INTEGRATED SYSTEM-DYNAMICS LEARNING ENVIRONMENT (ISLE)

PROJECT REPORT 2000

July 2001

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PREFACE

This is the report on the ISLE (Integrated System-dynamics Learning Environment) project initiated by Georges Ecoffey (UAS at Fribourg), Edy Schütz (BS Uster), and myself, and supported by the Rector of the Zurich University of Applied Sciences at Winterthur (ZHW) in the year 2000. The report details the work done in Winterthur. It contains three papers which specifically deal with the ISLE trial run conducted in a class of mechanical engineering students in May and June of 2000. Brief descriptions of the history of the project, the structure of ISLE, and an Appendix containing learning materials complete the report.

The first of the papers included here is my personal account of the first ISLE trial run which lasted for a month in May and June of 2000. It starts with a brief overview of the concept of an Integrated System-dynamics Learning Environment and continues with a detailed description of what went on during the trial run. The second paper is the report of the assessment team—Rosmarie Ernst of the Department of Applied Linguistics, and Peter Fuchs of the Department of Physics and Mathematics at ZHW—who accompanied the trial run. The third paper, finally, contains the observations of Martin Ilg who was project assistant and accompanied the ISLE trial, partly as observer, partly as teaching assistant.

The learning materials—which were only partly finished at the time of the trial run—have been largely completed and are available from the authors (H.U.Fuchs, G.Ecoffey, and E.Schütz) on CD. They consist of experiments, data, models, and texts in a virtual learning environment implemented in the form of a web site (accessible through a standard browser). Moreover, there is a text providing assignments, problems, and summaries of theory in pdf format.

At the completion of the formal part of this first phase in Winterthur I would like to thank all who have supported this project, materially or ideally. Among those who have not been mentioned yet are Guido Steiner, Karl Weber, and Marcello Robbiani. In particular, my thanks go to the team of the Rector of the ZHW who made this project possible.

Hans U. Fuchs　　　　Winterthur, July 2001

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HISTORY AND FUTURE OF THE PROJECT

In early 1999, Georges Ecoffey of the UAS at Fribourg, Edy Schütz of the BS Uster, and Hans Fuchs of ZHW, began formulating a project for the development of an Integrated System-dynamics Learning Environment in physics instruction—an environment in real and virtual form which allows for activity oriented learning combining all relevant learning forms in a studio and on the computer (see A Brief Description of ISLEs on page 7). Toward the end of 1999, we were awarded CHF 250,000 by the UAS of Western Switzerland to be used for the development of ISLE materials and didactic assessment in Fribourg. In the Spring of 2000, the ZHW awarded us CHF 79,000 for developments in Winterthur.

In Winterthur, the contributions to this first project phase were three-fold: Production of written assignments, problems, and theory for a unit of an ISLE in introductory physics (Part IV: The Dynamics of Heat; see Appendix), teaching (see the reports by H.Fuchs and M.Ilg) and assessing (R.Ernst and P.Fuchs) of the unit, and acquisition of some equipment for the studio. Together with the experiments and the virtual learning materials of Part IV which were provided by the team of authors (Fuchs, Ecoffey, Schütz), the equipment will make it possible to continue to teach this unit and produce some further materials.

After the main phases of the Winterthur part of the project have been completed, the development of ISLE continues through the support of the UAS at Fribourg. Georges Ecoffey has made funds available for the work of a researcher in physics didactics—Jana Paice—who has worked, and continues to work, on the assessment of the second trial run of the thermodynamics unit in Winterthur. Through this and through the development and assessment to be completed in Fribourg, we expect to improve upon the original ideas of our initiative.

The work up to this point has revealed strengths and weaknesses of this novel approach to teaching and learning. The authors now know what it takes for strong and meaningful learning to take place, and how modern learning environments in the real and the virtual worlds can be designed. The project has demonstrated above all how attractive activity based forms of learning are for the students (see the report by R.Ernst and P.Fuchs, p. 25–38). However, to make an ISLE—both in its real and its virtual forms—a viable alternative to standard approaches to teaching, much more research and development is required, and steps have to be taken to provide the necessary infrastructure for learning in studio environments. With strong research based learning materials and the necessary buildup of rooms and communications infrastructures, attractive models of learning can be offered in the future.

A Brief Description of ISLEs

The project "Integrated Systemdynamics Learning Environments (ISLEs)" seeks to create new learning environments for laboratory or observationally based sciences—from physics to the social sciences. We are using introductory college physics as the platform to build and investigate such an environment for the first time.

In an Integrated Systemdynamics Learning Environment (ISLE) the most important forms of learning (laboratory, system dynamics modeling and simulation, concepts and theory, short lectures, discussions, presentations, etc.) are combined in a single environment allowing students to be actively engaged in the learning process.

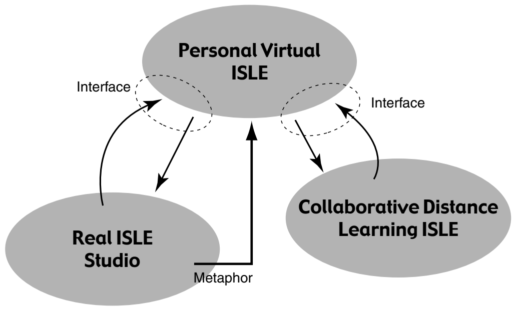

Figure 1: Integrated System-dynamics Learning Environments come in different forms: For Real, Personal Virtual, and Collaborative Distance Learning.

An ISLE comes in at least three forms (Figure 1): a studio learning environment at a school called the *Real ISLE Studio* (consisting of students, teachers, experiments, computers, ISLE materials and a studio room, Figure 2), a *Personal Virtual ISLE* (an individual learner with ISLE materials on her computer), and a *Collaborative Distance Learning ISLE* (several students at home with ISLE materials on their computers connected over the Internet—mainly to engage in Collaborative Modeling).

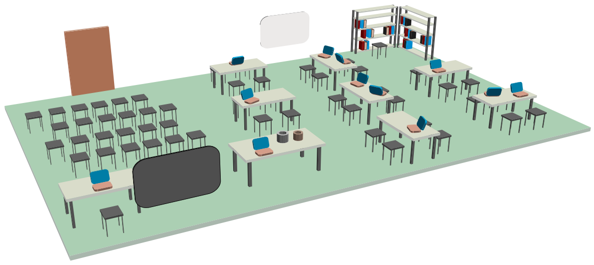

Figure 2: A Real ISLE can be conducted in an appropriate studio room providing materials for all forms of learning.

The computer based ISLE materials—simply called the *Personal Virtual ISLE*—form the backbone of an ISLE in that they are used in all three ISLE environments. They consist of computer based materials structured like the Real ISLE, and an accompanying textbook (Figure 3). We think that activities in an ISLE can be divided into two major classes: working on experimental and modeling assignments and small projects, and activity based studying using hypermedia materials and system dynamics models to explore the same concepts. Thus we divide the Personal Virtual ISLE into two sections called the *Active Lab Environment* (ALE) and the *Active Study Environment* (ASE); see Figure 3. Each environment of the Personal Virtual ISLE provides materials (such as assignments, experiments and data, background information, models) and tools (such as modeling tools and tools for data acquisition and data handling). The materials of the Personal Virtual ISLE are to be created using the latest multimedia tools and should be made available in platform independent form on CD (DVD) and intranets or the Internet.

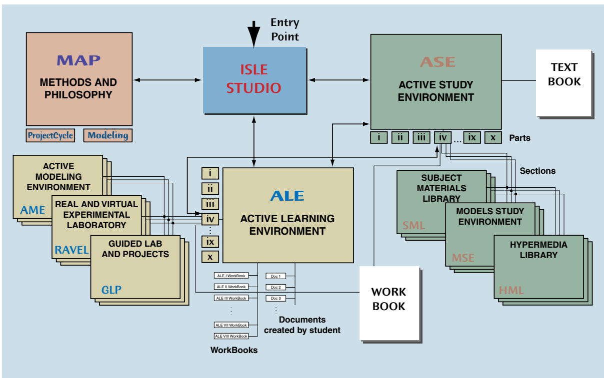

Figure 3: The structure of the Virtual Personal ISLE takes the structure found in the real learning environment as its guiding model.

The Personal Virtual ISLE presents one more environment: the *Methods and Philosophy* (MAP) section. Laboratory or observationally based sciences can be conducted in a Project or Design Cycle (Figure 4) consisting of experimental/observational activities and modeling and simulation, respectively. Each of these major activities forms a cycle, and together they combine to the dual Project Cycle of Figure 4. [It appears that the steps in the Learning Cycle identified in science learning consist of the dual project or design cycles.] System dynamics modeling is our preferred methodology to introduce beginners to modeling and simulation as a learning tool in the sciences. Research and development of system dynamics based physics courses at Zurich University of Applied Sciences in Winterthur has demonstrated the existence of a general structure of models of dynamical processes which can be mapped to a generalized problem solving strategy (Figure 5). The MAP section provides background material on the Experimental Cycle and the Modeling Cycle.

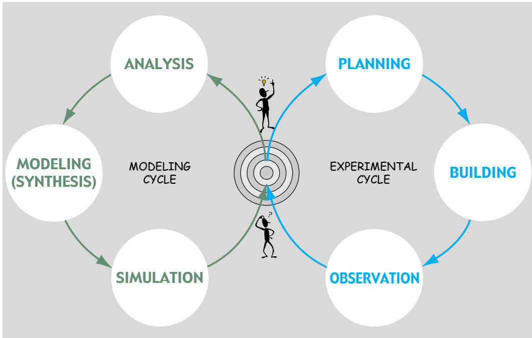

Figure 4: The Design Cycle is a dual learning cycle consisting of an experimental and a modeling cycle. Learning progresses by comparing the results of the two simple cycles.

The computer based Personal Virtual ISLE materials are used either as a stand-alone version (for personal studies), or they are combined with interfaces to the Real ISLE Studio (essentially data acquisition in the laboratory section of the studio) or to the Collaborative Distance Learning ISLE (software to facilitate collaborative work, particularly Collaborative Modeling).

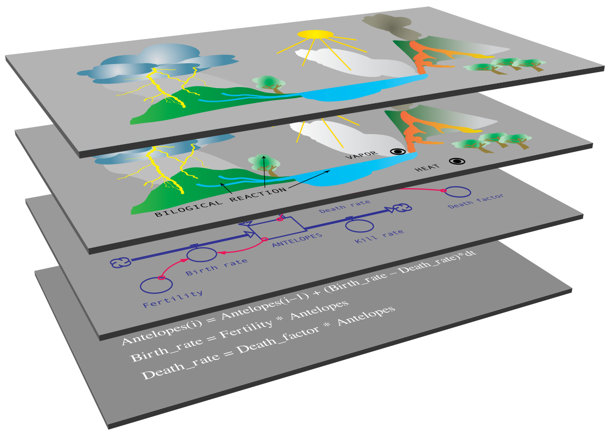

Figure 5: The modeling part of the Design Cycle consists of clear steps leading from the observation of reality through analysis to a model. The model can be created first in the form of a word model, then by using graphical elements. Finally it is turned into a mathematical model which can be simulated.

“Hand-made” improvised ISLEs for introductory college physics have existed at Zurich University of Applied Sciences in Winterthur for several years. The experience gained so far makes us confident that they can successfully be combined with modern learning technologies leading to a greatly improved “product” for learning in the modern world.

A FIRST REAL ISLE TRIAL RUN

OBSERVATIONS AND PERSONAL REMARKS

July 2000

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ABSTRACT

(July 2000)

From the middle of May to the middle of June 2000, I taught a unit of the planned Integrated Systemdynamics Learning Environment (ISLE) for introductory college physics. The subject of the unit was introductory thermodynamics. First year students of mechanical engineering worked for two double periods per week. The class of 17 students was divided into two groups to fit them into the small lab and computer room in P214. This trial run constitutes the very first and preliminary attempt at creating a Real ISLE.

The experiment built up on materials which had been prepared over several months before the trial period. Materials for activities (experiments, data, models, assignments) were largely ready to use. Background materials (texts, animations, models, solutions), however, were still missing—reducing the effectiveness of the "virtual" learning environment which was to accompany the "real" environment.

At the end of the four weeks of activity based learning, students worked on a small project involving an experiment and modeling, and summarized their results in a short report which counted toward the final grade for this unit. A week later students took a test which showed rather different results than the previous two standard exams given during the year.

The trial run was accompanied by researchers observing students and the teacher to determine the quality of teaching and learning. Their report—based on observations and questionnaires—will be published shortly (by now it has been published; see pages 25–38 of this report).

Here I will describe my own personal observations and interpretation of what happened and what I saw and heard. In summary—in my own view—the experiment proved the feasibility of ISLEs, their attractiveness to students, and their importance as an example of activity based learning. The single most interesting discovery for me is the role played by students' knowledge of methods—from data analysis to modeling: the success of learning in an ISLE crucially depends upon the level of the students' methodological know-how. In the future, this point has to be given much more attention, and ways have to be devised to build and strengthen students' know-how early on in the course.

1 A BRIEF DESCRIPTION OF THE ISLE EXPERIMENT

For some time now an Integrated Systemdynamics Learning Environment (ISLE) for introductory college physics has been taking shape. Briefly stated, the physics ISLE is based on the physics of dynamical systems developed at the University of Applied Sciences at Winterthur (Maurer and Fuchs[1]), the use of system dynamics modeling in physics education advanced by the same authors[2], and the idea of integrated and activity based learning environments as embodied in studio teaching (Wilson, Rensselaer Polytechnic Institute[3]). In an ISLE, experiments, modeling, and theory are integrated into a single activity based environment. ISLEs come in three flavors (as shown in Fig.6): Real ISLEs (a real studio learning environment at a school), Personal Virtual ISLEs (computer based materials for individual learning which use the metaphor of the Real ISLE), and Collaborative Virtual ISLEs (the Personal Virtual ISLE enhanced by software making collaboration over large distances possible). In our experiment in May and June, we have tried out a unit of a Real Physics ISLE. Materials in the form of a Personal Virtual ISLE have been prepared to guide students through their class work and some of their individual home work.

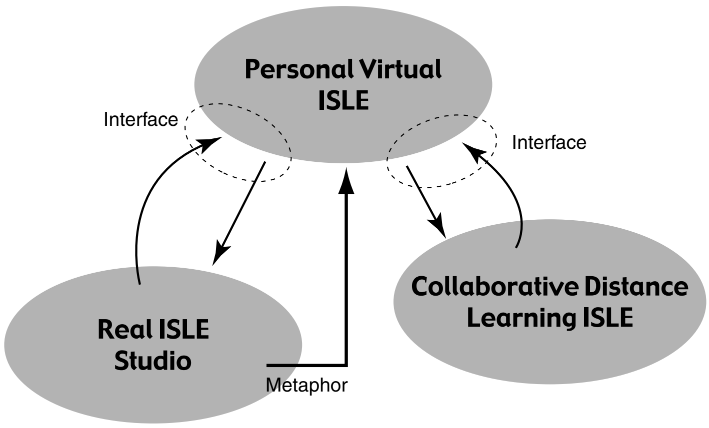

Figure 6: Real, Virtual, and Collaborative ISLEs. A Real ISLE is centered around a studio at a school. In it, students can study a subject by seamlessly integrating experiments, modeling, and theory. The Personal Virtual ISLE is composed of computer based materials which take the metaphor of the Real ISLE. Collaborative Distance Learning ISLEs are learning environments created by students (and teachers) meeting at a distance to collaborate on modeling and other activities to advance the learning of their subject.

The ISLE authors (G.Ecoffey, E.Schütz, and H.Fuchs[4]) decided to develop Part IV (The Dynamics of Heat) of a complete physics ISLE (see Table 3 in the Appendix) and try it out toward the end of the first year of physics instruction in the Department of Mechanical Engineering at the UAS at Winterthur. A part like the one on introductory thermodynamics roughly takes a month of class work, with two double periods per week. A full year of introductory physics can cover seven to ten similar parts plus the necessary development of methodological skills[5].

The first six double periods were devoted to six sections of Part IV introducing the concepts and applications of heating and cooling of simple materials, including phase changes (see Table 1). A typical double period would begin with a short presentation of the most important aspects of the relevant theory, summarized on a small blackboard. Then, an experiment would be presented (or the students could view the experiment in a video implemented in the Personal Virtual ISLE materials; ideally, time and resources permitting, students would perform an experiment themselves), and the assignments for the present section were discussed. After this students started their work on the assignments which involved steps such as analyzing the experimental setup, data analysis, analysis of the processes, implementing a model or preparing an almost finished model for simulations, importing data into the model, simulating the model and comparing experimental and simulation results—often with the goal of determining missing parameters. The assignments would then be followed by some questions and problems, already preparing students for their home work.

Most of my time during a double period was spent helping and coaching the teams of students doing their assignments. Sporadically I called upon the entire group of students to discuss an issue which had arisen.

The students were asked to finish assignments and some of the questions and problems at home and to prepare the next section by spending a few minutes on reading a couple of pages in the Personal Virtual ISLE or in the accompanying book (I used Chapter 5 of Physik, by Borer et al.[6], and sections of The Dynamics of Heat, by Fuchs[7]).

Table 1: Contents of Part IV of the Physics ISLE

Section	Subject
Section IV.1	Thermal Phenomena
Section IV.2	Hotness and Temperature
Section IV.3	Entropy and Temperature in Simple Materials
Section IV.4	Entropy and Energy in Heat Transfer
Section IV.5	Heat Transfer and Entropy Production
Section IV.6	Melting and Evaporation
Section IV.7	Heat engines and the absolute temperature (not taught)
Project IV.1	Cooling of Water in a Thick-Walled PVC Container
Project IV.2	Latent heat storage (not used)

During the last two double periods students worked on a small project involving an experiment and modeling (cooling of water in a thick-walled PVC container). Simple data acquisition hardware and software (for now we decided on Vernier's ULI or LabPro with LoggerPro[8] software), and user-friendly modeling software (in introductory courses we mostly use Stella[9] created by High Performance Systems, Inc.) were employed. For this and the forgoing parts, students had access to computers running the MacOS in a small studio room.

2 STUDENTS

The group of 17 students was divided into two smaller groups for the ISLE trial run. Each group studied thermodynamics for two double periods per week. [The remaining two periods per week were devoted to finishing a different project which had nothing to do with the ISLE experiment.] In each group, teams of three (or in one case: two) students were formed for the subsequent class work and final project. To what extent students continued to work in the same teams during home work, I do not know. Certainly, some of the work like reading and writing a summary for the exam was done individually.

Preparing a section. I had asked the students to read one or two web pages summarizing the subject of each section. When the trial period neared, it became clear that the summary of only one of the sections (Section IV.4, Table 1) was going to be ready. So I changed the request to reading one or two pages in Borer et al.[6] Discussions with students indicate that only few of them really did what they were asked to do. What turned out to be a persistent problem for the entire trial period already showed up very early: the students were busy with projects and deadlines in a number of other courses. A single student who said that he adhered to my advice of reading before coming to class felt that the preparation had been important—given the fast pace at which learning progressed during this experiment.

Introduction of a section by the teacher. When I gave the brief summaries of background information at the beginning of a double period, only one or two students took notes. Actually, I had asked them not to because I expected them to find the material on the blackboard (which was supposed to be sufficient for their subsequent assignments), or to find it in the accompanying text or in the Virtual ISLE materials (which were only partly implemented). This advice may have been a mistake since my students often demonstrated difficulties with orienting themselves during the subsequent periods of independent work. Since—as I suspect—most students had not read the introductory materials at home, the quick pace of my introduction left them disoriented.

Students orienting themselves and starting to work on an assignment. My students had a hard time understanding what they were supposed to do. At the beginning the learning environment was too different from how we had worked before.[10] It took some time to get each group to work more or less efficiently. Reading the assignments properly, learning to orient themselves in the still unfamiliar environment of the Virtual ISLE materials on the computer, and then successfully implementing a solution strategy proved to be too hard at first. Much of the time of a double period was spent relatively unproductively. Only slowly did this problem recede into the background. Still, students kept reading assignments only superficially (three students in front of a single computer trying to read from the computer screen simply did not work), kept calling up wrong information (the wrong video, descriptions or data belonging to a different experiment than the one they were supposed to work on, models referring to a different case, etc.), or kept expecting information from the Virtual ISLE where there was none (this was in part due to the incomplete state of the materials).

Working on assignments. Another difficulty persisted almost to the end of the four week trial period: my students' skills needed to solve practical problems effectively were woefully inadequate. I was unprepared for the severity of this problem. From what we had done in class and in the lab for almost one and a half semesters,[10] I had expected students' modeling skills to be significantly better. Also, I did not expect the difficulties most of my students had with simple data handling and data analysis tasks, not to speak of the trouble they had with handling the tools themselves (Excel and Stella). Later some students blamed their troubles on the fact that the lab was equipped with Macintosh computers rather than Windows machines (even though they had spent their lab time of the previous five or six months in the same room with the same equipment). For me these observations are the most important result of the trial run. Rather than calling into question the project itself, they demonstrate the importance of training the learners in the methods and skills necessary today to successfully solve real world problems in sciences and engineering. Moreover the observations call into question the quality of training in lab skills if the lab conducted separately from the learning of physics—as was the case in the months preceding our experiment.[10]

I had clearly overestimated the time available for productive work, or the speed at which my students could solve practical problems. In almost every double period, the number of assignments was too large. On the other hand, the first one or two assignments usually could be finished and they proved to be chosen well enough to enable some substantial learning to take place. Given the criticism I have leveled at how the work progressed during the ISLE trial period, it seems to be almost a miracle that useful learning took place at all. However, as we shall see below when we discuss the result of the exam and the experimental and modeling project, some good learning must have occurred. All in all, the teams were mostly motivated and hard working. They heroically struggled with the software, and ended up with some very good results. No doubt the activity level was incomparably higher than anything seen during standard instruction—but then, what else should we expect of an activity oriented learning environment?

Creating documentation of the work done. Another weakness of the project, or of my initial implementation of it, or of my students learning skills, showed up in the creation of a WorkBook to document the progress of the work done by a team or an individual. I had considered writing a WorkBook (or lab journal or log-book) to be an almost indispensable part of the learning process—and I still do. However, during the class periods, only two or three students kept taking notes for themselves (by hand) while the others on their teams worked on the assignments using the computers. Since I required them to hand in some sort of WorkBook or summary at the end of the month long experiment, most students created a kind of standard summary which they were allowed to use during the exam. Hardly anyone included results of the assignments obtained during the studio hours. Nobody used the computational facilities to create a WorkBook while the actual work was in progress.

Pace and pressure. Most students commented on how the pace of physics instruction had increased from the standard physics course they had before. This and pressures from other courses (project deadlines) made keeping up with our experiment difficult for many—if not most—students. For whatever reason—be it increased motivation because of the nature of our experiment, or simple positive attitude toward their teacher's desire to try out an interesting new way of teaching and learning—many students responded by actually putting in even more time for physics. At least this is indicated by some preliminary responses to the question of how much they worked during the trial period. In my view we will have to make sure that students can succeed reasonably in the course with normal average work loads.

Student ideas regarding heat. The nature of the learning environment made it possible for me to observe some interesting student ideas and concepts concerning heat. For example, when confronted with data of the cooling of water in an aluminum beer can showing that the temperature of the water remained above room temperature even after very long time, almost all of my students suggested that the heat transfer properties of the can had changed toward the end of the experiment. (In reality, we expect the dissipation as a result of magnetic mixing of the water to be the reason for this behavior.) Also, when asked why the temperature of the surface of the thick-walled PVC container, into which we had filled hot water, showed a delay in its initial rise (Fig.7), the very first reaction was to blame an "inductive" effect (rather than the series connection of many thin RC elements). In the same experiment, when asked what they expected to happen to the temperatures of the water and the surface of the container (before they made the actual measurements; see Fig.7), students responded that either the temperature of the container would quickly reach that of the water whereupon both would decrease together; or they believed that the temperature of the container would rise above that of the water after some time. Only one student had the right idea and could even give the proper reason for the real behavior during class discussion at the beginning of the final student project.

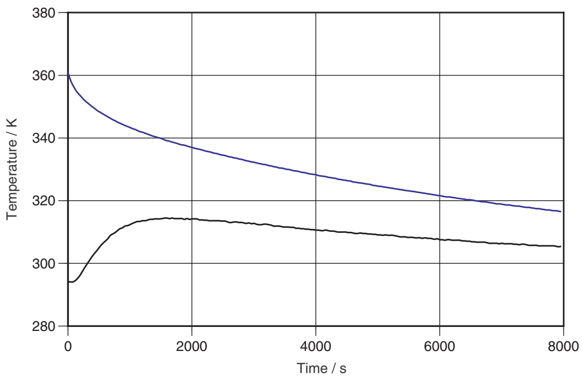

Figure 7: Data taken during the cooling of hot water in a thick walled PVC container (upper curve: water; lower curve: surface of container).

Student project. After six double periods dealing with the fundamentals of heating and cooling in dynamical settings, my students worked on the final small project for two more double periods. They continued working in the same teams they had formed at the beginning.

As mentioned before, the project centered around an experiment in which hot water was poured into a cold thick-walled PVC container and the temperatures of the water (continuously mixed) and the surface of the container were measured (see Fig.7 and Fig.8). Students had to put most of their effort into creating a proper system dynamics model to explain the process they had observed. Here, after some trial and error, most teams realized that they could use models they had encountered during the previous part of the ISLE trial, and build a more sophisticated version upon these. Several teams noticed that in a first step they could modify the model explaining temperature equilibration in two bodies of water in thermal contact (Section IV.5, see Table 1). Since this model uses the entropy representation of the process, some teams continued working with entropy. Others switched to the energy representation when they finally divided the container wall into several thin elements.

Figure 8: Experimental setup for the final project of Part IV: Cooling of hot water in a thick-walled PVC container. There are two thermometers, one for in the container, the other mounted on the outside wall of the PVC tank.

The teams needed my help with this project, particularly with the modeling. I'm quite satisfied with their general understanding of the processes and their ideas for improving upon the model. Most of the difficulties actually arose from small mistakes and sometimes sloppy implementation. At least two of the teams forgot to divide the mass of an element of the container wall by the number of elements in their model. A more serious—but certainly understandable—difficulty arose from the students' unwillingness to question the values of thermal properties found in tables (the value for the specific heat of PVC was wrong).

Many of the teams were highly motivated to do a good job, experimentally, with their model, and with the final report. In fact most of them spent much more time on the project than I had anticipated or had wanted them to put into this part. Some of my misjudgment may be due to the complexity of the example, but most of it may be the result of poor skills and a misunderstanding of what their teacher would look at as an acceptable report. The grades I gave for the project are listed in Table 2 in the Appendix. The relatively high marks reflect the level of "blood, sweat, and tears" put in by the teams. Only one team handed in an absolutely minimal piece of work, probably more the result of lack of motivation or time than the inability of reaching a better result.

Final Exam. Since the learning environment for this part of physics differed considerably from our standard environment, I asked students to give me feedback on what they would consider to be a good, interesting, and fair exam at the end of Part IV of the didactic experiment. Three students followed my call and spent an hour or so with me discussing a possible exam. They stressed the importance of probing of qualitative understanding and of their ability to work with graphs, and solve problems relating to actual processes. As a consequence I designed a test having 5 multiple choice questions, three smaller problems, and two advanced problems. Standard exams before this trial always contained four advanced problems of which students had to solve roughly 80% to get the highest possible grade. I decided to leave this 80% benchmark for the new exam. Results of this and an older exam are reported in Fig.9.

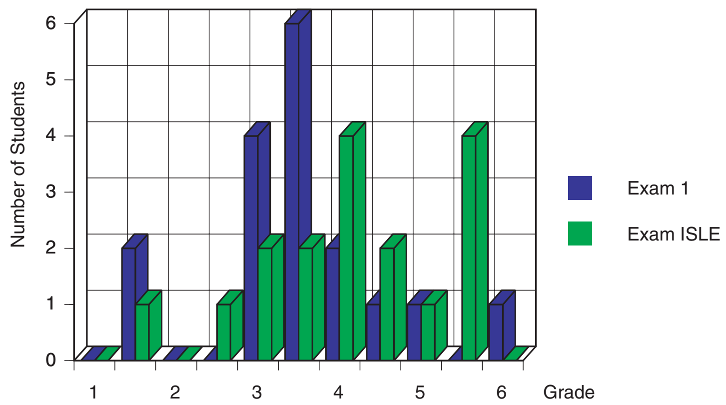

Figure 9: Histogram of the grades of the seventeen students in one of the standard exams before the ISLE experiment (Exam 1) and of the grades achieved in the exam covering the subject of the ISLE trial. Results are clearly better in the new exam. It must be noted, however, that the two exams did not have the same format (see discussion in the text).

Because of the change in format, the new exam is hard to compare to the old ones. Therefore the overall much better result is to be taken with a grain of salt. Nevertheless, a few positive trends can be confirmed. The hard problems at the end of the test were solved as well as the standard hard questions in previous exams. While the achievement in the four problems of Exam 1 (Fig.9) was 43%, 46%, 23%, and 43%, respectively, the final two advanced problems in the new test were solved at a rate of 47% and 38%, respectively. [The results for the multiple choice questions ranged from 17% to 75%, those for the three smaller problems from 36% to 75%.] Another specific result is worth mentioning here. I have been including problems where students had to determine rates of change from graphs routinely for many years. On average, hardly more than half the students ever solved these problems correctly. In this last exam, however, the success rate for the three occurrences of this type of question was 80%. The practical nature of the learning they had done may have caused this change in students' skills.

Moreover, I find the achievement of two of the students rather remarkable (they are numbers 14 and 15 in Table 2 in the Appendix). Their previous average grade had been a 3 and a 3.5, respectively. They put in a tremendous effort in the final project and then scored grades of almost 5.5 in the final theoretical exam. Also, it may be interesting to note that the grades of the weaker students did not improve all that much, at least not in the theoretical exam.

An interesting incidence took place five minutes before the beginning of the exam. Several students came up to me asking me to postpone the exam. Their reason was that I had not taught them anything during the last month, and they felt disoriented and underprepared. I was able to convince them to take the exam anyway and wait for the results. Personally, I look at the results as being modestly positive. [One student vehemently disagreed. He maintains that the exam was much too easy, and that he personally would have learned better and more efficiently in the standard class environment; he is Student Number 17 in Table 2.]

3 TEACHER AND ASSISTANT

While I had great fun during the ISLE trial and learned more about teaching in one month than during the last fifteen years (see below), I am less than happy with my own performance in the ISLE. I see room for considerable improvement in my own role in such a learning environment.

First, looking back, I realize that I did a poor job telling students about my own motivation for the experiment and what I expected of them in the end (I was particularly vague about what I expected in terms of the report for the final project). I was slow in reacting to the methodological difficulties of my students—expecting them to be much better from what we had done before in the lab. I felt under pressure to spend as little time as possible on the introductory presentation as possible to leave more time for independent work, possibly leading to some disjointed presentations. Again, feeling the pressure to succeed in the given amount of time, I was much too fast intervening with team work when I saw a group being stuck, often taking the mouse or the pen in my own hand and doing something for my students they should have done for themselves. I'm particularly annoyed at my quick response to student ideas regarding some of the processes (see above in the paragraph on "Student ideas regarding heat"). I jumped too quickly telling them that the ideas were wrong, instead of taking them as the opportunity to do some investigations of models to come up with an answer in this way.

Finally, probably as a result of the lack of positive ideas and concrete personal experience, I was not able to guide the students in creating WorkBooks or lab journals detailing the progress of their work. Considering that I still look upon this activity as crucial for a high quality learning process where computers are used extensively, I believe that we still have quite a way to go in this question.

During the entire trial period I was strongly supported by my assistant Martin Ilg. Given the nature of trying out an approach which is so different from standard teaching, I would have been hard pressed to get all the materials, hardware, and software ready. Also, he accompanied all the sessions, carefully observed students and at times helped when I was not available.

This brings up the question of manpower necessary to conduct an ISLE session. I still believe that under good conditions a single well trained instructor can deal with an entire group of 20 to 30 students. “Good conditions” means that the learning materials have been prepared, that there is help in setting up the hardware for each session, and that the students have a good level of skills. Since we may not be able to expect a high methodological level from our students at the beginning, extra time or the support of a (teaching) assistant may be needed during the first couple of months of a course.

As I said before, the teams mostly worked hard, heroically struggled with the software, and ended up with some very good results. For me, helping them and observing them proved to be one of the most enlightening periods of my teaching career. The richness of the learning environment was matched by the richness of students’ learning habits—if habits we can call something that developed in a very short period of time. I saw behavior, ideas, and approaches which I had never seen before. To me this—more than anything else—demonstrates that integrated activity based learning environments are worth building and investigating.

4 Observers

The ISLE experiment was accompanied by R.Ernst (Department of Linguistics) and P.Fuchs (Department of Physics and Mathematics). The two researchers designed questionnaires for the students, interviews with the teacher, and observations of ISLE classes. Moreover, during two double periods, M.Robbiani (Department of Physics and Mathematics) was present as an observer. At the end of the trial period, R.Ernst and P.Fuchs conducted an intensive discussion with the group of students. Their report detailing all their observations will be published shortly.

5 The ISLE Team of Authors

Let me mention here that without the personal devotion of the team of authors—putting in their private time over the course of the last two years—this didactic experiment would not have been possible. The authors designed and created all the experiments, took videos and data, created system dynamics models to accompany the activities, and integrated the materials in a shell created as a Web application running in a standard browser on different platforms.

6 Outlook

The work reported here is the result of the first trial of a still very preliminary version of a physics ISLE. It encourages the team of ISLE authors to continue improving upon their product and to try to implement ever larger sections of a Real ISLE at the Universities of Applied Sciences at Winterthur and at Fribourg. Georges Ecoffey has secured a large sum of money to conduct research and development of an ISLE in Fribourg, and we are working to do the same here in Winterthur. I am planning to teach a complete one year ISLE with the next year of mechanical engineering students. While I do not expect to have a complete ISLE finished with all the materials implemented in their final form, I believe we will be able to create many of the most important materials necessary for activity based learning. The observations made during this first trial run will be important in creating a better learning environment next time.

ACKNOWLEDGMENT

Individuals and institutions have made this didactic experiment possible. I would like to thank my school for providing funds to support this project. The physics of this project rests on the research and development that Werner Maurer and I conducted since 1983. I would like to thank Werner for his part in this endeavor. Much of my knowledge of system dynamics modeling grew out of the work with Johannes Heeb, Martin Simon, and Karl Weber. I would like to thank Jack Wilson, Brad Lister and Bruce Laplante of RPI for showing me the studio developments at their school. To Rosmarie Ernst, Peter Fuchs, and Marcello Robbiani goes my gratitude for accompanying the project and making it a more solid product through their scientific inquiry into the ISLE process. Martin Ilg was the most important and valuable critic of the materials we had produced and a great help during the ISLE trial phase. Naturally, I am greatly indebted to my colleagues and friends of the ISLE team of authors. Last but not least I would like to thank the students of class MB1a who stayed with me through an interesting and—also for them—turbulent time.

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5 Early results of the ISLE trial run indicate that we need extra time to develop the skills necessary for successful work in an ISLE. It may be possible to cover the subjects of the first year of introductory physics in the Department of Mechanical Engineering—which so far is taught in 6 class periods per week, two of which are done in the lab—in four periods per week in an ISLE, provided the students know how to work and study. It appears that we will need much of the extra 2 hours per week to develop these skills, which range from simple manipulation of tools, through data acquisition and analysis, to system dynamics modeling.

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8 LoggerPro and ULI, Vernier Software & Technology, Beaverton, Oregon (http://www.vernier.com).

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10 Teaching and learning before the ISLE trial period roughly progressed as follows. Students had four hours of physics per week in a small lecture room equipped for demonstration lectures. My style of teaching engages students during some time of a double period—answering questions I pose, or working on small problems alone or with their colleagues. Two more hours per week were spent in the lab, the same room which we used for the ISLE project. This room is equipped with 7 Macintosh desktop computers on tables set up as isles

scattered through the room. There is a beamer connected to one of the computers, and there are two more small tables for occasional small-scale experiments. Some books, journals and reports are available to students in this room. We used most of the time of the first semester in the lab for an introduction to system dynamics modeling using Stella[9] (with only occasional reference to experiments). Sometimes I used the time for recitation. Much of the time of the second semester was used for a fairly large project involving a mechanics experiment and the necessary modeling. The project concluded with a relatively extensive formal report.

APPENDIX

Table 2: Results of Exams and Projects

Table 3: Contents of the Physics ISLE

Table 2: Results of Exams and Project

Student	Exam 1 Hydraulics Electricity	Exam 2 Mechanics	Exam 3 ISLE trial	ISLE final project
1	1.5	1.5	1.4	3.0
2	1.6	1.6	2.8	4.5
3	3.1	2.0	2.9	3.0
4	3.4	2.4	2.5	5.5
5	3.4	3.4	3.3	4.5
6	3.7	2.2	4.2	5.3
7	3.0	2.6	3.9	6.0
8	3.7	3.6	3.8	4.5
9	3.1	3.0	4.1	5.5
10	4.1	4.0	3.4	4.5
11	2.9	3.4	4.4	5.3
12	4.3	2.2	4.6	5.5
13	3.8	5.4	5.1	3.0
14	3.5	2.6	5.3	6.0
15	3.5	3.6	5.4	6.0
16	5.0	4.4	5.3	4.5
17	6.0	5.8	5.4	5.3

Table 3: Contents of the Physics ISLE

Section	Subject
Part I	Storage and flow of fluids and electricity
Part II	Inductive behavior in fluids and electricity
Part III	Rotational systems
Part IV	The dynamics of heat
Part V	Transport and change of substances
Part VI	Balance and transport of momentum
Part VII	Motion I: Translation in 2D and 3D
Part VIII	Motion II: Combined rotation and translation
Part IX	Dynamics of fluids I: Gases and radiation
Part X	Dynamics of fluids II: Open systems

REPORT ON THE ISLE TRIAL RUN AT THE ZURICH UNIVERSITY OF APPLIED SCIENCES AT WINTERTHUR (ZHW) IN MAY AND JUNE 2000

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PREFACE

The report presented here is a didactic evaluation of the ISLE-trial run at the University of Applied Sciences at Winterthur which took place in May and June of this year. At the beginning of the year, a working group in teaching research at the Department of Applied Linguistics of the UAS at Winterthur was asked to didactically accompany the trial run. We accepted the request with great interest. Marcello Robbiani actively supported us in this undertaking. We wish to express our gratitude to him at this point.

In composing this study we have attempted to make it understandable. Readers without special knowledge in the fields of physics or didactics should be able to comprehend the text. For the interested reader, the scientific annotations and references to further literature can be found in Chapter 7. In the main text, the essential results of our observations of teaching as well as oral and written questionnaires will be presented and analyzed. More general recommendations and concrete suggestions for improvement have been woven into the text in cursive print. In future teaching trials using the ISLE concept, it would be worth observing the cognitive learning process separately and to look more deeply into (subject area) learning gains as well as transferability. Investigations into the effectiveness of previous training in cooperative learning or problem solving would, in our opinion, also be meaningful and profitable. The ISLE concept provides promising possibilities beyond teaching in real classrooms. When further developed and modified, the software learning materials could be used for virtual distance learning.

We hope that further work with the ISLE model will receive the support both ideally and materially that it deserves.

Rosmarie Ernst and Peter Fuchs Winterthur, October 11, 2000

TABLE OF CONTENTS

1 DIDACTIC ACCOMPANIMENT OF THE ISLE PROJECT

1.1 Short description of the trial run

ISLE is the realization of a new type of laboratory based teaching in physics. Experiments, exercises and modeling with validation are done virtually on the computer. The instructor and the students, though, work together in a studio allowing for some of the experiments to be done in real. Some of the elements found in an „Integrated System Dynamics Learning Environment", ISLE for short, have been developed and tried in the USA.[13] The ISLE itself was tried out at the Zurich University of Applied Sciences at Winterthur. Mechanical engineering students in their second semester were the first subjects. The theme was an introductory unit of thermodynamics which lasted four weeks. Three weeks (each with two double periods) were spent on working on the subject matter in studio format, and one week (two double periods) was used for a small project dealing with the theme. The physics studio usually had eight or nine students (half the class) who worked in fixed groups of two or three students. At the end of the trial run the students took an examination of the subject matter.

At the beginning of a double period the instructor usually discusses a few aspects of theory which compose the basis for the exercises subsequently done by the teams of students. During this input phase which lasts for fifteen to twenty minutes, the students gather around the instructor listening to the oral instruction and making use of written information on the blackboard. The rest of the time is spent working in small groups at the computers studying the ISLE problem tasks, modeling physical processes (meaning the representation of physical processes on the computer using physical laws) and validating. Filmed physical experiments as well as measured data are part of the ISLE learning materials available on the computer. (More about the learning software in Section 5). A part time physics assistant is there and occasionally aids the small groups. The instructional language is English.

1.2 Didactic accompaniment

The project leader Hans Fuchs acts as the instructor in the ISLE trial run. We, two independent specialists, who also belong to the faculty of the UAS, accompany the project. The didactic aspects of this new form of instruction are of primary interest to us. Because it cannot be compared to a "traditional" style of laboratory based physics instruction, the idea of a comparative study was discarded right away. Instead, a descriptive approach was chosen. Our primary interest are general didactic questions such as learning goals and student expectations as well as questions about teamwork and individualization. An important subject in the education of adults, instructional quality, is included in the research. The learning materials will also be evaluated.

1.3 Data

In the sense of perspective-triangulation,[14] all three participating groups should contribute their views to the study: the students' perspectives, those of the instructor as well as our observations and thoughts. We have gathered information and data before, after and during the trial run.

- We interviewed[15] the physics instructor, who is also the project leader, before and after the trial run. These interviews lasted sixty and ninety minutes, respectively.
- We also received a comprehensive fourteen page evaluation report from the instructor three weeks after the trial run.[16]
- The seventeen students in the participating class filled out individual questionnaires[17] before and after the trial run; the questionnaires had twelve and twenty eight questions, respectively.
- A one hour discussion with the class two weeks after ending the project revealed further aspects of the students' point of view (which were only partly dealt with in the questionnaires). We not only tried to collect these new aspects but to quantify them in that we counted the students' acceptance or rejection in the individual ratings or suggestions.
- Finally, we visited several of the lessons during the trial run,[18] observing what went on in the classroom. For this we used a simple standardized observation form.[19]

2 LEARNING

The new type of learning is of central importance to our didactic accompaniment. The goals of the instructor, the students' expectations as well as satisfaction with the results will be represented along with our observations, evaluations and suggestions.

2.1 Teaching and learning from the instructor's perspective

Motives

The basic motivation for the ISLE project lies in the dissatisfaction of the physics instructor with conventional teaching and learning using the lecture form of instruction with a separate laboratory which commonly does not include modeling; moreover the laboratory work usually has a week relation to the main part of instruction. The instructor hopes the new type of instruction results in more intensive learning. He got to know similar instructional methods at universities in the USA[20] and decided to produce the necessary teaching materials together with a physics instructor at the UAS in Fribourg and to try out ISLE instruction for the first time at the UAS Winterthur for a four week period of time.

Learning goals

The instructor's goals were—apart from the subject (introductory thermodynamics) itself—"better learning" by active forms of learning. By letting the students deal with the subject in a more direct and more practical manner he hopes for a deeper understanding of physical relationships and better retainment than with traditional lecture type instruction. He considers the relation between modeling and experiments as central. This sets ISLE apart from conventional laboratory instruction. Moreover, the instructor spoke of learning goals relating to “future oriented learning”, which, in his opinion, is very important in the work of engineers. When asked about encouraging team-working skills, the instructor realizes there are possibilities for learning in this form in his trial run, although he does not consider himself a specialist in this area. He wants to require a “learning journal” from each student. Exactly what he means by that is not clear to him at the interview. The students are told to create a journal during the trial run, without further instruction. Shortly before the examination they produce mostly individual collections of formulas which can be used during the examinations. We cannot speak of a real “learning journal” in the didactic sense here.

Results

The instructor is basically satisfied with the learning results of the trial run. He could observe that most of the students “dealt more deeply with the material” than in conventional instruction. He attributes this to the more active learning in the ISLE method. This statement agrees with our own observations of the instruction. We have seen few inactive students. The students also unanimously praise the central idea of ISLE instruction (compare section 2.2). The instructor cited two students as an example who had previous grades in physics of about 3 and 3.5. They both had excellent results in the examination as well as the small project at the end of the trial run, having grades of between 5 and 6.

- *We consider the forms of learning with complex and application related problems, where the students must also create models, as challenging and at the level of university studies. The ability to transfer what is learned to later problem solving in the same subject area, in other subject areas and in professional activities is developed by this learning concept.*[21] *Instruction which activates students shows different and better results than conventional lecture type instruction.*

The examination at the end of the unit of the materials taught and learned in this new way was, to a certain extent, different from a conventional physics examination (as used by the instructor in previous years). There were questions based upon traditional physics problems, but there were also questions about processes. These had to be described, explained and represented. Problems having specifically to do with the ISLE were a part off the exam. The instructor judged the exam results after ISLE instruction to be a little better than previous results. It is difficult to judge if there is a real improvement over conventional instruction, as there is no parallel group to compare it to and the participating group was very small.

- *It certainly makes didactic sense to construct the final examination so that several aspects dealt with in the instruction—including modeling—can be tested. Important as well is the fact that problem solving (including modeling) is very important for practicing engineers. The examination tested the abilities and methodological competency learned during instruction. The fact that teamwork, in the form of the small project, became a part of the final grade, makes sense.*

The learning journal was unsuccessful. The assignment was - according to the instructor - not specific. The students only started making notes toward the end of the instruction and those did not describe or reflect the learning process. They were only a list of scientific formulas. These notes were unfortunately not presented to us.

- *The idea of a learning journal is very appropriate to the ISLE concept. The realization of this idea must be better planned and precisely defined though. Learning journals are notes by the ones learning about their results in learning (in relationship to the material being learned) and their own learning process. The learners gain an overview of the things learned, on the one hand, and of successful or unsuccessful learning and problem solving strategies on the other.*[22]

An interesting result of the trial run in which modeling played an important role, was that the students' preconceptions became apparent. During interaction between students or between the instructor and the students, the instructor was directly confronted with correct or incorrect conceptions about physical relationships.

- *Precise knowledge of the preconceptions of the ones learning are very valuable. They allow for more focused and more efficient didactic work. A university of applied sciences is where students with differing amounts of previous training are taught in the same classes or groups. Acknowledgment of the students' preconceptions and the willingness to meet students where they come from, is an essential requirement of successful teaching and learning.*[23]

2.2 Learning from the students' point of view

In the first questionnaire before the beginning of the project, we asked, among other things, what the students' expectations were of the new way of learning. We also asked about their expectations of computer aided learning, a could be a trend setting method of learning. Students' expectations concerning teamwork were also investigated. The students' expectations proved to be basically positive in relation to the "new" way of learning from which they expected more than from conventional laboratory instruction. They also had positive attitudes towards computers as promising learning tools, as well as toward the idea of teamwork.

In the written questionnaire after the trial run of the project (and after the examination!) the students were less positive about the new way of learning in comparison to traditional instruction. What they experienced was noticeably less than what they had expected. The class discussion, as well as written comments, have shown that part of the negative criticism had to do with the unfinished software (more about this in section 5). The opinions about the usefulness of computers as a learning medium was positive, though. The students believed that this method of learning would make learning easier in other areas if the corresponding learning software were available.

- *The computer serves an the learning medium in ISLE instruction. Methodological* *competencies in dealing with a future oriented way of learning were learned. It is very important, though, that the computer based materials are complete enough so that one can deal with them without frustration (compare section 5).*

The students had a high opinion of the knowledge gained in teamwork (more about this in Section 3). In the class discussion at the end of the project, all the students praised the basic idea of this type of instruction, namely, getting the students to actively learn. The idea of "immediately applying what is learned" was generally approved of. The possibility for teams to go their own ways in solving problems and that the instructor could deal quickly and individually with questions, was judged as positive. These last two aspects were also observed by us during our class visits.

- *We see another strong point of ISLE instruction in its openness to varying ways of problem solving. The different teams can choose the strategies for solutions which suit them. The concept guarantees chances for promoting creativity among students.*

3 TEAMWORK

Team-working skills and other social skills are among the most important requirements described in job advertisements for mechanical engineers. It is, doubtless, a key ability in the engineering profession. Teamwork plays an important role in ISLE instruction. More than three quarters of the class time is spent sitting in small groups with paper and writing materials, sometimes with a book, in front of the computer dealing with the materials being learned. If a team member does not know something, others do. Ways of solving problems are proposed and evaluated. Useful data records are searched for and the numbers to be used are discussed.

It is clear that we have stressed teamwork in our qualitative study.

3.1 The instructor's perspective

As mentioned in Section 2.1, the encouragement of teamwork among students was not one of the learning goals mentioned by the instructor in the first interview.When asked, the instructor confirmed the importance of teamwork in the ISLE concept. He explained that because he was not educated in the area, he did not know how to promote this specifically. At the end of the project, though, he required a team project which would make up one quarter of the final grade.

In the second interview (after the end of the project) the instructor was just as vague in his comments as before: He knows how important teamwork is for ISLE instruction, but is not sure how much the participating students have profited from the teamwork and what he, as the instructor, can do about it.

3.2 The students' view

Before the start of the project, all the students expressed positive expectations in regards to teamwork. The spectrum ranged from personal preferences for team work to hope for more efficient learning and the conviction that instruction using teamwork is a good preparation for future employment as engineers. The responses about this at the end of the project were far above what had been expected: they liked working in teams and they profited greatly from teamwork. The greatest praise was given to the possibility for team partners to explain problems to each other which they made constant use of.

- *Physics instruction using the ISLE concept can greatly promote the key skill "team working ability". Almost all the students were satisfied and reported a gain in learning. In our opinion though, this social aspect of group work should be more of a focus: A short theoretical input is necessary. The students should build upon this and be supported and motivated to role changing as a reflection of their teamwork in the ISLE project. Notes in the learning journal would serve to sensitize and cause reflection. Further theoretical input about role changing and gains in learning*[24] *could widen and strengthen social skills. Theory about teamwork should definitely be formulated; it can also be dealt with in another subject area. Most important is that the students apply this theoretical input to their own work.*

3.3 Observations of instruction

The teamwork aspect which the students praised is confirmed by our observations: As described under the title „team work", there was much student activity to be observed. Almost no one was passive. Nevertheless, we could distinguish the faster, more active students from the more hesitant, passive ones by watching and listening to them. We also noticed during all of our visits that certain roles had been established. The same students always had the computer keyboard or mouse in their hands. Obvious role changing did not seem to occur, although in the second interview, most of the students denied that fixed functions had been assigned to certain team members.

4 Quality of Instruction (Importance, Efficiency, Learning Atmosphere)

To qualitatively assess ISLE instruction, we will use a didactic approach which, in our opinion, is especially well suited to teaching at a UAS. These are the three „Quality Criteria for Instruction": namely importance, efficiency, and learning atmosphere.[25] These quantities were conceived theoretically on the basis of didactic principles and empirically investigated in the classroom. In a first interview, the students and instructor(s) of the course are asked about their expectations and attitudes. After the end of the teaching project, there is a second interview about satisfaction with the project. Here, the meaningfulness and efficiency of the teaching unit in question as well as the learning environment are the focus.

4.1 Importance

In the first poll, the students judged the trial run of the project as something very important. They especially expressed high expectations of this type of computer-aided learning which, as opposed to traditional instruction, promises to promote learning by active student participation. The students consider the immediate connection between theory and experiment, flexible time management, and fun of learning, to be important for successful learning.

For these same reasons, the project was still judged to be important by both the students and the observers after the trial run was over. Most of the students said that the experience with a new and interesting method of learning was meaningful. Being able to relate knowledge to experiments and modeling at the computer was deemed important. A few students, though, complained that they were dissatisfied and that the same material could have been taught in a traditional classroom situation. We believe that the exam results which were made known shortly before the second interview played a role in the dissatisfaction of these few students.

4.2 Efficiency

Just about half the students thought that they had learned more in a shorter amount of time than in a conventional classroom situation. This is especially interesting to note when one realizes that the students spent little time on average (two hours per week) on studying by themselves. Their reason was the study and assignment load in other subjects. In spite of this, the students realized that they had gained deeper knowledge, thanks to their active participation. In addition, in the second interview, they expressed that team-working skills were successfully promoted (compare to Section 3.2).

4.3 Learning atmosphere

We observed a very good learning atmosphere. The relation between the instructor and the students can be described as decidedly open and friendly. The students were mostly very active, asking questions, and showing no hesitation in answering the instructor's questions. Remarkably, the instruction did not take place in the students' mother tongue, but in English. The first interview showed that the students' make high demands of the learning atmosphere. They stated that a good learning atmosphere is absolutely necessary to their motivation and success. These high expectations by the students explain the somewhat less positive opinions of the students afterwards. Still, most of the students judged the learning atmosphere as positive also after the trial.

4.4 Summarized theses about the quality of instruction

- *The students as well as the observers judged the project trial run as basically meaningful and worthy of development. The individual work of the students outside of the classroom must be networked, checked and coordinated. A cooperative and open learning atmosphere encourages motivation and successful learning. The ISLE model* *is especially well suited to encouraging teamwork, motivation and active "holistic" learning. On the whole, taking the three aspects „significance", "efficiency" and "learning atmosphere" into account, we can ascertain a high level of didactic quality in the project's trial run.*

5 ISLE LEARNING MATERIALS

The observations and interviews about learning materials resulted in the following points of emphasis:

5.1 Incompleteness of the ISLE software at the point of the trial run

The learning materials for the subject of thermodynamics were incompletely implemented into the software at the time of the trial run. The missing elements made it impossible for the students to test the software as a whole. They had to depend upon other sources. Most students found this to be a drawback. There were mostly positive expectations of the students in the first interview on the subject of learning in a new type of environment. For about one quarter of the students, though, this gave way to a certain amount of skepticism about the usefulness of software for learning. Most of them based this upon the incompleteness of the learning materials.

- *The ISLE software should be further developed (concrete suggestions for improvement in section 5.3). The idea of integrating theory, experiments and modeling into a holistic learning process is promising. The next trial run should be carried out with more complete learning materials.*

5.2 Application of ISLE software in the trial run of the project

5.2.1 Working with the software

During our observations we determined that most of the students had problems using the computers and with the software in particular. They spent a lot of time trying to master technical difficulties. All the students find it necessary to have an introduction for this.

- *An introductory course before starting the actual course is absolutely necessary.The students must also be taught journal keeping skills to be able to keep track of what they learn. A cooperation with instructors in the social sciences and humanities is to be recommended. (Compare to Section 2.1)*

5.2.2 Software application and holistic learning

ISLE software supports holistic learning. Theory, experimentation, modeling and validation all happen interconnectedly. This form of learning forces the student to be more active. We did notice though, that weaker students had trouble with this. The instructor's help and input was especially important for these students. Only a longer trial run with more groups will show if students can accustom themselves to this form of learning and if they have greater success in learning this way as compared to traditional methods. The statements by students that they approve of an integrated learning environment point to a long term success for this.

- *Apparently working at a computer screen is as tiring as listening to lectures. We expect more and faster success of this form of learning if working at the computer is combined frequently with input from the instructor, working with books or other written materials.*

5.2.3 Limits of application of the learning materials

Most of the students were of the opinion that it is not practical to deal with theory at the computer. All of them prefer the simultaneous use of a book or other written materials.

- *The question arose about whether or not software should be used more as an instrument of training in coordination with a book or other written materials. The instructor should also give more input in the plenum. These could then be summarized in written form.*

5.3 Suggestions for improvement

5.3.1 Suggestions for improvement of the user interface

- Improve legibility on the screen
- Design the appearance of the different levels to be simpler and easier to understand („less is more”).
- The different levels should be made easier to differentiate with color and graphics.
- All the necessary files should be available by mouse click (searching for files in folders, i.e., subdirectories, should not be necessary in the next version)

5.3.2 Suggestions for improvement of the structure

- Possible integration of on-line help.
- Do not implement theory; possibly summarize it, though.
- Simplify and improve navigation.
- Improve the possibility to check one’s own work (i.e. solutions should be available).

6 ECONOMICS OF AN ISLE

The actual instruction during the trial run took place in four instead of six weekly class hours. The instructor believes that the same subject goals can be met as in the six hours necessary for conventional instruction. The results of the final exam at the end of the project’s trial run appear to support this.

The amount of work involved in creating an ISLE cannot be correctly estimated as, at least at the beginning, the amount of work involved in the instructor's preparation was great. Also, how much effort will be needed for looking after the students in a studio is still unknown. Because of the infrastructure, the instructor had to divide the class into two smaller groups. For this reason the time spent with the students by the instructor was not less than otherwise. Moreover there was an assistant present who worked with the instructor on software development. Although he was not required to look after students, he advised them now and then. A further trial run with a larger group in an environment appropriate to it, would give more concrete results. It would be especially interesting to see if a larger number of students participating in this form of instruction can be tended to by one instructor. It should also be mentioned that the amount of time and effort needed to introduce the students to the learning materials is relatively great. This problem is of lesser importance, though, because the time needed for it will be less when this form of instruction is used for other areas of study in physics, and if it starts being used in other disciplines.

- *The question about the amount of work necessary by the instructor in this form of education is still undetermined. This will be more carefully looked at in further trials of the ISLE method.*

7 NOTES

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[12] Peter Fuchs, Ph.D. in mathematics. Project leader of Quality Management at ZHW, formerly project leader of the reform project at Technikum Winterthur Ingenieurschule.

[13] Studio learning was introduced at Rensselaer Polytechnic Institute, Troy, New York. System dynamics modeling is used in several high schools in the United States, in management training at MIT, and as the basis of a degree in system dynamics at Worcester Polytechnic Institute in Worcester, Massachusetts.

[14] See Flick 1998, p. 66 and p. 249.

[15] We used the form of the "partially standardized interview" which is an interview with prepared, partly complex questions. These questions serve as a guide. However, they can be omitted if the subject was dealt with before in sufficient detail. It is possible to insist if necessary or to add questions.

[16] Fuchs 2000

[17] The questionnaires combined questions requiring answers of yes or no, or "grades" on a scale from -3 to +3, or open questions requiring reasoning or suggestions. (See Wottawa/Thierau 1998, p. 131 and following.)

[18] In addition to Rosmarie Ernst and Peter Fuchs, Marcello Robbiani participated in the observations in the ISLE studio. This led to a welcome third perspective. During observation, we normally sat down behind small teams of students without participating in their processes of communication or problem solving.

[19] On the observation forms we noted the activities of the instructor and the students-including, if possible, students' use of the software.

[20] Rensselaer Polytechnic Institute, New York, and MIT (see Note 3).

[21] Seel 2000, Chapter 5 (p. 303 and following); Steiner 1996, p. 286 and following.

[22] Metzger suggests students at universities should use "learning strategy journals". Such journals would allow students to become clearly aware of their learning processes and to control them. (Metzger 1996, p. 96 and following).

[23] Anticipating previous knowledge and learning experiences of learners is called a “didactic principle” of adult education. (Siebert 1996, p. 103 and following).

[24] We know of interesting research results relating to learning in teams consisting of two students. In particular, the efficacy of explaining to each other has been investigated. The abilities of students, particularly the ability to transfer knowledge, are higher if students learned in teams of two instead of alone. Teams of two taught the dyadic learning methodology demonstrated the best results (Dansereau in Steiner 1996, p. 307 and following). Training students to use “dyadic cooperative learning” before the actual courses increases their abilities in the subjects as well as their methodological competencies with respect to problems solving strategies and social interaction. Also see the research on cooperative problems solving presented by Seel (Seel 2000, p. 343 and following).

[25] Kramis 1989; Kramis 1991/92. Also see Patry 1996, who stresses the importance of Kramis’ concept.

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A FIRST REAL ISLE TRIAL RUN

Beobachtungen, Bemerkungen, Eindrücke von
Martin Ilg

1 EINLEITUNG

ISLE ist die Kurzform für *Integrated Systemdynamics Learning Environmen*t. Die virtuelle Lernumgebung, von der im folgenden immer die Rede sein wird, besteht aus verschiedenen Unterumgebungen, die z.B. Experimente in Filmform, virtuelle Experimente, *Stella*-Modelle, Theorie, etc. enthalten können.

Am Mittwoch, den 17. Mai, begann die erste Gruppe von Studierenden das Kapitel *IV. The Dynamics of Heat* mit ISLE zu erlernen. Ich selber begann die Arbeit bei Hans Fuchs am Montag, den 15. Mai, hatte also den ersten Kontakt mit ISLE an diesem Tag. Die Situation für die Studierenden und für mich war in dem Sinne identisch, dass sowohl für sie wie auch für mich, das Lernen mit ISLE eine Premiere war. Die Vorkenntnisse in Physik und in der Methodik[1] waren jedoch verschieden. Während meiner Studienzeit am TWI[2] habe ich die Thermodynamik bereits kennengelernt; durch Vorlesungen in herkömmlichem Sinne und durch Modellieren einiger physikalischer Phänomene mit *Stella* im Physiklabor[3]. Bezüglich Methodik stufe ich meine Kenntnisse höher ein, als diejenigen der Studierenden, weil ich mehr Erfahrung in der Handhabung der verschiedenen Programme habe. Da ich mich in den letzten Jahren nicht mit Thermodynamik befasst habe[4] und zudem die Art mit ISLE Physik zu lernen grundlegend verschieden ist zu den herkömmlichen Vorlesungen, bot sich für mich ein Probelauf mit ISLE an. Dieser Probelauf sah wie folgt aus:

1. Wie ein Entdecker habe ich mich zuerst in die Umgebung begeben, um zu sehen, was ISLE alles beinhaltet und ein bisschen später wie ISLE strukturiert ist. Ich habe alle Experimente angeschaut, die Nase in den Theorieteil gesteckt, geclickt, wo man clicken kann, Modelle betrachtet etc. Alles war noch ziemlich unverbindlich und ohne Ansprüche, etwas zu lernen.
2. Nach dieser Entdeckungsreise habe ich mit den Assignments der Sektionen *IV.1 Thermal Phenomena* und *IV.4 Entropy and Energy in Heat Transfer* begonnen und dazu ein Workbook[5] geführt. Ich bin dem Pfad, der in jeder Sektion vorgeschlagen wird, mehr oder weniger gefolgt.
3. In der darauffolgenden Zeit habe ich einerseits auch noch die anderen Sektionen bearbe-

1. Im wesentlichen die Handhabung von *Stella* und *Excel* und die Fähigkeit mit Daten umzugehen
2. Maschinenbaustudium von 1993 bis 1997
3. In der Thermodynamik z.B. Wärmeleitung in einem Stab
4. Mathematikstudium von 1997 bis 1999
5. siehe Anhang

itet, um mich für den Kurs mit den Studierenden vorzubereiten[1], und andererseits einige Aufgaben, Fragen und Lösungen zusammengestellt und *Stella*-Modelle für noch fehlende Sektionen kreiert.

Die Beantwortung von Fragen seitens der Studierenden und das Definieren von Aufgaben verlangten ein profundes Verständnis der Physik. Nicht alles war mir auf Anhieb klar. So konnte ich aber gleich in die Studierumgebung[2] eintauchen und testen, ob sie meine Fragezeichen beseitigen kann. Im weiteren habe ich aber auch die beiden Physiklehrbücher[3] für Vertiefungen im entsprechenden Gebiet benützt. Bei jeglichem Arbeiten mit ISLE, sei es beim Lösen der Assignments oder allgemein beim Navigieren, habe ich Mängel und Schwachpunkte die ich entdeckt habe, aufgeschrieben, mit Hans Fuchs besprochen und Verbesserungen vorgeschlagen. Im folgenden lege ich meine Erfahrungen und Beobachtungen zu den folgenden Fragestellungen dar:

- Wie habe ich das Arbeiten mit ISLE erlebt?
- Wie habe ich den Kurs mit den Studierenden erlebt?
- Inwieweit könnte sich ISLE für das gemeinsame Lernen auf Distanz eignen?

2 WIE HABE ICH DAS ARBEITEN MIT ISLE ERLEBT?

2.1 Bemerkungen zur Navigation

Zu Beginn bekundete ich Mühe, mich in den Umgebungen zurechtzufinden, sprich die Struktur zu erkennen. Oft wusste ich nicht genau, wo ich mich befand. Kurzfristiges Ziel war dann, an einen Ort zurückzukehren, an dem ich mich von neuem orientieren konnte. Bevor ich diesen Ort dann erreichte, hatte ich schon einige unnötige Clicks hinter mir. Die Gründe dafür waren vor allemvor allem die folgenden zwei:

- Bei jedem Click wurde das aktuelle Fenster durch das neue ersetzt. Sprang man z.B. vom ALE[4] in das ASE (beispielsweise mit dem Ziel Begriffskonfusionen zu beseitigen) und navigierte im ASE weiter, entschied sich dann wieder ins ALE zurückzukehren, so wusste man gar nicht mehr recht, wie man wieder zum alten Ort im ALE gelangte.
- Es fehlte ein Button, der einem in der Hierarchie eine Stufe höher bringt.

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1. zusammen mit Hans Fuchs habe ich die Studierenden während des Kurses betreut
2. ASE: Active Study Environment
3. Borer & Co.: Physik: Ein systemdynamischer Zugang für die Sekundarstufe II; H.U. Fuchs: The Dynamics of Heat.
4. ALE: Active Lab Environment

Diese beiden Punkte sind jetzt behoben. ALE und ASE erscheinen je in einem separaten Fenster und bei vielen Button, die man anclickt, öffnet ein neues Fenster. Einen Button, der das Höhersteigen in der Hierarchie ermöglicht, erscheint nun in der linken oberen Ecke. Das Navigieren und die Bedienung sind nach den Änderungen nun bedeutend einfacher. Trotz der einfachen Bedienung scheint es mir sehr wichtig, dass die Struktur und die Möglichkeiten des Programms bei Beginn des Arbeitens mit ISLE erklärt werden. Falls jedoch jemand ohne vorherige Anleitung zu lernen beginnt, hat er über den *Info-Button*, den *ISLE Structure-Button* und den *Methods and Philosophy-Button* Zugang zu wichtigen Programminformationen. Für den Kurs ist es aber sicher sinnvoll, eine Einführung durchzuführen.

2.2 Bemerkungen zu den Filmen mit den Experimenten

Mit wenigen Ausnahmen erkennt man in den Filmen sehr schön, was im Experiment passiert. Als Einstieg in die Assignments und später als Inspiration für das *Stella*-Modell eignen sie sich sehr gut. Ausserdem machen sie die Physik lebendig, bringen zusätzlich Dynamik ins Lernen und prägen sich ins Gedächtnis viel besser ein, als eine Beschreibung des Experiments.

2.3 Bemerkungen zum Active Lab Environment ALE

Im ALE habe ich mich die meiste Zeit mit den Assignments befasst (die ihrerseits aber zu fast allem Material im ISLE Bezug nehmen und demzufolge im ALE praktisch alles abdecken) und parallel dazu teilweise ein Workbook geführt. Die Assignments bauen auf einem Experiment auf und führen den Lernenden Schritt für Schritt zu einem meist wichtigen Resultat oder zu einer Erkenntnis. Dieser Aufbau ist aus meiner Sicht ideal, wobei mir eine gute Führung auf dem Weg zum Ziel besonders wichtig erscheint.

Alle Daten[1], die ich für das Modellieren des Experiments benötigte, waren vorhanden. Es ist nicht vorgekommen, dass ich Daten gesucht und nicht gefunden habe. ALE ist durchdacht und sehr vollständig in Bezug auf den Inhalt. Ich konnte in dieser Umgebung sehr gut lernen.

2.4 Bemerkungen zum Workbook

Da man Diagramme, Herleitungen, Modelle sehr einfach in ein *Word*-Dokument hineinkopieren kann, bietet sich die Führung eines Workbooks an. Neben diesem technischen Vorteil ist es aber wohl das Wichtigste, dass man gewonnene Erkenntnisse und Überlegungen notiert, damit sie nicht verloren gehen. Die Idee dabei ist, dass man neben den ISLE-Fenstern ein *Word*-Dokument geöffnet hält. Dies ermöglicht einem, jederzeit Einträge zu machen. Später kann man das Workbook bearbeiten, ergänzen und nach Fertigstellung als Skript benützen. Mein Probeworkbook[2] ist noch bescheiden ausgefallen. Einiges habe ich auf normalem Notizpapier aus-

1. z.B. Masse, Material, Geometrie des Behälters, Anfangstemperatur des Wassers, Raumtemperatur etc.
2. siehe Anhang, das Workbook liegt in unbearbeitetem Zustand vor

geführt, so z.B. Diagramme oder *Stella*-Modelle skizziert. Auf jeden Fall bieten sich eine Menge Möglichkeiten an, das Workbook zu gestalten. Das Führen eines Workbooks beim Arbeiten mit ISLE würde ich sehr empfehlen. Wie man es führt, mit einem *Word*-Dokument oder auf normalem Papier, spielt dabei eine untergeordnete Rolle.

2.5 Bemerkungen zum Active Study Environment ASE

In die Studierumgebung habe ich gewechselt, um beispielsweise Begriffskonfusionen zu beseitigen oder um Unklarheiten bezüglich der Physik zu klären. Hilfreich empfand ich die Diagramme, die beim Darüberfahren mit der Maus Erklärungen zum Diagramm erscheinen lassen und der *Derivation*-Button, der beim Draufclicken ein Fenster mit der Herleitung der entsprechenden Gleichung erscheinen lässt. So kann man durch elegante Art Zusatzinformationen zu einem Diagramm oder zu einer Gleichung auf einer Seite unterbringen und somit ein Blättern, wie es beim normalen Buch vorkäme, vermeiden. Allgemein ist die Oberfläche des ASE attraktiv und sauber gestaltet. Die Sprache empfand ich als angenehm und den Inhalt als gut verständlich, so dass ich häufig länger als erwartet dort verweilte. Positiv habe ich auch die Möglichkeit empfunden, *Stella*-Modelle zu studieren und mich von ihnen inspirieren zu lassen.

2.6 Bemerkungen zu den Büchern

Die zwei Physikbücher[1] habe ich rege benützt. Für längere Lesezeiten bevorzugte ich, ein Buch zur Hand zu nehmen und mich an einen Ort abseits des Bildschirms zu setzen. Zu langes Lesen am Bildschirm ermüdete meine Augen. Ein Begleitbuch zu ISLE soll ansprechen und attraktiv gestaltet sein, damit man es bei Problemen auch wirklich zur Hand nimmt. Beim Arbeiten mit ISLE könnte einem Buch eine andere Bedeutung zukommen; beispielsweise könnte es mehr unterhalten und weniger harte Theorie vermitteln. Beide Bücher empfinde ich als attraktiv. Das Physikbuch von Borer&Co. eignet sich sehr gut als Begleitbuch. *The Dynamics of Heat* finde ich für die behandelte Physik in ISLE zu anspruchsvoll.

3 WIE HABE ICH DEN KURS MIT DEN STUDIERENDEN ERLEBT?

Wie bereits erwähnt, war ich in den Kursen anwesend und habe, falls nötig, den Studierenden bei technischen und physikalischen Problemen geholfen. Das Wichtigste gleich vorweg: Ich hatte das Gefühl den Studierenden hat es Spass gemacht, auf eine vollkommen neue Art, Thermodynamik zu lernen.

1. siehe Fussnote 8

3.1 Bemerkungen zur Arbeitsweise

Es wurde vor allem in Zweier- und Dreiergruppen gearbeitet. In den allermeisten Gruppen wurde lebendig und produktiv gearbeitet. Es wurde diskutiert (auch zwischen den Gruppen), es wurden Unklarheiten formuliert und einander Lösungswege vorgeschlagen. Manchmal wurde meiner Meinung nach zu früh in den Lösungen nachgeschaut oder mit einer anderen Gruppe ein unvollständiges Modell verglichen. Ein Problem war auch, dass mit den Parametern gespielt wurde, ohne sich deren Bedeutung und Einfluss auf das Resultat bewusst zu werden[1]. Die Studierenden waren in physikalischen[2] und in methodischen Angelegenheiten auf die Hilfe von Hans Fuchs und von mir angewiesen. Die Physikbücher wurden eher selten zu Rate gezogen, gegen Ende des Kurses und während des Projekts jedoch immer häufiger. Bei den Dreiergruppen habe ich öfters beobachtet, dass zwei aktiv mitarbeiten und einer relativ passiv daneben sitzt.

Ich habe beobachtet, dass viele Studierende enge Führung brauchen bei der Vorgehensweise im ISLE, insbesondere beim Arbeiten an den Assignments. Fehlte beispielsweise ein Wert, so haben sich die meisten nicht freiwillig auf die Suche gemacht (jedoch eher im ISLE als in einem Tabellenbuch), sondern uns gefragt wie gross denn dieser Wert sei. Diese Reaktion ist aber verständlich, denn das Lernen mit ISLE verlangt mehr Selbständigkeit und bietet mehr Freiheit als die klassische Unterrichtsform. Ich glaube, dass man sich an den neuen Arbeitsstil zuerst gewöhnen muss.

3.2 Bemerkungen zur Methodik

Es ist mir aufgefallen, dass die Kenntnisse in der Benützung von *Excel* und *Stella* bescheiden und die Ingenieurfähigkeiten[3] noch nicht ausgeprägt sind. Häufig mussten wir helfen, als es darum ging, Daten von *Excel* in *Stella* zu importieren, den Diagrammbereich zu ändern, die Zeitachse zu formatieren etc. Ich kann mir ein einführendes Beispiel vorstellen an dem man lernt, wie man mit *Excel* und *Stella* arbeitet. Die Ingenieurfähigkeiten könnte man mit geeigneten Übungen fördern. Die Diskussionen dazu sind im Gange.

3.3 Bemerkungen zum Workbook

Ein eigentliches Workbook wurde beim Arbeiten mit ISLE nicht geführt. Die Rechnungen und Diagrammskizzen zu den Assignments wurden auf Papier ausgeführt. Bei der 15 bis 20-minütigen theoretischen Einführung haben die meisten mitgeschrieben. Auch diese Arbeitsweise ist verständlich. Man ist sich gewohnt, den Stoff mehr oder weniger von der Tafel abzuschreiben, jedoch ist es ungewohnt zu entscheiden, “was ist wichtig?, “was nehme ich in mein Workbook auf?”, “wie soll ich mein Workbook gestalten?”Auch hier braucht es Zeit, bis

1. z.B. Wie sieht die Temperaturkurve aus wenn ich den Wert für die Wärmeleitfähigkeit ändere?
2. siehe Bemerkungen zur Theorie der Thermodynamik
3. z.B. folgende Fähigkeiten: mit Daten umgehen (lesen, interpretieren), ein Diagramm interpretieren, eine Funktion skizzieren, Annahmen treffen, Näherungswerte bestimmen, Vereinfachungen treffen...

man den Mut und die Sicherheit hat, diese Fragen zu beantworten. Auf jeden Fall soll man die Studierenden am Anfang nicht mit zu viel Freiheit überfordern und die Führung eines Workbooks eher sehr empfehlen als diese Frage offen zu lassen. Dazu könnte man ein Exemplar vorstellen, welches als Anschauungsbeispiel dient.

3.4 Bemerkungen zum Projekt

In den letzten zwei Laborstunden konnten die Studierenden das Experiment *Cooling of water in a thick-walled sealed PVC container* durchführen. Im wesentlichen haben sie Vorbereitungen getroffen (wie Temperatursensoren angebracht, den Container ausgemessen, Laufzeit bestimmt etc.) und danach die Daten mit *Logger Pro* aufgenommen. Ziel war, das Experiment zu verstehen und es mit einem *Stella*-Modell nachzubilden und zu simulieren. Die Stimmung im Labor war gut. Es hat den Studierenden Spass gemacht, das Experiment aktiv vorzubereiten und es live zu beobachten. Die Spannung, wie die Temperaturkurve aussehen würde, nachdem man darüber diskutiert hat, war spürbar. So wurde dann auch gleich nach Beginn der Datenaufnahme mit der Interpretation der Temperaturkurve begonnen. Aus meiner Sicht ist diese Art Physik zu betreiben attraktiv und ich glaube, dass der Lerneffekt umso grösser ist, je mehr man selber aktiv ist.

4 Inwieweit könnte sich ISLE für das gemeinsame Lernen auf Distanz eignen?

Da ich das Lernen auf Distanz noch nicht erprobt habe, sind meine Überlegungen hypothetischer Natur. Ich kann mir vorstellen, dass man mit geeigneter Software gemeinsam lernen kann, auch wenn grosse Distanzen zwischen den Teilnehmern liegen. Gemeinsam lernen heisst vor allem miteinander zu kommunizieren. Und kommunizieren kann heissen: diskutieren, Informationen austauschen oder auch fragen und Fragen versuchen zu beantworten. Um die Kommunikation auf Distanz zu ermöglichen braucht es Hilfsmittel, wie zum Beispiel eine Diskussionsplattform (ähnlich Chatroom), ein Kommunikationssystem, welches das Miteinandersprechen ermöglicht oder auch Kameras, welche die Teilnehmer noch näher zusammen bringt. Das gemeinsame Lernen auf Distanz könnte etwa folgendermassen aussehen. Ich stelle mir zwei (oder mehr) Studierende vor, die gleichzeitig an den Assignments arbeiten. Beide haben am Computer verschiedene Fenster offen. ISLE selber mit verschiedenen Fenstern, die Diskussionsplattform (oder ein Kommunikationssystem), das Mailsystem und ein Bildschirm. Die Diskussionsplattform (oder ein Kommunikationssystem) dient der Besprechung der anfallenden Probleme und Unklarheiten, das Mailsystem dem Senden und Empfangen der kreierten *Stella*-Modelle und der Bildschirm der Beseitigung des Distanzgefühls. So hat man mit wenig Clicken Zugang zu den verschiedenen Kommunikationsmitteln und bleibt miteinander in engem Kontakt.

5 ALLGEMEINE BEMERKUNGEN

Die folgenden Bemerkungen sind vor allem Erfahrungen aus meiner Studienzeit aber auch Erkenntnisse aus Diskussionen mit Dozenten, Kollegen und Studierenden und Beobachtungen aus dem ersten ISLE-Kurs mit den Studierenden.

5.1 Bemerkungen zur Systemdynamik-Physik

Da an den meisten Berufsmittelschulen BMS und Berufsschulen BS die klassische Physik gelehrt wird, bekunden viele der Neustudierenden Mühe mit der Systemdynamik-Physik. Irgendwie kann man die innewohnenden Ideen[1] noch nicht verstehen und man ist versucht, die alten Bildern oder die noch bekannten Formeln, auf die neue Art, Physik zu betreiben, anzuwenden (Allerdings lässt sich dieses Verhalten unabhängig der Systemdynamik-Physik beobachten; das heisst, den Studierenden fällt es schwer, den Schritt von der BMS- oder BS-Physik zur Fachhochschul-Physik zu vollziehen und so versuchen sie, beim Lösen von Aufgaben alle bekannten Register zu ziehen, anstatt die ZHW-Physik lernen zu verstehen und anzuwenden). Für viele ist der Schritt, eine neue Betrachtungsweise[2] zu erproben und anzuwenden zu gross und so bleiben sie irgendwo zwischen der klassischen und der, sagen wir, anderen Betrachtungsweise hängen. Man fürchtet sich, die alten Bilder (sofern vorhanden) zu verlassen und sich den neuen anzuvertrauen. Dies muss nicht für alle Studierenden gelten. Von einem Studienkollegen weiss ich, dass ihm die Systemdynamik-Physik von Anfang an sehr vertraut war und seiner Denkweise entsprach. Ich vermute jedoch, dass für das Gros der Studierenden die Systemdynamik-Physik längere Zeit fremd bleibt und sie einige Zeit brauchen, um sich darin wohl zu fühlen. Vielleicht sollte man früher damit beginnen, denn hat man die innewohnenden Ideen einmal begriffen, so wird das Lösen von Problemen meiner Meinung nach einfacher und die Art, Physik zu betreiben, eleganter und ästhetischer. Beispielsweise kann man sich, durch analoge Betrachtungsweise in verschiedenen Teilgebieten der Physik, ein Widerstandsgesetz[3] merken und dann in den Teilgebieten anwenden. Auch kann einem das Flüssigkeitsbild zur Veranschaulichung hilfreich sein. Mir selber behagte die Systemdynamik-Physik während des Studiums nicht und ich war verunsichert, als plötzlich die Rede von Systemen und Bilanzen die Rede war. Ich hatte ganz einfach etwas anderes erwartet. Ausserdem fiel die Physik in der BS sehr bescheiden aus. Es wurde mehr Wert auf Formeln und deren Umformungen gelegt, als auf das Verständnis physikalischer Phänomene.

5.2 Bemerkung zur Theorie der Thermodynamik

Viele Studierenden bekundeten Mühe mit dem Kunstwort *Entropie*. Sie wussten nicht, was sie sich darunter vorstellen sollten und ob Entropie wirklich dasselbe bedeute wie Wärme, welche

1. grob: “es fliesst etwas”, bilanzieren, Analogien ausnutzen, Flüssigkeitsbilder benützen
2. Mühe bereitet z.B. die Formulierung “Impuls aus der Erde pumpen”
3. Voraussetzung: man muss wissen, welche Grössen in den Teilgebieten den Strom, den Widerstand und die Potentialdifferenz repräsentieren.

schon seit jeher bekannt war. Da in den maschinentechnischen Fächer mit physikalischen Begriffen häufig salopper umgegangen wird[1], kann es diesbezüglich zu Unsicherheiten und Begriffskollisionen kommen. Ich glaube, dass mit einigen Erklärungen die Unsicherheiten grösstenteils genommen werden können.

5.3 Abschliessender Kommentar

Ich hoffe, dass die saubere Ausarbeitung von ISLE Früchte trägt und dass es für die Studierenden ein attraktives und intelligentes Werkzeug wird. Ausserdem bin ich gespannt, wie sich ISLE nach Implementierung anderer Teilgebiete der Physik präsentieren wird.

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1. Man spricht beispielsweise von Wärme, obwohl man die Wärmeenergie meint.