree of interactivity and the option to pursue further explorations beyond the questions students were asked to go after. Each digital learning object has a specific additional value and had to be embedded into the lesson plan according to the different potential and the teaching goals.

[1] ICT (information and Communication Technologies)

In the Java simulation "Hydrostatic pressure in liquids" (see Fig. 1) pupils can explore the relation between hydrostatic pressure and depth. The manometer can be raised or lowered with pressed mouse button. On the right side it is possible to select one of several liquids or to write the values of density or depth directly into the text fields.

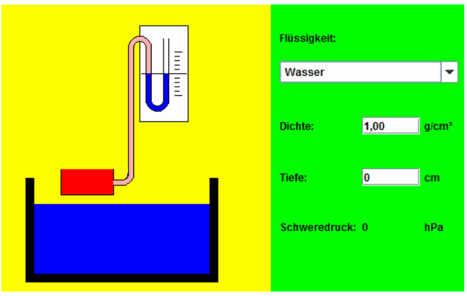

Figure 1: Learning object LO-1 / Hydrostatic pressure in liquids[2]

The application LO-2 (see Fig. 2) allows pupils to move the red circle horizontally and vertically with the certain barriers of the vessel. The density of the liquid can be changed within certain limits. The additional value compared to LO-1 is the possibility to explore the independence of hydrostatic pressure from the shape of the container.

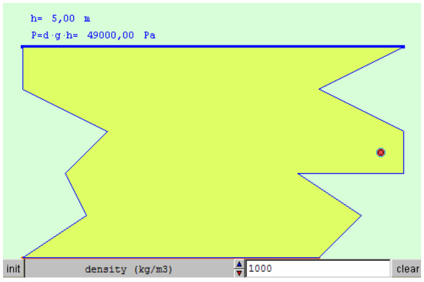

Figure 2: Learning object LO-2 / Hydrostatic pressure in liquids[3]

LO-3 (see Fig. 3) allows a visualization of the hydrostatic paradox and can raise further questions.

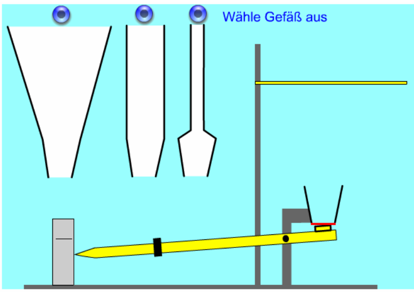

Figure 3: Learning object LO-3 / Hydrostatic paradox[4]

In the activity LO-4 (see Fig. 4), pupils will determine the relationship between the mass of a boat and how low it floats in the water and experience Archimedes' principle by visualization. As length, width, height and mass of the boat and the density of the liquid can be changed and as the tool offers immediate feedback to pupils, it can introduce a more experimental, playful style in which trends are investigated and ideas are tested and refined.

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[2] http://www.walter-fendt.de/ph14d/druckdose.htm
3 http://recursostic.educacion.es/newton/web/materiales_didacticos/pressure/mayorabajo.htm?2&1
[4] http://leifi.physik.uni-muenchen.de/web_ph08_g8/versuche/11paradoxon/paradoxon.htm

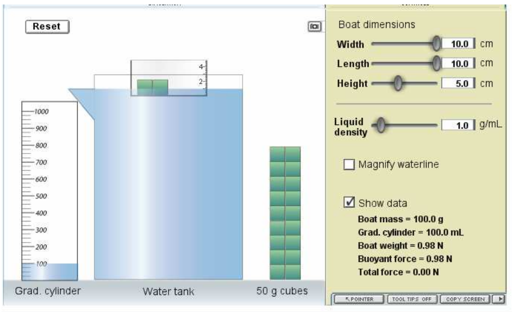

Figure 4: Archimedes' Principle[5]

The applet in Fig. 5 shows a simple experiment concerning the buoyancy in a liquid. A solid body hanging from a spring balance is dipped into a liquid by dragging the mouse. In this case the measured force, which is equal to the difference of weight and buoyant force, is reduced. The preselected values of base area, height and densities can be changed.

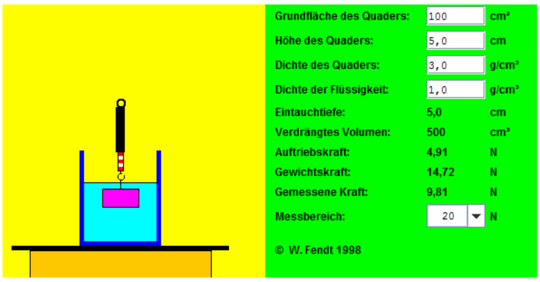

Figure 5: Buoyant Force in Liquids[6]

Table 1: Learning objectives, developed from official curricula

Hydrostatic Pressure		Buoyant **Force**	
L1	Because of gravity, pressure increases with depth in a fluid. This is called hydrostatic pressure.	**L5**	The buoyant force seems to reduce the weight of a body immersed in a liquid.
L2	Hydrostatic pressure doesn't depend on the shape of the vessel.	**L6**	The buoyant force is equal to the weight of the replaced liquid. This is symbolized by: $F_A = V_E \cdot \rho_{Fl} \cdot g$.
L3	Hydrostatic pressure of water increases by about 0.1 Bar for each meter (m) of depth.	**L7**	The buoyant force doesn't depend on the density and the shape of the object placed in the liquid.
L4	Hydrostatic pressure only depends on the density and the depth of the fluid. This is symbolized by: $p = h \cdot \rho \cdot g$.	**L8**	The relationship of the object's weight and the buoyant force determines the floating and sinking behavior of the object.

Table 2: 5 Lessons in hydrostatic pressure and buoyant force

Lesson	1	2	3	4	5
Content	Hydrostatic pressure in water; Hydrostatic paradox	Hydrostatic pressure is dependent on the density of the fluid.	Forces affecting an object submersed in liquid; Archimedes' law	Buoyant force depends only on the density of the liquid and volume of submersed object.	Assignments to repeat and deepen the subject; Applied topics
Method	Whole class teaching; Experiment with pressure sensor / LO-2 and LO-3	Computer Lab **LO-1** **2A: Scenario X** **2B: Scenario Y**	hands-on group experiments; virtual experiments with LO-4; inquiry-based teacher demonstration	Computer Lab **LO-5** **2A: Scenario Y** **2B: Scenario X**	Presentation of selected assignments; groups of 2 pupils discuss solution; Broad discussion with class
Learning Objectives	L1, L2, L3	L4	L5, L6	L7	L8

[5] http://www.explorelearning.com/index.cfm?method=cResource.dspView&ResourceID=603
[6] http://www.walter-fendt.de/ph14d/auftrieb.htm

The study was performed over a whole course of five lessons, when hydrostatic pressure and buoyant force were the subjects of the physics content. After ensuring that the use of each selected digital learning object was appropriate, added value to ongoing teaching and learning activities and met classroom aspirations, based on defined learning objectives (see Tab. 1) five lessons were designed to exploit the interactive potential of the software (see Fig. 2).

3. Aims, assumptions and research questions

The aim of the current study was generally to understand better the critical role of the teacher in creating the conditions for ICT-supported learning of physics, not only through selecting and evaluating appropriate technological resources and designing, structuring and sequencing a set of learning activities but setting a focus on appropriately guiding pupils during their work.

The virtual experiments in this study are not conceived as substitutes of the real laboratory experiences. The focus is on their use as a complement of experimentation allowing pupils to explore phenomena which are difficult to be done experimentally. Students can handle a group of variables at will, what cannot be made in a real experiment and elaborate their hypotheses by contrasting them with the results obtained. The digital learning objects are therefore assumed to promote pupils to think about underlying concepts and relationships, creating time for discussion, reasoning, analysis and reflection.

The focus of research was a) on pupils' behavior and learning outcomes in two different learning environments and b) on the impact of the teacher's behavior on the learning efficiency of the pupils.

- What kind of support do pupils need to be able to work successfully with digital resources and what do they prefer?
- Does the offered personal step-by-step-guidance support all students best?
- Do the pupils perceive support of autonomy and competence in the digital learning environment, where they can work completely independent?
- Are the pupils encouraged to explore their own questions?

4. Methods and samples

Two parallel classes of the same grade (class 2A and class 2B) of 25 and 23 pupils took part in the study. In Class 2B there were much more gifted and motivated pupils than in class 2A. The average physics grade is 2.12 in class B and 2.88 in class 2A on a scale from 1 to 5[7]. At grade six, pupils attend one physics lecture lasting 50 minutes per week. Two lectures during these five weeks using the learning objects LO-1 und LO-5 (see 2.1) were spent in the computer lab using two different scenarios X and Y (see Tab. 3).

Table 3: Cross-over-design for supporting pupils' work

Learning	Class 2A	Class 2B
LO-1	**Scenario X** o Pupils are introduced to the technological use of the virtual experiment by a screen-shot-video accompanied by text information. o Pupils work with the assignment without guidance. o The teacher answers questions.	**Scenario Y** o Pupils get an introduction how to use the virtual experiment by the teacher. o Pupils are guided step by step through the assignments. o Answers are discussed in the class.
LO-5	**Scenario Y**	**Scenario X**

Student's activities during courses have been observed and documented. Students were asked to describe their learning experiences in learning journals. Several methods have been combined to gain insight into activities and into the individual student's perspective:

- Interactive observation, documented in teaching protocols
- Submitted assignments
- Pupils' essays in their learning journals
- Questionnaires

[7] Grade 1 is the best grade

- Test

5. Results and Implications

Although there are differences between the two classes in attitude, learning styles, motivation and knowledge the overall results of the knowledge tests showed better results in both classes for those specific questions which were related to the close-up step-by-step guided lessons in each class (see Fig. 6). Questions T12 and T13 are related to Lesson 4, when class 2A worked in scenario Y. These two tasks are the only ones on the whole test, were class 2A performed better than class 2B (T12: 76% right answers in class 2A and only 52% in class 2B; T13: 88% right answers in class 2A and only 61% in class 2B). T5 was related to Lesson 2.

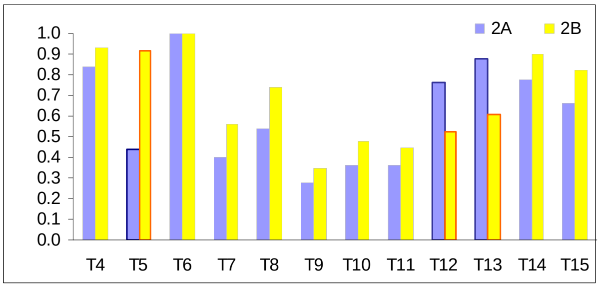

Figure 6: Test results

Looking only at the test results (see Fig. 6) leads to the conclusion that a close-up step-by-step guidance actively stimulating independent experimentation, communication with peers and autonomous reflection seems superior versus a more relaxed approach by the teacher supporting students with problem set assignments for self regulated work and only coaching them by being available for questions. But based on students' questionnaires not discussed in detail in the paper it can be derived that able and motivated students are stimulated by a more "open" learning environment to a more intense and autonomous exploration. These pupils value the autonomy given to them and they interact actively with the learning objects. They are highly interested in the validity of the results obtained and they pose very informed questions. They also appreciate rapid feed-back from the teacher.

However, less able and less motivated pupils learn better with close-up supervision, as they seem to have difficulties progressing when given room for autonomous learning. They explicitly stated that they profit more in a more rigidly structured learning environment.

The results of the present study show the pivotal role of the teacher when pupils work independently with digital learning objects. Critical for these new learning processes are learning situations which offer guidance as well as room for individual exploration keeping in mind that independence does not mean pupils working alone. The teacher's role is critical in structuring tasks *and* interventions in ways which prompt pupils using ICT to think about underlying concepts and relationships and to find the right way of instruction and level of complexity in order not to bore the more gifted and to avoid underperforming pupils to feel overwhelmed.

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