PROCEEDINGS OF SCIENCE

HPC and Simulations: Teaching the Unteachable? Relaying HPC knowledge at secondary schools – progress report

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Simulierte Welten (engl. "Simulated Worlds") relays HPC knowledge at secondary schools in the German state of Baden-Wuerttemberg, through the collection, design and provision of related material, the documentation of successful teaching concepts, as well as direct interaction with teachers and scholars. The project was initiated by High Performance Computing Centre Stuttgart (HLRS) and Steinbuch Centre for Computing (SCC) in Karlsruhe, and enjoys support from the Department of Technology and Environmental Sociology (SOWI V) of University of Stuttgart. The team, consisting of both scientists and teachers, particularly focuses on computational simulations. This area can also be used as a vehicle to relay the strong (but frequently invisible) impact that HPC applications have on society today. This paper focuses on the practical aspects of teaching the complexities of computational simulations at schools, analyzing the boundary conditions and presenting the chosen strategy.

1. Introduction

We live in a two-tiered world. One side is moved by simulations ranging from testing the best automobile design, to developing and testing the highly advanced medication and surgical tools, all calculated over many hours on incredibly fast and expensive supercomputers. On the other side is the general public, including young students going through their high-school years, wondering if the mathematics and physics they have learned will ever be used for anything they can think of as useful.
These two worlds exist in parallel to each other: the scientists working in the high performance computing centers around the world probably do not think too often about their high school days; and rarely will teenagers sitting in a classroom even notice all the simulations already embedded into their lives every day. The same applies to their parents and indeed most people in our society.
At first glance, these two groups do not seem to be relevant to each other, since students will go on through school, being prepared for life. And those scientists will go on through their professional lives, developing their theories and bringing in further advance in technology. However, these two worlds could only profit from a stronger interaction with one another.

2. Goal

In this project, four major science and education institutions in the German state of Baden Württemberg joined efforts, and started a science outreach project that works as a bridge to connect those two worlds, and create a steady and clear stream of communication between them. The aim of the project "Simulated Worlds" is to reach out to students and get them actively involved in the workings of high performance computing through simulations, raising awareness to the importance of that kind of technology to modern society.
The project was born out of the necessity to make High Performance Computing a science more known to the public in general. Simulations, in turn, grow in importance every day and we rely on them more as we need to have so many things tested in a safer and less expensive way and develop them more efficiently. The cost of such efficiency is high and grows accordingly to the developments made in that sector. Due to the variety of possible topics and the direct impact on society, simulations initially appeared as a useful vehicle to relay the importance of HPC. However, over the course of the project, the topic of "computational simulations" gained a life on its own, putting it at the focus of the project and indeed giving it its name.
Most citizens have no idea of the amount of public money invested into Simulations and HPC and should be made aware of the need, as well as the risks and opportunities arising out of such investments. The next challenge was to find a way to execute the plan. What would be the best route?

This paper is linked to the paper from the year 2013 (Simulated Worlds: Relaying HPC knowledge at secondary schools). But the focus is this time on the current status of the concepts and the way forward, so many details relating to the curricula and scope of the project are not replicated here, if they have already been mentioned in the 2013 report. Readers are instead referred to the project web page[1], and are welcome to contact the project members directly, should further details be required.

3.The knowledge mountain

To reach the goal, the project team designed a three-tiered strategy, shown in figure 1, to relay knowledge about HPC and simulations at secondary schools in the German state of Baden-Württemberg.
There are three levels of knowledge transfer on which the students will be addressed:

1. **Basic knowledge**: At this level, basic knowledge should be taught via evening lectures at participating schools, targeting students as well as their parents and teachers. Also, a simulation game called "Energetika"[2] is used by the project at this stage to illustrate many of the topics. The focus is on the application point of view, is the "what" and not the "how". The aim is to provide an overview of the range of developments, as well as the aforementioned risks and opportunities.
2. **Learning by example**: On the second level students groups receive the opportunity to get a deeper insight, for example in their own small projects and seminars. The aim is also to integrate "simulated worlds" into the curricula and to relay experience with the subject. So it is a mixture of "what" and "how". This second level is aimed at students from the 9th grade in high schools, where skills for simple programming tasks can be provided.
3. **Detailed knowledge**: At this level, selected students get a deeper methodological knowledge. This can be done along the lines of student assistants were they have their own little project, possibly embedded directly into one of the participating HPC centers.

Beyond this "knowledge mountain, the team also conducted "teaching the teacher" sessions, where teachers were given a detailed insight into the topic, as well as the curricula that were developed as part of the project. The aim of this activity is to ensure sustainability beyond the projects lifetime.

[1] www.simulierte-welten.de
[2] www.energiespiel.de

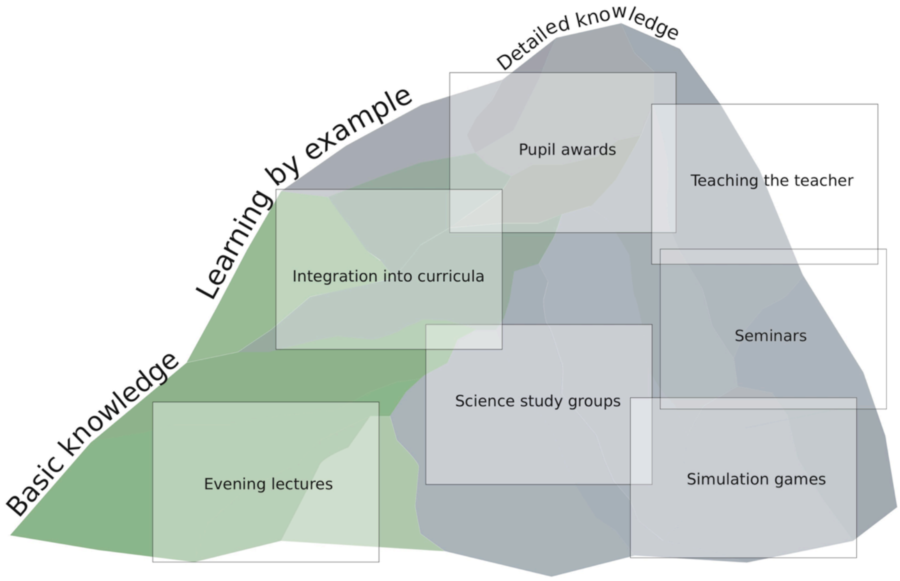

figure 1: knowledge mountain

4. Deeper look at the concepts

In the following part, we want to have a deeper look at some of the concepts shown in figure 1 that have been already conducted.

4.1 Basic knowledge

Evening lectures

Lectures by members of the project team or external experts serve the direct transfer of knowledge to students, teachers, parents, etc. So far, the evening lectures had been lectures on the following topics in the context of:

- Simulation and High Performance Computing
- Simulation and reality
- Sustainable Behavior! Playful learning of sustainability in simulated worlds.
- How can computer simulations help to answer the question "what if"?
- Practical implementation of simulations in "Scratch"

figure 2: Evening lecture at Bismarck Gymnasium, Karlsruhe with pupils, parents + teachers

Simulation games

The online game "Energetika" was developed in the year 2010 by different scientific intuitions. The goal of the game is to supply the fictive country of "Energetika" with 40 years worth of electricity. To solve this complex task, players slip into the role of energy managers. From this point on they must demonstrate strategic skill: they have to choose the right technologies, they have to built new power plants and they have to find a solution for the problems connected with the end-storage of atomic waste. At the same time, the interests of the population, environmental protection and the economic system must also be accounted for. Only those players who keep these aspects well balanced are able to collect points on social, ecological and economic accounts and will successfully conclude the game.

The game is very similar to an entirely computer-based simulation of the same topic, aiming to find a suitable strategy for an "energy mix", with the one exception that decisions are taken by humans. By personally experiencing the complexity of taking the right decision at the right time, players will learn to appreciate the difficulties involved in creating computer-based simulations of this type. They will also learn to understand the possible bias inherent to computer-implemented procedures taking the place of humans in this simulation type. As just one example, consistently rating particular technology types higher than others, e.g. by assuming a very "green" policy will lead to entirely different outcomes of the game. Energetika thus presents a very direct way of experiencing both the opportunities and risks of computer-based simulations.

figure 3: Energetika 2010

The game is currently being reworked, with the addition of data centers being one of the major improvements. With data centers it will be possible to accelerate research projects and to obtain information for the perfect place for wind power plants.

4.2 Learning by example

Seminar course & science study group for students

The *seminar course* was held in the school year 2013/2014 for the first time with eight students. A seminar course is a voluntary service. However, the seminar course provides the advantage that the oral exam (part of the German Abitur) examination can be replaced. In addition, a lot of methodological knowledge is developed, which can be useful for the subsequent studies. The seminar course lasted one academic year and is taught in three lessons per week. The aim is that the students work independently at a subject, alone or in groups, write a term paper and orally present the results.

The *science study group*, was held in the spring of 2013 for the first time. Here, groups of students look for a topic (related to HPC and simulations) in which they are interested. Afterwards they familiarize themselves with this topic, search for an expert from this field and prepare questions around this topic. Then they invite the expert for a prolonged Q&A session. In the last school year the students dealt with the topic “escape behavior” and developed their own (albeit simple) escape simulation.

figure 4: Science Café at the Schelztor Gymnasium

Integration into the curricula

The theme of "Simulated Worlds" can be integrated in many ways in the school classrooms, as simulations include various properties and areas of interest. Thus, the physical-scientific area is obvious, the Computer Science is an essential component and also the engineering sciences are a field for simulations. Even humanities subjects such as history or ethics are heavily involved when it comes to development, risk assessment and social significance.

An integration into school teaching is therefore ideal for integrative subjects like ITG (Information technology Basic Education) and NwT (science and technology). In NwT simulations are a key theme and are firmly anchored in the curricula of the high schools in Baden-Württemberg (simulations can be found indirectly in ITG).

The structure of the lesson follows the pattern "from the width in depth". As shown in the embedded "Didactic overview" poster (see figure 5), the start is a basic question: "What is a simulation and why do we want to simulate?" This happens in a teacher-centered, question developing teaching style.

This brief introduction is followed by a student-activating phase of the application reference, in which the pupils have to program a billiard game simulation under the guidance and with the help of the teacher.

In the third phase, the students select – according to their individual interests – a topic. The students then work in small groups on this topic. These topics cover four basic fields, which play an important role in the consideration of simulations:

- The physically forced limitation of simulation possibilities by phenomena of Deterministic Chaos,
- the analysis and assessment of existing simulations based on the energy game "Energetika 2010",
- the utility and complexity of simulations in the example of protein folding,

- and their their direct applicability in engineering at the task, to bring a raw egg in a free fall or "oblique litter" safely to the ground.

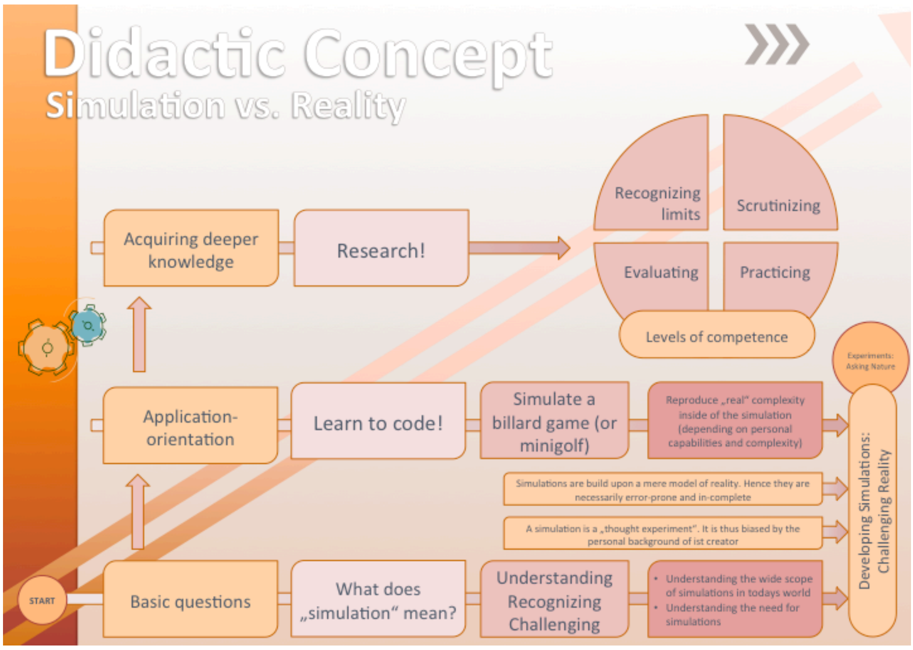

figure 5: Didactic overview

4.3 Detailed knowledge

Teaching the teachers

In the project, two training courses for teachers have been conducted. The goal was to relay theoretical and professional as well as didactic and practical content developed by the project to selected teachers, in order to achieve a multiplier effect through their activity.

After a lecture by Dr. Rüdiger Berlich on simulations from the scientific point of view, their importance in everyday life and its relation to high-performance computing, one of the projects HPC ambassadors[3], Peter Lürßen, gave an introduction to the didactic structure and the structure of the lesson unity. Then the participants were offered a crash course in the programming language "Scratch" from MIT, which is essential.

After the lunch break, Dr. Almut Zwölfer, another HPC ambassador, showed the participants a variation of the unit: instead of a billiard game simulation she used a mini golf simulation that opens a less difficult path into the world of simulations. After that, teachers had the opportunity to try different operations at eight prepared stations and come in touch with some well chosen aspects of simulation ("learning bar").

[3] HPC Ambassadors are project members who are at the same time teachers. Through their direct understanding of related teaching methods and regulations they help the project to develop teaching material in a way suitable for direct integration into curricula.

Finally, a discussion and feedback session was conducted, to address remaining answer questions. Further school projects, like the "Science AG" and a “seminar course” were also presented briefly.

figure 6: Teaching the teacher

5.Awards

In December 2013 the project was voted 2nd best in the national prize competition „**Schule trifft Wissenschaft**“ („School Meets Science“) set up by the Robert-Bosch-Stiftung. The award is associated with a prize money of € 20,000.
In April 2014 the project was voted as "Besonders Preiswürdig" (Especially Prizeworthy) in the competition „**Ideen. Bildung. Zukunft.**“ („Ideas. Education. Future.“) set up by the Bildungsstiftung der Kreissparkassen für den Landkreis Esslingen (Education Foundation of the district Savings Bank of Esslingen). The award is associated with a prize money of € 5,000.

6. Conclusion

The topic of “computational simulations” has so many aspects that its relevance to society, including its opportunities and risks, cannot be fully explored without direct interaction with the topic.
Relaying this knowledge at schools was initially assumed to be limited to showing examples of simulations, as it was assumed that scholars would not have sufficient interest and capability to develop custom simulations.
With the help of the programming language Scratch and in close cooperation with the teachers from our model schools, however, a complete teaching unit was developed.

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The three-tiered design of the project (compare figure 1) proved to be very useful. The approach can be likened to a filter, where general knowledge is relayed in the first tier (quite possibly also to the general public, so it fits in nicely with general dissemination and outreach activities), interested groups of scholars are taught specifics in the second tier (and teachers are coached to relay existing material or further develop own ideas), and the most talented individuals may receive direct coaching in the third tier.
The appointment of "HPC ambassadors" was very helpful and important for the project. The HPC ambassadors serve as a kind of bridge between the specialized knowledge of scientists and practitioners on the one hand, and scholars on the other.

With many surrounding offers, such as a science study group, evening lectures and further seminars, the project team believes to be capable of fulfilling its task: to design a program that allows to relay the topics of HPC and computational simulations at schools in the German state of Baden Württemberg.

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[4] http://mwk.baden-wuerttemberg.de
[5] https://www.scc.kit.edu
[6] https://www.hlrs.de
[7] http://www.uni-stuttgart.de/soz/tu/index.html