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Outreach Initiatives Operated by Universities for Increasing Interest in Science and Technology

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Abstract

Since the 1990s, the low number of students choosing to study science and technology in higher education has been on the societal agenda and many initiatives have been launched to promote awareness regarding career options. The initiatives particularly focus on increasing enrolment in the engineering programmes. This article describes and compares eight European initiatives that have been established and operated by universities (and in some cases through collaboration with other actors in society). Each initiative is summarised in a short essay that discusses motivation, organisation, pedagogical approach, and activities. In the introduction, the initiatives are characterised by looking at The initiatives are characterised by comparing the driving forces behind their creation, how the initiative activities relate to the activities at the university, size based on the number of participants and cost per participant and pedagogical framework. There seem to be two main tracks for building outreach activities, one where outreach activities are based on the university's normal activities, and one where outreach activities are designed specifically for the visiting students.

Keywords; outreach, outreach initiatives, engineering education,

Introduction

Most countries in the western world have encountered decreasing interest in science, technology, engineering, and mathematics (STEM) education and careers (EU 2004) and in the European Union (EU), the percentage of STEM graduates in relation to the total number of graduates has fallen (Business Europe 2011). This trend became obvious to universities back in the 1990s, and several recruitment interventions were established by both institutions and national governments at that time.

During recent years the number of students engaged in the fields of science and technology has recovered (Eurostat 2014); however, since the need for talented people in STEM fields has been growing, many countries are now facing a shortage of STEM professionals (Business Europe 2011). For instance, increasing interest in the use of big data in industry has resulted in a higher demand for workers with scientific and ICT (Information and Communication Technologies) skills. This shortage has raised national and international concerns, and many initiatives were created in an attempt to improve the situation.

When universities and society realised that the shortage of STEM candidates was an increasing problem, universities started to take more responsibility for attracting students to their programmes. Some universities saw this as part of their third mission—community engagement—which includes the responsibility to develop programmes that promote scientific vocations, mainly among prospective students. However, many universities have also initiated activities at different levels to increase interest in STEM fields among young people as a whole.

The scopes of these initiatives are very different from one university to the next. While some initiatives are limited to short-term activities, others have developed into permanent organisations linked to the universities, but with partnerships with other organisations. There

is limited research about these types of activities, and this article as a whole addresses the following question: Why and how have universities taken on the role of an outreach actor? The question is addressed by characterising eight initiatives operated by universities in five European countries. Summaries of the initiatives are provided below in the form of short essays. The initiatives are characterised by comparing the driving forces behind their creation, how the initiative activities relate to the activities at the university, size based on the number of participants and cost per participant and pedagogical framework. Each essay ends with a discussion of the impact of the initiative and how it is evaluated.

The initiatives that have been chosen are: TUMlab (a student laboratory in the Deutsches Museum), which is connected to the Technische Universität München (TUM) in Germany; Vattenhallen, which is connected to Lund University in Sweden; Universitarium, which is connected to Aalborg University (AAU) in Denmark; Vetenskapens Hus, which is connected to the Kungliga tekniska högskolan (KTH) (the Royal Institute of Technology) and Stockholm University in Sweden; the House of Learning, which is connected to Chalmers University in Sweden; Praktikum UPV Camp, which is connected to the Universitat Politècnica de València (UPV) in Spain; Stockholm University summer school, which is connected to Stockholm University in Sweden; and Building with Sand, which is connected to the University of Aveiro in Portugal. These initiatives were chosen simply because they all submitted an article to this journal for this special issue on outreach and attractiveness.

Background

Outreach activities in general

As already mentioned, there are several kinds of outreach activities that encourage young people to consider careers in science and technology. We know by experience that many actors are involved in these activities, such as the STEM (science, technology, engineering,

and math) industry, science centres, museums, municipalities, schools, and universities.

In 2008, the Swedish government appointed industry and university representatives as well as other actors to participate in the initiative Teknikdelegationen, which aimed to develop strategies to avoid engineer shortages in Sweden in the future. In a published report, the representatives and actors identified 223 outreach initiatives in Sweden that aimed to increase interest in science and technology (Teknikdelegationen 2009).

In Germany, student labs are one of the many initiatives that have helped to encourage STEM education. Based on current knowledge, there are more than 300 student labs in Germany (Haupt et al. 2013). These labs are mainly linked to universities and research facilities, although to a lesser extent some are affiliated with museums and science centres, the STEM industry, technology centres, associations, private initiatives, non-profit educational establishments, or schools. These two examples portray how wide and broad community involvement is in this area.

Universities' role in university outreach

In this article, we focus on outreach activities offered by universities. These actors engage in a broad variety of activities aimed at public outreach and enhancing the attractiveness of science and engineering studies. These include direct recruitment strategies addressed at prospective students as well as indirect measurements (e.g. improving teaching and learning conditions for students).

The initiatives are often created by a group of enthusiastic teachers at a particular school or institution that are trying to increase the number of freshmen that choose to major in a certain field. Other university initiatives are more general in scope, especially when surrounding actors, such as sponsors, provide financial support or when the local government voices support for the initiative.

Discussions about university outreach initiatives often reveal that even though universities view the impact of outreach initiatives as important or crucial (Jeffers et.al. 2004), the numbers of universities that promote these initiatives are low. Often internal problems arise since outreach is not one of the main purposes of a university but needs to be handled by or involve university faculty. Outreach can be seen as a university's third mission, but it is a mission that is not measured. In addition, since government funds are rarely specifically allocated to outreach, it is hard to argue that outreach should be financed and operated by the university. In nearly all observed cases, outreach programmes hardly contribute to the promotion of the professors who developed the programmes. If they are provided financial compensation for their efforts, it is usually much lower than what could be obtained by conducting a research project or teaching a technical course.

However, teacher intervention has become more valued during the last decade (Gibbs and Coffey 2004). Examples of processes of qualification of the teachers' efforts can be seen at many Swedish universities. In addition, as technical universities are developing engineering education research, outreach activities are more easily adopted by technical universities. There are several recent examples, a few described in this article, in which universities have considered outreach from a management perspective and have hired faculty solely to perform outreach.

Characterisation of outreach activities

According to Smaill (2010), the United States (US) has published the most reports on university outreach activities, especially school-based activities. Similar initiatives have been reported all around the world by researchers such as Gattis et al. (2003), Dawes and Rasmussen (2006), Elton et al. (2006), Little and León de la Barra (2009), Lopez-Martin (2010), Rawot et al. (2011), Smith and Monk (2005), and Smaill (2010). These initiatives are

examples of activities aimed at changing stereotypes related to gender and technology as well as increasing interest in STEM fields through competitions, shows, school programmes, and recruitment activities.

Outreach programmes can take several forms and have different target groups (e.g. teachers, students, females, minorities). According to Jeffers et al. (2004), outreach efforts in the US range from developing classroom and web-based materials to conducting professional development programmes and engineering contests and sponsoring teaching fellows and service learning programmes. These activities are often facilitated by older K–12 students, teachers, undergraduate or graduate students, postgraduate students, and university faculty. Jeffers et al. (2004) analysed 59 different K–12 outreach programmes in the US and identified six common features of the approaches used, including active learning through the use of hands-on activities, inquiry-based learning, curriculum supplements, engaged role models, a focus on younger students, and K-12 teacher involvement.

The focus on hands-on activities is in line with the results of several studies: Early handling of technologies appears to be a good indicator of later career choices (acatech/Körber-Stiftung 2014; acatech/VDI 2009), while young people unfortunately often lack hands-on experience with engineering (acatech/VDI 2009, 57f). It seems crucial to combine both hands-on and minds-on components when introducing student-centred experiments and hands-on activities into STEM education (Prenzel et.al. 2009, 28). STEM education is required to enable practically relevant, project-oriented, and autonomous learning processes (Renn 2008) and to be context-oriented (Prenzel et.al. 2009, 27).

Outreach activities also encourage dialogue between university students on the one hand and secondary students and teachers on the other, help secondary students better understand the academic life of engineering students, promote interpersonal and communication skills among university students, and (in some cases) create additional income for university students.

Jeffers et al. (2004) also identified a set of goals of varying importance that are likely to initiate outreach activities: increasing enrolment in engineering programmes, diversifying engineering by attracting more women and minorities, promoting technological literacy among K–12 students, training teachers, and contributing to the teaching development of undergraduate students. Most engineering outreach programmes share a common goal: to increase the interest of K–12 students in engineering and STEM fields in general.

Methodology

The eight initiatives participating in this study have been characterised by comparing them according to four different frameworks, which are listed below.

1. Driving forces behind their creation
2. How the initiative activities relate to the activities at the university
3. Initiative size based on the number of participants and cost per participant, as well as collaborating partners
4. Pedagogical framework, analysed according to Jeffers's (2004) six features that were found to be common for the 59 US initiatives included in his study

The analysis was conducted by reading and analysing the essays included in this article.

Characterisation of the eight European initiatives

Driving forces

Decreasing interest in science and engineering was the main reason for the creation of all but one of the initiatives. This decrease could be due to an overall reduction in interest in the field or to the circumstances related to a certain programme. A decrease in the number of applicants to a certain educational programme has often been cited as the wake-up call that led someone with a passion for increasing the interest for science and technology to develop outreach activities. Stockholm University summer school is the exception, and its primary aim

was to develop collaboration between the university and high schools. This initiative was started in 1985 (see figure 1), before the decrease in student applications was seen, whereas the others were initiated in the 1990s and the 2000s.

Activities often began relatively small, with 20–200 participants yearly, which was the case for the Stockholm University summer schools, the House of Learning, Praktikum UPV Camp, and Building with Sand. In these examples, bottom-up strategies dominated the start of the initiatives as enthusiasts began the activities. Alternatively, other activities began when a group of people at a high level within a university created the initiative. However, it seems that these initiatives started somewhat later in time (see figure 1). For instance, a passionate dean initiated Universitarium as a yearly event that resembles a temporary science centre. The initiative was designed to be a relatively large operation with many actors. That was also the case for Vattenhallen, Vetenskapens Hus, and, to some extent, TUMlab, which was planned to be a smaller initiative, but was owned by several partners from the start.

Figure 1. Description of the size, funding, and ownership of the eight initiatives. Yearly budgets are given in euros. (The year given in parentheses in the first column indicates when the initiative was launched.)

Organisational characterisation

The eight initiatives were grouped by how closely they are linked to the universities' everyday activities. This was done by sorting the initiatives based on the answers to three questions: 1.) How does this initiative use the university facilities? 2.) What kind of personnel run the activities? and 3.) How are university research projects connected to the activities? Figure 2 depicts a linear spectrum where the initiatives that are the most closely linked to university activities are placed to the right, and initiatives that are the most separated from

university activities are placed to the left. The three initiatives to the right (Stockholm University Summer School, Praktikum UPV Camp, and Building with Sand) take place in university laboratories, which are normally used by university students. University staffs develop those activities, and PhD students often lead the projects. The two initiatives furthest to the right (Stockholm University Summer School and Praktikum UPV Camp) allow high school students to perform small research projects with PhD students at the universities through summer schools. These initiatives are characterised as being rather time-consuming for university teachers because they do their projects in small groups. Their activities also seem to need less funding compared to larger projects, and the necessary funding is provided by the department, or even by individual faculty members. In addition, the target group is high school students, who will likely apply to universities a short time after taking part in the activities.

The initiatives to the left of the spectrum run their activities in special facilities designed for learning activities. The leftmost initiative is Universitarium, which is a contemporary science centre not located on a university campus, but linked to a university by its personnel, who are university students and staff. Universitarium is open during the summer and is free to the public. Vattenhallen is also a science centre that is open to public during part of its open hours. This initiative targets both schools and the general public. Vetenskapens Hus and the House of Learning are mostly used by classes or school groups as part of specific programmes, but they are also open to the general public at some times.

TUMLab is situated in the middle of the spectrum, near Building with Sand. Unlike Building with Sand, TUMLab is not located on a university campus, but the initiative does fully rely on university personnel and equipment, which makes the concept of these two initiatives rather similar.

Activities to the right of the spectrum are limited in that they normally do not have as many participants or as large of a space, and the personnel are primarily responsible for other duties at the university. Additionally, most of the personnel involved are not trained to teach younger students and might not have the knowledge necessary to foster the most efficient or inspiring learning among the target group. The advantages of this type of activity are that personnel and facilities are already in place, the visitors can obtain a more in-depth view of a research career, and less financial support is needed.

On the other hand, activities to the left of the spectrum can become anonymous because they do not expose students to a real “working place”, they may not have obvious connections to universities, and they may require a substantial amount of support and need trained personnel to run the activities successfully. However, these activities can reach many participants, can be designed specifically for the target group, and can be more flexible. The initiatives described in this article are hosted by universities or museums, but none are hosted by schools or are mobile. Initiatives hosted by schools are another type of activity that represents a different group with both similar and different advantages and limitations compared to the cases presented in this article. The main limitations of these kinds of activities are difficulties regarding the lack of university equipment, as the school facilities are not designed for the activities. On the other hand, having the activities located at a school or close to a school makes them easily accessible. It also allows school teachers to be more involved, which may make it easier to link the activities to school curricula.

Figure 2. Grouping of the eight initiatives according to their proximity to universities' everyday activities.

Size (i.e. number of participants reached per year) and economic situation

The initiatives differ significantly in terms of the number of participants (see figure 1). University-like activities (i.e. activities that are similar to a researcher's normal activities), which are here considered small-size activities, handle up to 200 participants. Stockholm University's summer schools and Praktikum UPV Camp offer activities that last several days, which also makes it more difficult to handle a large number of visitors. Larger initiatives, including TUMlab, the House of Learning, Vetenskapens Hus, Vattenhallen, and Universitarium, often host events at which many visitors participate in a short time period of a few hours, such as researchers' night discussion cafés. For the leftmost initiatives on the spectrum in figure 2, typically half of the visitors attend the events and half visit the school programmes where school classes attended a specific timed programme. The number of visitors should not be seen as a measure of quality but as a way to characterise activities. Although it is difficult to measure the benefits of an activity for a single person, it is possible that longer activities are more effective.

Figure 1 shows the yearly budget for all initiatives. The cost per visitor differs markedly—from €0 (Building with Sand) up to almost €500 (Stockholm University summer schools). These two initiatives represent two rather extreme cases, where Building with Sand is a project supported only by a voluntarily work force and the Stockholm University summer schools is a project where the participants build long-term relationships with the university staff and where a rigorous selection process is used, which is also costly. The other initiatives cost between €13 and €50 per visit, which is closer in range. Among those initiatives a trend can be seen that smaller and longer-lasting activities cost more per visitor. Both Building with Sand and House of Learning depend largely on voluntary work, which is very person-dependent and might not be as sustainable.

Collaborating partners

Five of the eight initiatives are each supported by a single university, which bears all the costs involved. For example, Vattenhallen is a large initiative and is therefore seen as a major investment for a single university. The three initiatives not funded by single universities are funded and owned by several partners. Two of these initiatives have two or more universities and a local municipality that support them, and TUMlab is supported by a university and a science museum. The STEM industry also supports the activities of TUMlab and Vetenskapens Hus. The three initiatives owned by multiple partners have access both to pedagogical competence through teacher education departments/colleges and subject competence through the STEM departments.

Pedagogical framework

As mentioned earlier, Jeffers et al. (2004) identified six features that seem to be common for most university outreach initiatives in the US. Figure 3 shows a summary of how all eight examples relate to Jeffers's features, and thereby the figure gives sort of a pedagogical compilation for all initiatives. Analysis of these eight initiatives shows that experiments and hands-on activities are regarded as essential for all. Thus, there seems to be a dominating discourse that hands-on activities and active learning promote learning and/or increase interest in STEM fields. A review on research about activities aimed at increasing interest, motivation, and attitude towards science and technology indicates that active learning and inquiry-based learning are proved to have the most positive effect on attitude and interest (Potvin and Hasni 2014), rather than hands-on experiments without reflection. However, inquiry-based and active learning are most often linked to hands-on and experimental activities. Most initiatives say they use inquiry-based learning, at least in part of their activities. Only two view themselves as having a role in helping schools by offering activities that facilitate teaching on specific parts of the syllabi. Half of the initiatives focus on younger

pupils, but most initiatives offer activities for both older and young pupils, except the two initiatives furthest to the right in figure 2. Few offer special teacher training, but teachers are usually invited to take part in the visit. It can also be noted that using older students to interface with the visitors and thereby act as role models is very common, as seven out of eight initiatives use this solution.

Figure 3. A presentation of whether the initiatives have the features identified by Jeffers et al. (2004).

In addition to the six features identified by Jeffers, another important feature for these initiatives is the connection to everyday life. The authors of the essay on Universitarium say that if they conduct experiments that are linked to the social responsibilities and problems of everyday life, more visitors are interested in visiting the centre. This is also true for other initiatives, and it is one of the factors described as important for increasing interest in the Potvin and Hasnis study (2014). For example, the House of Learning develops activities in line with the latest brain research. The authors of the essay on the House of Learning argue that the results of modern brain research will initiate an enormous change in how learning is viewed in learning institutions.

Evaluations

Evaluations have been conducted to measure visitors' interest in the activities of six of the eight initiatives. For all initiatives, participants said that they enjoyed taking part in the activities. Participants found the activities interesting, and they often thought that they improved their knowledge of the STEM fields. TUMLab and Praktikum UPV Camp used digital questionnaires that could be filled in after visits, and the other initiatives used digital or paper forms that were filled out during the visit.

Some initiatives also asked teachers their opinions of the activities (Universitarium, Vattenhallen, TUMlab, Vetenskapens Hus, Stockholm University summer schools). These evaluations show that teachers also appreciate the activities as interesting and educational and that the activities serve as curriculum complements when that is the intention.

Evaluations also show that students who teach as part of the activities learn their subjects better and serve as role models (Vattenhallen, Praktikum UPV Camp). Evaluations of Building with Sand measure visitors' conceptual understanding of science before and after an activity, demonstrating that participants' understanding was higher after a visit than before. It is hard to change a teenager's mind, and it is difficult to measure the effect of a single activity. Most initiatives are evaluated based on whether participants liked the activities or not. In some cases, conclusions are formed based on changes in the enrolment of a degree programme. Stockholm University summer school and Praktikum UPV Camp both measured the number of initiative participants who chose to enrol in a STEM programme at their university. At Stockholm University, 12–14% chose to study a STEM field at Stockholm University, and 70% chose to do so at UPV. However, these numbers are difficult to use as a measure to determine efficiency, since participants might choose to attend a STEM programme at another university, which is not reflected in the percentage but must be considered a success. Potvin and Hasin (2014) reviewed articles dealing with interest, motivation, and attitude in science and technology, and they say that even though improvements can often be seen after an outreach event, the picture on how interest, motivation, and attitudes are changed is very complex.

In general, it is found that outreach activities do not serve as an epiphany for students in the way that Aronica and Robinson (2009) describe. Moreover, results often cannot be directly obtained after the activities are over as the effect may vary over time. It also must be pointed out that many of these initiatives are targeted for teenagers, who are likely to already have an

interest in the topic if they decide to take an active part in the activities. Nevertheless, activities such as these remind them of scientific vocations and strengthen the conviction of pupils planning to go into STEM fields.

Conclusions

Outreach activities are a common feature of universities in Western countries. They are usually created to increase interest in STEM subjects among young people, thus increasing the number of applicants to engineering or science programmes at the universities.

The pedagogical ideas behind outreach initiatives are similar in the sense that all initiatives are based on the hypothesis that hands-on experiments and active learning promote interest in the STEM field. This can be seen in all eight initiatives and in literature, as this was one of the six common features of outreach activities in the US (Jeffers et. al. 2004). The eight initiatives also had similar features to those identified in the US, as seven out of the eight used older students as role models and six out of the eight say that they use inquiry-based learning to some extent. An additional common feature for these eight initiatives is the belief that everyday examples are important for increasing the interest.

This article shows that outreach activities can be organised in many different ways with a lot of different hands-on approaches to promote STEM fields. The eight initiatives presented in this article were grouped based on how closely they related to everyday university life as well as their size, funding, and ownership. The initiatives that are based on everyday university life often reach fewer participants but host longer events. The initiatives that are not very closely linked to university life often are larger, reach more participants and include more collaborating partners. Three of the five larger initiatives were supported by several actors. Although this is a mission that was widely regarded as necessary for bringing a large number of talented students to universities, many do not fully accept that it costs money and requires expertise. It is still unclear which actors should operate and pay for these initiatives.

The wide range of ideas for hands-on outreach activities can be seen as proof of innovation and creativity, but it can also be seen as proof that there is no consensus on the most effective way to attract more students to STEM.

The evaluations reported in this study show that students generally like the activities they are attending and that they obtain a better understanding of STEM fields and research careers. However, measuring the effectiveness of these activities in changing attitudes, motivation, and interest is much harder. In order to measure their efficiency, an innovative process and new evaluation tools need to be developed. It would be interesting to build upon common knowledge about the efficiency of these activities both through efficient evaluation methods and by taking greater account of the research that has been done on interest in and attitudes towards the STEM field.

A case from Aalborg University: Universitarium

Lene Klitgaard

Objectives and background

In 2003 Aalborg University (AAU) launched an initiative called “Universitarium” as a response to statistics showing a low interest in natural science and technology among children and young people. The objective of the initiative is to increase interest in science and thereby increase interest in science education. Universitarium is open every day for three months every summer, and the entrance is free of charge.

Target groups

During the summer holidays the target group is families. After the holidays school classes are invited to attend guided tours. The interactive exhibition is designed with a 12-year-old child in mind. However, since many adults have limited knowledge of STEM subjects, the parent

or guardian who accompanies a 12-year-old to visit Universitarium may have the same level of knowledge. Therefore, student guides are needed to help parents guide their children, and it often turns out that parents learn a lot, too. The student guides are able to quickly get an idea of the visitor's background and age and adapt communication appropriately.

Description of the activity

Like most other science centres, Universitarium owes its heritage to the Exploratorium in San Francisco, California, but Universitarium further developed the science centre and took it to a new era. Universitarium moved away from showing natural science in its own right and emphasises the social context. This way of communicating science led to the motto "Science that changes your world." Universitarium also changed the perspective from doing science education to facilitating experiences that lead to science formation. Universitarium places science in a wider perspective, always with a link to the visitor's own life experiences.

Although AAU was the original owner and developer, today Universitarium is funded and owned by a partnership of local educational institutions: AAU, University College of Northern Denmark, Tech College Aalborg, and the City of Aalborg. AAU is still the main shareholder. All partners share an interest in recruiting students and educating them to become skilled citizens that both take and provide jobs.

Universitarium is managed by a secretariat with a project manager, a part-time secretary, and a part-time assistant professor. A working group of people from the partner organisations decides a theme for each year. The theme is implemented in collaboration with local businesses and relevant departments of the partner institutions. Some of the exhibits are produced in workshops at the university, some are built by students, and some are made by the local businesses that sponsor Universitarium.

In recent years Universitarium has increased cooperation with local businesses that show more and more interest in Universitarium as a recruitment project as well as a serious showroom. This is a natural offshoot of the approach that focuses on themed experiences dealing with the “science that changes your world” concept. In practice it means that real—often locally produced—equipment is displayed and made interactive if at all possible. These in-kind sponsorships are a part of the business model for operating Universitarium. Student guides are recruited from different science and engineering programmes in order to ensure that a variety of skills are represented at the exhibition. After the school holidays the university students are replaced by student teachers from the University College of Northern Denmark, and these students conduct special two-hours science tours to the school classes invited from the local region.

Funding

Another objective of the Universitarium project has been to present academic programmes at an understandable level to address the social responsibility of providing education for everyone and making it possible for future generations to break the barrier of social class. Universitarium has free admission for everyone. Combining this with an informal style and approach we try to address all social classes.

It is indispensable to the Universitarium concept to have the adaptive communication provided by the guides. The guides are employed by the university, making this a big part of the university’s contribution. This has led to what could be called a reverse business model compared to many commercial science centres. In traditional science centres, exhibits are expected to be highly polished and delicate. They are expensive and are often exhibited in the science centres for years. The centres normally cannot afford either to exchange the exhibitions or to add guides to assist visitors. Universitarium has introduced a 180-degree

reversed approach: Exhibitions are made as “Do It Yourself”; they are rather unpolished and obviously made in a workshop or by students. But this means the Universitarium can afford to exchange them and staff them, which provides a greater agility to deal with relevant and current topics.

The overall budget of Universitarium is approximately €375,000 per year. The funding comes partly from the partnerships (€310,000 in 2015) and partly from private foundations (€65,000 in 2015).

Distribution and impact

Universitarium has approximately 35,000 visitors each year. Universitarium is expected to have a long-term effect in attracting students to the partnership institutions. We aim to build a relationship with local families who often make it a tradition to visit Universitarium as a fun, free summer experience. The motive behind this is that not only the children but also the parents become familiar with the educational institutions represented at Universitarium and tie the hopefully positive experiences to the institutions. This is especially important for the mother, who plays an important role in a child’s choice of education. The long-term impact is not easy to measure because so many other factors influence the choice of their future education. In the evaluation done 2015 the teachers visiting Universitarium were asked to answer to which extend the pupils would be interested in knowing more about science and technology. The survey indicates that the pupils would like to know more about science and technology after a visit Ununiversitarium.

Pedagogical framework

Universitarium focuses on being hands-on and interactive. The approach to learning is very pragmatic and not founded on any specific learning theory. But Universitarium is inspired by

the experience economy research that started blossoming at the same time that Universitarium was initiated. This means that every exhibit revolves around a theme. This is one of the main rules of the experience economy theorists Joseph Pine and James Gilmore (1999). A theme must have high relevance to society and allow visitors to experience science through different lenses, such as sustainability, social impact, or economics, within the same exhibition. An example of a theme in Universitarium would be “See the invisible”, where visitors were invited to explore the questions of how we can visualise or make visible things that are too small or too far away to see or that no longer exist—or to put it scientifically, how and why we use optical science and photography to solve serious problems for individuals and society—from keyhole surgery to security checkpoints that include x-ray scanning of luggage to avoid terrorism.

Vattenhallen, a university-driven science centre using engineering and science students as guides and role models

Monica Almqvist, Anna Árnadóttir, Anders Axelsson and Torgny Roxå

Objectives

Vattenhallen Science Centre is built and operated by Lund University. One obvious advantage of this is the direct access to scientists and students. Here we have enthusiastic university students at the frontline meeting the public and engaging with the children. We strive to be a source of knowledge and answers for all our visitors, but also to encourage curiosity and inspire each visitor to question the world around him or her and to seek more knowledge. In the end we want our visitors to leave with a smile on their face and thinking, “I too can become an engineer.”

When the science centre opened, its objectives were to

- increase recruitment to the engineering and science programmes
- balance the gender distribution in several educational programmes
- meet school teachers' need to get in contact with the university
- open the university to society through a visible outreach activity
- combat the effects of an oncoming demographic dip
- help increase the number of licensed school teachers in the science and engineering fields
- offer a scientific tourist destination in Lund

Our goal is to show that engineering and science can be seen everywhere in society. We aim to be a platform where Lund University, local schools, the local industry, and the general public can come together.

Description of activities

A two-hour inspirational visit offered to *school classes* is our core activity. Teachers are also welcome to request a theme for their visit, such as construction, medical engineering, astronomy, or programming (Haux 2011). On arrival the class is introduced to Vattenhallen by a member of the staff. Teenagers are introduced to the university's faculties of science and engineering and encouraged to pursue higher education and to apply to the university. The children then conduct experiments and laboratory exercises in groups, led by our student guides.

Through these visits we reach thousands of children and teenagers from varying socioeconomic and educational backgrounds every year. These school/group visits have been given the highest priority from the very beginning.

As Vattenhallen is an integral part of the university, it also supports several *recruitment activities*:

- The *Engineering project* is a three-step activity aimed at 9th-grade students. It concludes in a science expo where the pupils present their projects to an audience, such as younger pupils at their own school.
- The *Science, Medicine and Technology days* (Swedish: “*NMT-dagarna*”) are aimed at high school students. During one week every spring, over 120 lectures are delivered by university researchers in a popular way. Vattenhallen participates each year with planetarium lectures and experimental activities. In 2014 over 1500 high school students came to Vattenhallen during this week.
- On *Researchers’ Night* (Swedish: “*Forskarfredag*”) 240 high school students meet younger researchers who present their work in a popular way as a science expo. The event ends with a much appreciated “*science slam*”.
- For *Techno Girls* (Swedish: “*Flickor på teknis*”), 120 teenage high school girls are invited annually to live and study among students for a few days and get acquainted with university life.
- *Tension Detectives* (Swedish: “*Spänningssökarna*”) is a competition for secondary school pupils carried out in cooperation with a local electric power company. In 2014 we had around 1000 participating pupils brainstorming about future energy solutions.
- Vattenhallen helps to coordinate the activities at *RobotLab* during the EU robotics week. Researchers from the Departments of Automatic Control and Computer Science present ongoing research on robotics. The visits to Vattenhallen consist mainly of one-hour activities for school classes. We had almost 900 visitors in 2014.

Vattenhallen offers *internships* (one week) to about 100 teenagers annually. The interns participate in the various activities, meet and engage with university students, and gain insight into university life and education.

On weekends and holidays Vattenhallen is *open to the public*. Families come to attend the shows, visit the planetarium, enjoy the great exhibition hall, and conduct experiments with our student guides who are always ready to assist and answer questions.

Several popular *five-day courses* are organised every summer. These are led by our student guides who share much of their scientific and engineering thinking with the attending children.

Vattenhallen organises *continuing up-to-date education for teachers* at all levels in the Swedish school system. This is founded on a combination of access to expertise from university scientists, Vattenhallen's efficient organisation for handling visitors, and plenty of interactive activities.

Companies, departments, institutions, and associations are all welcome to visit the science centre. Most such bookings are informal get-togethers with *science-based team building activities*.

A project called "*Programming for Everybody*" (Swedish: "*Programmering för alla*") was initiated in 2012 to enable young learners to discover the joy of computer programming and to promote gender equality within engineering. More than 7000 children have tried our programming experiments and more than 300 teachers have passed our programming courses (Regnell *et al.* 2014).

Vattenhallen possesses a theatre, which can house an audience in excess of 100 spectators. Here we offer performances regularly, such as "*Quantum show*", "*Chemistry show*", "*Biology*

show”, “*World of Sounds*”, “*Thunderstorms*”, and “*The brain*”.

Our state-of-the-art digital *planetarium* simulates the universe on a six-metre dome. Space exploration requires all fields of science to come together, making the planetarium an ideal place for inspiration. Our planetarium is run by astronomers and produces much of its own content.

Vattenhallen has developed *interactive exhibitions* on various topics in collaboration with different Lund University departments. Some examples include:

- “*Medicon Alley*”: An exhibition aimed to highlight biomedical engineering with stations such as: “*Tinnitus noise*”, “*Ultrasound investigation*”, “*A Journey through the Digestive Tract*”, and “*Imaging the human body (CT- and MR-tomography)*” (Bengtsson *et al.* 2013).
- “*Shooting Protons and Tickling Electrons*”: Two large material research facilities are currently under construction in Lund: MAX IV (a synchrotron light generator) and the European Spallation Source (ESS), which is a high energy neutron source. Our exhibition explores how these research facilities will work (Micklavzina *et al.*, 2014).

Facts

Vattenhallen is situated on the Faculty of Engineering campus. It encompasses about 1000 square metres and welcomes approximately 40,000 visitors each year. About half of our visitors are from our target group—school children—but we do welcome everyone and offer activities and exhibitions that can inspire all ages.

Vattenhallen is currently organised and driven by the Faculty of Engineering in collaboration with the Faculty of Science at Lund University and is managed by a supervisory board.

The deans of the two faculties have appointed a director with a background in science research. In addition, we have one manager, two teachers, one engineer, one astronomer, one interaction designer, and one receptionist. It is worth noting that the centre has access to the university's administration and maintenance facilities. Of course the most important employees at Vattenhallen are the 40 part-time student guides that meet and interact with the visitors.

Funding

Vattenhallen has a budget of approximately €1,000,000. The Faculty of Engineering supports 45% of the cost; the Faculty of Science, 15%; and external sponsors, 15%, while the centre activities generate 25% of the income.

Pedagogical framework

Vattenhallen, like many other science centres, aims to increase interest in science and in engineering in general. Young people coming from non-academic families, especially girls, are of high importance since this group tends to not receive the encouragement needed to pursue a science or engineering career (Schreiner *et al.* 2010).

From a sociocultural perspective (Wenger 1999, 2010) two things are important for science centres with these ambitions: 1.) visitors should be able to identify themselves with the scientific/engineering community and 2.) visitors should be able to experience a successful use of newly acquired scientific/engineering knowledge and skills.

In order for visitors to identify with individuals who representing science and engineering, a sense of similarity is most important (Tellhed 2014). Science centre visitors should have the opportunity to interact with students, scientists, and engineers who seem similar to

themselves. A tangible proof of successful engagement is necessary for influencing the identity of those visiting a science centre.

The visitors should feel that they have crossed a boarder into a community that is new to them and that this crossing was successful and rewarding.

At Vattenhallen we meet these needs by using undergraduate students to coach and guide the visitors through the exhibitions or to assist them in assembling gadgets and complete experiments.

Evaluation

Vattenhallen is continuously evaluated. In 2012–2013 we questioned over 100 teachers about their visit. We learned that many of the teachers had spent classroom time preparing for the visit, and most of them intended to spend time in the classroom after the visit exploring new concepts and ideas. This indicates that a visit to the science centre fits well within school curricula.

This evaluation also indicated that the school classes have been very satisfied and do get a meaningful experience. Teachers report that their pupils often show interest beyond the teacher's expectations.

When asked, the teachers agree that using students as guides and role models is working very well. This again confirms that the most important employees at Vattenhallen are the approximate 40 guides, who are all part-time employed undergraduate university students.

Vetenskapens Hus, a science education centre in Stockholm

Lena Gumaelius and Ceciia Kozma

Objectives

Vetenskapens Hus (“House of Science”) was initiated in 2001 as a collaboration between the Royal Institute of Technology (KTH) and Stockholm University. The main driving force for building Vetenskapens Hus was concerns about the declining interest of young people in pursuing higher education in science and technology. The idea was that municipality, university, and industry should address this issue together, since low interest in science and technology affects all levels of society.

Vetenskapens Hus was developed to be an arena where school and university meet (Johansson 2004). This is facilitated through teachers meeting researchers during visits with their classes or during teacher training activities, pupils meeting university students during the experimental programmes, and school and municipal leaders meeting university management. Leaders are also included in the strategic work by being represented on the board of Vetenskapens Hus, in programme groups, and also in larger projects.

Description of activities

The core activities of Vetenskapens Hus are the experimental programmes offered to school classes. About one hundred different programmes are offered in the STEM fields.

The programmes last for about one and a half hours and most often include an introduction and a hands-on activity in which the students can participate; the programmes all fill a portion of the school's objectives and curriculum content. Examples of programme themes include electron diffraction, encryption, rocket fuel, solar cells, digital waste sorting systems, and plants for business and pleasure. Descriptions of experiments are available in Angelin et al. (2012), Johansson, Kozma, Nilsson (2007, 2006), Johansson, Nilsson, Tegner (2006), and Gumaelius, Johansson (2006).

The programmes are led by tutors who are students at KTH or Stockholm University; they act as role models and “experts” in their discipline of interest. Teachers always join their classes

during a school visit, and the activities offer them both a learning opportunity and the possibility to observe and assess their students.

For teachers, Vetenskapens Hus also offers teacher-training programmes in all subject areas. About twenty different teacher-training programmes are offered each year. These are often designed and implemented together with researchers from the universities, teachers, and the business community. The teacher training programmes bring up current themes in society, such as climate change and Nobel Prize science, as well as other themes requested by teachers.

Besides these core activities, Vetenskapens Hus is also involved in many different events and projects for K–12 students and teachers as well as the general public. The focus of these events and projects is always to increase interest in science and technology for young people. These events and projects may be regional, national, or international. A few examples of such events and projects include the children's courses conducted on weekends and during the summer holiday where children between the age of six and fifteen are able to conduct hands-on experiments, Researchers' Night—a European project that aims to make researchers visible to the public in a positive way, Teknikåttan, First Lego League, Amusement park physics, and Science on Stage, to mention a few.

Facts

Number of visitors

In 2014 about 28,000 K–12 students attended the experimental programmes during school hours. In total, over 60,000 K–12 students and teachers and members of the general public participated in activities arranged by Vetenskapens Hus.

Target group

The target groups for the activities at Vetenskapens Hus are mainly K-12 students and teachers at all stages. Events and courses on weekends and holidays are also occasionally arranged for the general public.

Organisation

Vetenskapens Hus is jointly owned by KTH and Stockholm University in the Stockholm area. The initiative is organised as a centre with its own board that decides upon the activities. The board reports to the universities. Board members represent the two universities and the Stockholm municipality and industry. The activities are led by a director that is appointed by the universities, and the director has a research background (i.e. a PhD). Furthermore, Vetenskapens Hus is staffed by full-time experts either in pedagogy or in the subjects of physics, chemistry, biology, math, or technology, which means that most of the staff members have a research background or pedagogical training in a subject as a base for their expertise. As a complement to the ordinary staff, the house also hires students who work as tutors and teachers who work part-time with the development of the school programmes.

Funding

Vetenskapens Hus has a yearly budget of about €2,000,000 annually. Not surprisingly, the funding has been a big issue over the years, which of course has influenced the development of the activities at Vetenskapens Hus.

The centre has passed through three distinct phases.

1.) At the beginning, its task was to give a picture of the activities that could be accomplished to attract potential investors. Initially, this was hard work, but once some investments were in place, this first period provided some freedom and time for the organisation to evolve to meet its objectives.

2.) After five years of operation, the centre reached a downturn. By this point, the initial investments were consumed and the centre was forced to operate as a day-to-day business. This phase resulted in some major changes that at first seemed to be very negative, but turned out to have a positive impact as well. An example is that visit fees were introduced for school classes. Previously, all school visits had been free of charge. This change caused a decline in visitors from 20,000 in 2005 to 12,000 in 2006—a dramatic decrease, but it only took two years to recapture the same number of visitors as the popularity increased. This phase led to the realisation that long-term funding and clear goals were needed to achieve sustainable development.

3.) In 2007 a partly new board of Vetenskapens Hus decided upon a strategic ten-year plan that included both financing objectives and activity goals. Today KTH, Stockholm University, and Stockholm municipality are its main financiers, contributing equally to the centre. The future financial goal is that Vetenskapens Hus will be permanently supported by these three main financiers, but that the business sponsors will also contribute to the same extent.

Pedagogical framework

From the beginning it was decided that experimental activities would be a focus of this venture. The hypothesis was that hands-on activities facilitate understanding, which in turn increases interest in the subject. Another reason for the experimental focus was to support schools with modern and expensive equipment. A generous grant from the Knut and Alice Wallenberg Foundation gave Vetenskapens Hus the opportunity to build an instrument park in which school classes could access fancy instruments such as electron microscopes, radio telescopes, particle detectors, a DNA sequencer, and more. Another important perspective is that the activities offer the possibility for K–12 students to visit and become acquainted with a university environment and to meet university students who act as role models.

Evaluation

Evaluations of the activities are performed annually from the perspective of both students and teachers in order to continuously develop and improve the quality and relevance of the activities. The visitors are usually very positive, but they also point out areas for further development.

Public Outreach in cross-institutional collaboration—TUMlab in the Deutsches Museum

Miriam Voß, Manfred Prenzel, Johanna Ray

Objectives

TUMlab, TUM's student laboratory in the Deutsches Museum, gives teachers and students, including children and teenagers, the opportunity of literally "grasping" technology and research. Participants can immerse themselves in constructing, building, controlling, and programming—in other words: hands-on science and technology. The TUMlab is one of the initiatives developed in response to the shortage of young applicants for STEM subjects. The laboratory is a joint venture of the TUM and the Deutsches Museum, one of the largest science and technology museums in the world.

Since 2005 the TUMlab has been run for students and teachers with the aim of raising the interest of children and young people in STEM fields and providing an interactive, experimental, and playful access to their own discoveries in science and engineering. By addressing a wide variety of groups the TUMlab programmes aim to reach as many students as possible. Without assuming too simple of a cause-effect-mechanism, the hope is to kindle a long-lasting fascination in STEM and to help students detect their own abilities that may attract them as students to the university. The TUMlab is mainly a starting point from which interested students can go on to other TUM programmes or to the museum to deepen their

experience.

Belonging to the faculty for teacher training and educational studies of the TUM School of Education, the TUMlab is an integral part of the university's teacher training programme. It serves to give teacher trainees insights and practical experience in and with informal learning environments and, in the long run, to enrich and improve teaching in STEM fields. In turn, positive experiences in school classes on STEM subjects are expected to have a substantial impact on students' career choices.

Description of activities

The TUMlab offers courses in technology and engineering (robotics, automation, and computing), environmental engineering¹ (hydro-power, energy consumption, river renaturation, and bioindication) as well as courses in natural sciences (chemistry and astronomy). The programmes last three to five hours and are designed to allow students to carry out hands-on experiments and inquiry-based learning. Teacher trainees and university students studying relevant disciplines work as course instructors. Besides their role as tutors, they act as role models and often serve as a first contact to the university.

The remarkable location in the Deutsches Museum enables links between courses in the lab and museum exhibitions, thus providing distinctly diversified approaches to STEM topics: whilst the lab focuses on active, self-directed research, experimentation, construction, and engineering, the museum enables participants to perceive and construct meaning through vivid demonstrations and interactive and/or very intuitively accessible exhibits.

The TUMlab is a teaching/learning laboratory (Skiebbe-Corrette et al. 2014; Haupt et al. 2013a, 2013b; Haupt and Hempelmann 2013a). University students get to know the educational practices in the TUMlab as they take part in hands-on-seminars that are offered as

¹ The development of the new course programme "Environmental engineering" was rendered possible by funds of the Deutsche Bundesstiftung Umwelt.

compulsory additional subjects in teacher training. In these seminars, teacher trainees will develop either educational resources, e.g. materials for preparation or post-processing of courses, or new course contents. As is typical for teaching/learning laboratories, university students are prepared to take on the role of supervisors and course instructors.

Facts

Number of visitors

Since its opening in 2005 more than 18,000 participants attended TUMlab courses, and the number of participants has now reached 2000–3000 per year. Furthermore, the TUMlab addressed considerably more than 100 teacher trainees in STEM subjects with hands-on-seminars since 2010.²

Target groups

Target groups of the TUMlab are school classes, children, and young people, as well as teachers and teacher trainees. The courses mainly address children and adolescents ages 10 and up and take place on an almost daily basis. Teachers, associations, and private groups can book the lab online, choosing dates to suit their requirements.

Organisation

The term “student lab” signifies hands-on laboratories for students outside of school (Haupt et al 2013a; Haupt and Hempelmann 2013b). Rather than being a standalone measure, the TUMlab is deeply embedded in cooperation and coordination of STEM initiatives. The most essential cooperation for the lab is the one between TUM and the Deutsches Museum. This is clearly an example of cooperation partners combining their strengths: While TUM provides a

² The Deutsche Telekom-Stiftung supported the project [TUM@SCHOOL](#) - [SCHOOL@TUM](#) at the TUM School of Education since 2010 to strengthen teacher training.

link to current research and teaching, the Deutsches Museum is a long-standing, highly esteemed, and popular platform for public outreach. Both institutions offer programmes for schools and young people on a broad scale, for a range of different target groups, choosing appropriate methods and modes of operation for varied approaches. TUMlab offers schools and young people mentoring programmes, gender-specific projects, guided tours, competitions, information days, lectures, presentations, workshops, and the opportunity to study at the university. The TUMlab is closely connected to various other initiatives. For example, the TUMlab participates in the yearly TUM programme “Girls and Technology”, offers workshops for the kids of TUM alumni and is working with the Kerschensteiner Kolleg, an educational institution of the museum which offers advanced training. The TUMlab also has a close cooperation with the Open Research lab, an authentic university research lab in the Deutsches Museum, to conduct courses about scanning probe microscopy (Brunner et al. 2014).

The cooperation between TUM and the museum offers a clear organisational structure: While the museum provides room and facility, the TUM, specifically the TUM School of Education, provides staff, equipment, and content. As the head of the education department in the museum also serves as professor for museum education at TUM,³ there is a strong link between the TUMlab and both institutions. Representing different facets of the lab, the TUMlab is run by an engineer with experience as a teacher as well as a biologist with experience in public outreach and science communication. These two positions compose the regular staff of the laboratory, responsible for organisation, course development, allocation of resources, teaching, maintenance, fundraising, and public outreach.

Corresponding to the scope of courses offered at the TUMlab, student assistants who work as tutors in the lab have diverse backgrounds: Prospective teachers currently working for the lab

³ This affiliation is in fact doubled: The general director of the Deutsches Museum is at the same time holder of the Oskar-von-Miller-chair for science communication at TUM. Oskar von Miller was the founder of the Deutsches Museum.

pursue studies in chemistry, biology, mathematics, and computer science. University students of relevant disciplines come from study paths in bioengineering, chemical engineering, and mechanical engineering.

Funding

When the TUMlab was founded, it was heavily supported by external sponsors. From the beginning, moderate course fees were raised to remunerate course instructors. Third-party funds played an important role in professionalising the work of the laboratory and in increasing its significance in teacher training. Currently the TUMlab is part of the Department of Museum Education, and costs for staff and equipment are mainly borne by the TUM School of Education. Room-related costs are borne by the museum, including exhibition design.

Pedagogical framework

“Experimenting – Researching – Understanding”: This is the slogan of the TUMlab. All courses offer an opportunity for active, self-directed experimentation, research, construction, or engineering. This is combined with a short introduction on the course topic at the beginning of each course. Hands-on activities are designed to support the autonomous learning processes of participants. Inquiry-based learning is a core concept – thus, the courses often provide initial insights into scientific procedures. In addition, the courses contents provide links to everyday life and point to the relevance of the respective fields.

The TUMlab expands the experiences of teach trainees: They meet very diverse groups in the student lab, coming from different school types and having different backgrounds. The trainees can benefit from this experience as they learn to handle heterogeneity in groups as well as heterogeneity in groups in relatively good student–staff ratio conditions.

Evaluation

A lot of informal feedback is given orally through direct contact with the participants: Teachers and students tell course instructors and staff members about their assessments, impressions, and wishes for the future, and course instructors report to staff members about difficulties or things that work particularly well. This is an important base for swift improvements of courses and the lab, especially regarding practical issues. An online-evaluation form is available for more formalised and anonymous feedback. Overall, participants provide very positive feedback on courses and course instructors. University students are asked to reflect on their experiences as course instructors. Their reports indicate that they judge their experiences to be beneficial, such as with respect to handling heterogeneity, planning their lessons, and gaining experience in teaching.

The House of Learning at Chalmers University of Technology, Sweden

Per-Olof Nilsson

Objectives

The facility took off in 1997 when a bottom-up project was initiated at Chalmers University of Technology, Gothenburg, Sweden. The concept is an extension of the science centre idea introduced in the US in the 1950s, but with completely new pedagogical methods inspired mainly from neurodidactics. The initial activity, a workshop with hands-on experiments, has during the years resulted in a dozen of spin-off activities forming “The House of Learning”. This unit has mainly three purposes: 1.) to improve the public understanding of science, 2.) to increase the interest of children and young people in science and technology, and 3.) to introduce new forms of education at all levels.

Description of the activities

The various, often overlapping, activities aim not only to provide a better understanding of the world around us, but also to provide tools to use our knowledge, as described under pedagogical framework below. Eight of the projects are summarised in the following text.

The unique experimental workshop “Physics Toys” contains about 300 simple hand-on experiments in a 620-square-metre area for all ages and categories of people (see picture 1).

Picture 1. A view of the House of Learning.

Free entrance and guidance are given to groups from schools, industry, teachers, pedagogues, and anyone else who is interested. At the House of Learning, parameters such as learning speed, memory, and understanding are sometimes improved by a factor 5–10 compared to traditional education. The activity has received a number of awards and prizes. Most experiments can be performed with small items existing in an ordinary home. The theory has been worked out for all the experiments and can be adapted to any educational level from kindergarten to PhD. The website, www.fysikaliskaleksaker.se, is now being translated from Swedish into English.

To promote creativity we have established a special type of workshop similar to the so-called Maker Spaces or Fab Labs. It is a dedicated work place for students, teachers, artists, entrepreneurs, and others. The users get free access to simple fabrication tools for all ages such as materials, power drills, and 3D printers. The facility allows users to invent and construct items based on their own ideas. For instance, high school students do project work (100 hours per student) to build equipment they propose themselves.

Comentado [1.1]: Please check that I have not changed the intended meaning. Rephrased for clarity. Also, I recommend providing evidence to support this statement.

A science café is run every Thursday afternoon with free entrance and free drinks. It has mainly five purposes: 1.) Being a meeting point for anyone in society, 2.) Communicating what is going on in research, industry, schools, and more, 3.) Promoting communication in a popular science manner, 4.) Stimulating discussions on what is going on in the society, and 5.) Creating new contacts, friends, and networks. As of August 2015, the café has run 228 times and is visited by about 100 people each time (see records at www.cafealar.se). The guests are mainly external academicians from West Sweden, while other visitors include scientists, students, teachers, and industry leaders. The main activity is a popular science talk on any topic (humanities, technology, etc.) given by a scientist. Other activities include the display of a new book each week and a new physics hands-on experiment anyone can do at home. However, the most important part may be the mingling and networking among the guests, which has generated many cooperations and projects.

Another way of promoting the public understanding of science is through the project “Art and Science”. The university has allocated grants for the construction of large installations to be displayed in the departments, on campus, and hopefully also in the city.

An example of collaboration with teachers is our training for various teaching levels (including kindergarten) that is provided for half a year. The teachers are trained in hands-on experiments based on neurodidactic methods. They then bring the experiments (about 120 total) to their schools and reports back on the results.

An activity that is increasing at the centre is training in creativity to promote better use of knowledge. The request is coming, for example, from the industry to promote more innovations and from administrators to improve decision processes. We have for this purpose set up a one-day course including lectures and practical training.

An example of outreach conducted to other parts of the world is the “Touring the world with scientific shows” activities on various topics using physics toys. Einstein said: “A theory

which cannot be explained to a child is probably worthless.” With this philosophy House of Learning has made it possible to efficiently explain traditionally difficult concepts without mathematics, which has been highly appreciated by the audience and resulted in many awards.

Today, there are hardly any books in Swedish libraries or shops on popular science. House of Learning have developed a public library at the centre of about 1000 new books. The areas include experiments (physics toys), natural sciences, the brain, science history, didactics, and more. Anyone (even the public) can borrow this literature for free.

Facts

The hands-on workshop is visited mainly by groups of 10–30 people, particularly school classes on all levels. On average, 200 groups visit the centre per year. During these visits there are science and other free activities. As described above, there are many other programmes for individuals and groups, and there has been a total of more than 100,000 visitors during the 18 years since the centre was created.

Funding

The centre’s personnel consists of one professor (Per-Olof Nilsson, working 25 % of fulltime) and one lecturer (Kjell Sedig, working 80% of fulltime) employed by the university (€33,000). Both these persons work voluntarily 100%, full time. The floor space is paid by the university (30 000 Euro). New equipment is constructed and repairs are carried out using free surplus material. Running costs, mainly for consumable materials, are paid by the department (€5,000). For larger investments special grants have been awarded by an external agent.

The annual cost (except for special investments) is about €70,000, which is extremely low compared to the output. This situation is made possible by two circumstances. Firstly, the work is organised according to Parkinson's law from 1958, which among other things says that one person can execute the work of seven persons by using a small, slimmed organisation. The number of interaction channels among n persons is $n(n-1)/2$, and is thus increasing very fast with n . Secondly, it is very clear that the use of volunteers brings not only a qualitative but also an economic value.

Pedagogical framework

The uniqueness of the facility lies mainly in the pedagogical approach. We are employing the latest achievements in brain research and apply this knowledge to scientific communication. The results are staggering.

Our brain communicates with the outside world via our senses. Only 50,000 years ago Homo sapiens lived in Africa and could not read and write, and reading and writing are now important tools in our civilisation. However, our brain is essentially the same today as it was in Africa by then, and schools unfortunately do not fully realise how important learning via our senses is. House of Learning employ this idea to a small extent through the informal learning by applying hands-on experiments and emphasising experience, and to a larger extent by including concepts such as neurodidactics, creativity, curiosity, individuality, small size, closeness, and much more. Different aspects of these key concepts have been combined and are being further developed at House of Learning. As mentioned, not only do we stress knowledge, but above all we stress *how to use knowledge*, i.e. how to be more creative. This is an extremely important quality for solving all kinds of problems and challenges in our society. A high IQ score is not enough to accomplish this because it fails to assess rational thought essential for problem solving. To achieve this goal we should not only use the modern

part of our brain (neocortex) but also mix up our behaviour with signals from the limbic system, i.e. involving our spontaneous feelings. A “creative chaos” appears, strongly contributing to our creativity and helping us to solve important problems for our humanity, and also creating a happier life. This is practically achieved through special training methods, which reinforce the synapse connections, leading to new effective neural networks: the future of our educational system.

Building with sand - A simple activity to attract secondary students to civil engineering

Margarida Pinho-Lopes

Description in one sentence

“Building with sand” is a practical session in civil engineering where students build structures using sand and paper (as reinforcement) and test the ability of those structures to withstand loads.

Objectives

The activity has been offered both as a stand-alone activity for Science and Technology (S&T) Open Weeks and as part of the programme “How the world is built”, which is organised by the Civil Engineering Department of the University of Aveiro (UA) in Portugal for the Summer Academies.

The primary objective is to attract secondary students to the Civil Engineering degree at UA. To do this it was essential to choose a simple, cost-effective, and engaging project.

Additionally, the activity would have to be designed to allow students to experience some of the non-traditional teaching and learning models used in the Civil engineering programme (examples can be found in Pinho-Lopes and Macedo 2014 and Pinho-Lopes, Macedo, and Bonito 2011). The participants would also become familiar with ongoing research activities

relevant to their daily life and sustainability issues. The activity was defined according to the guidelines presented by Dawes and Rasmussen (2006) as well as the recommendations by Elton et al. (2006).

Description of the activity

The activity involves using sand and paper to build a reinforced soil wall, inspired by competitions in the US, particularly the Geo-Challenge Student Competition (Cerato et al. 2012). This activity was adapted to different groups of students, regardless of their level of previous knowledge on the topic.

The activity, which lasts around three hours, consists of the following elements:

- Receiving a short presentation on the topic;
- Touring the geotechnical laboratory to become aware of some of the research work under development on the topic;
- Building the models in teams of four or five students;
- Loading the models and compare their performance;
- Discussing the results and brainstorming to explain different behaviours observed.

The activity is held in the Geotechnics laboratory within the Civil Engineering Department of UA. The number of participating students per session is limited to 20. They are welcomed by the author and a group of research students (M.Sc. and Ph.D.). A short presentation on the topic of reinforced soil is provided in which students had an active role (questioning, handling materials, brainstorming, and discussing). Different concepts are dealt with, illustrated with everyday physical examples.

The large group is divided into four teams of four or five students; each group is given a separate toured around the laboratory. The teams manipulated soil samples and compared the behaviour of dry and wet sand (building small sand castles).

Each team is then directed to its working area, where a plastic container, sand, pouring material, wooden plates to compact the soil, old and used office paper, and scissors were available. Each team had to build its model following the constructive sequence of a real structure.

Then the large group is gathered, the loading phase begins, and the teams observed and documented the responses of the models. Each team gave a presentation how its model was built. Then, each model is progressively loaded, when possible, until failure and different failure modes are observed. The teams are quite competitive, anxious to see how their models will perform. The teams with the best models (that do not fail) are very disappointed.

After each failure the observed responses of the models and their causes are discussed, and the students suggest possible ways of preventing these failures. At the end, the author summarises the activity.

Facts

Number of visitors and target group

This activity was initiated in 2009. Each session includes up to 20 students. The target group differs based on whether the activity is conducted for S&T Open Week or for Summer Academies).

The S&T Open Weeks are displays of science and technology (held on Monday through Friday in November). Usually they are attended by a wide range of people: students and teachers from different levels, pre-school children, entrepreneurs, and the general public. The motto is “You can be a scientist for a day.” The organised events include experimental activities, presentations of projects, workshops, lectures, shows, exhibitions, films, guided tours, and games. Although registration is necessary, participation is free. The activities are organised independently so participants can choose which activities to attend.

The Summer Academies are programmes with scientific activities for the summer holidays. These are a week long and run from Sunday to Friday in July. Two Summer Academies are organised, targeting students of different age groups:

- Junior academy, for students from 5th to 9th grade (11 to 15 years old);
- Summer academy, for students from 10th to 12th grade (16 to 18 years old), who are about to apply to university.

Both academies are organised as blocks of activities with specific topics, and usually each academy is held twice every year. Participants must pay a fee.

Organisation

The S&T Open Weeks and Summer Academies are promoted and marketed centrally by UA with little intervention from the promoters of each activity. Each department has to nominate a local coordinator for these events, who then contacts the academic members of the staff to propose activities, deciding on their duration, the targeted age group, and the type of activity (lecture, laboratory tour, etc.).

The activity Building with Sand has been included in both events. The title and the description provided to students, teachers, and/or guardians are intended to be catchy and easy to comprehend. The first time this activity was implemented (in 2009) the university chose to have it broadcasted on national television as part of the S&T Open Week. Students in that group enjoyed the activity and were very enthusiastic. The teacher accompanying the group was very positive about how the students had learned from it. Similar feedback has been received after each Building with Sand activity is held.

Comentado [L2]: If the activities are promoted by UA, it is not clear who "the promoters of each activity" are.

Funding

The resources needed for this particular activity are practically zero: sand available in the laboratory was used, old office paper (to be recycled) was converted into reinforcements, containers were already available for similar activities. The monitors helping were volunteers and were given certificates by the university recognising their valuable contribution.

Pedagogical framework

To maximise the engagement and learning of the students participating in the activity, it included many features of active learning. Other strategies were used in addition to hands-on learning, such as questioning, teamwork (collaboration with a competitive component), reporting to the large group, brainstorming, and discussing.

To assess the impact of the activity on students' learning and their perceptions of the activity, pre- and post-activity questionnaires were used. The research questions underpinning them were:

- Can a simple activity using sand and paper promote understanding of complex concepts such as soil reinforcement?
- Can an activity developed for students taking the final year of an integrated master's programme be sufficiently simplified to be used as an outreach activity?

Evaluation***Method***

To assess the effectiveness of the activity in 2011 and 2012, pre- and post-activity, questionnaires focusing on the learning of the students and their perceptions/opinions on the activity were used. A set of five questions on the topic was put together and given to students before and after the activity. Twenty students participated in the activity in 2011 and 2012, and all answered the questionnaires. The students clearly answered the questions differently

after the activity. After the activity, students gave the correct answers to most questions, showing that the learning outcomes were achieved.

As was evident from the informal feedback, all students found that the activity significantly helped them learn new things and was very interesting and well organised. Most students would recommend the activity to friends and colleagues. All students said they liked building the structures.

One of the questions allowed students to provide comments. Some examples include: “I adored everything. It was very interesting and, besides learning new things, we had lots of fun.”, “It was a beautiful work.”, and “I am speechless. I really liked it.”

Summary

The activity was clearly a success both for the student’ learning and for the impact on the students’ participating. The group participating in the activity was of a good size, enabling a good support by the teachers. The session was informal, and all students actively engaged in the activity. The results from the questionnaires indicate that this activity made it possible for students to grasp complex concepts on soil strength and soil reinforcement.

This activity was initially developed for an elective course on Application of Geosynthetics in Civil Engineering (MSc level) where project or problem-based learning was used.

Nevertheless the results and the collected feedback indicate that the activity was effectively adapted to secondary students and has achieved the intended learning outcomes.

Acknowledgments

The author would like to express her thanks to all students that have participated in these activities and to the M.Sc. and Ph.D. students that help organise them.

Praktikum UPV—One-week stays for secondary school students within university research groups for fostering engineering and scientific vocations

J. Alberto Conejero, José P. García-Sabater, Julien Maheut, Juan Marín-García

Description

Praktikum UPV is a one-week scientific camp where students in groups of two or three develop a project within a research group of university teachers. The projects are documented with blogs and videos prepared by the students themselves. These materials are intended to be shared later with their high school teachers, their classmates, and, in general, with future university students.

Objectives

This case study refers to the implementation and development of a scientific camp held at the Universitat Politècnica de València (UPV). This camp has been designed as a reverse service learning initiative in which students still in secondary school attend the university for developing a small scientific and technological project within a university research group.

The outcomes of these projects are returned to the society through visual media intended for:

- 1.) contributing to a better knowledge for the future freshmen of the opportunities that each university degree offers to them,
- 2.) demonstrating that the contents in secondary education have a continuation and are the basis of more specific technological contents, and
- 3.) promoting vocations for engineering and scientific-related degrees.

Description of the activity

The summer camp is held at almost all the schools of the university. In 2012, a portfolio with 70 different projects was offered to the prospective participants so that they could apply to be admitted to one of the projects. The projects covered nearly all of the degrees offered by the

university. The projects are usually designed on the basis of one or two practice sessions of a subject in one of the degrees offered by the university. Examples of projects can be found within the following areas: aeronautics, agronomics, business administration, chemical engineering, civil engineering, computer science, design, electronics, fine arts, food science, industrial engineering, life sciences, management, and telecommunications. If required, a brief background is provided about the project to the students.

The projects are carried out in the research labs of the university under the supervision of one or two teachers as advisors. In some cases technicians or PhD students also help the students with the tasks and the content. They work on the projects in the mornings, usually in pairs.

The idea is that students should be able to exchange their own experiences with other participants, and this can be done during many of the common activities. A pool of activities for all the students participating in the camp has been designed by the leaders.

The projects are documented in blogs. One blog is activated for each university school. We tell the students to post information about their projects. Each post is labelled with the first name of each student and with a label that identifies the project. This allows readers to follow students individually or projects as a whole. Further details can be found in Conejero et.al. (2015).

Facts

Number of participants and target group

In 2010 the Praktikum UPV Camp was primarily held at UPV's School of Industrial Engineering. This pilot experience was conducted with 6 projects and 14 students. Two years later, the Praktikum UPV Camp was scaled up to 77 projects and 185 students from secondary schools in the Valencia local region. The projects were supervised by more than 100 university teachers, around 5% of the total number of permanent teachers of the university.

Organisation

After the pilot experience in the School of Industrial Engineering, we conceived a vertical structure with one general coordinator supervising the camp as a whole and the selection of the students. The collaboration of FUNCAE (Fundación para la Calidad en la Educación de la Generalitat Valenciana) and UPV's Communication Office helped facilitate these tasks.

One local coordinator was chosen at each school. Local coordinators are responsible for recruiting teachers to serve as student advisors. They also collaborate with the advisors to prepare the portfolio of projects from their school. In addition, a student is chosen from each school to help the local coordinator. The local coordinators are also responsible for overseeing the student participants at the school, taking them to the labs and places where the projects and activities are conducted.

Funding

The Praktikum UPV Camp has been conducted on a limited budget that only covers student meals and also provides a small remuneration to the students helping the local coordinators. The cost of materials for developing the projects is covered by the university schools and departments as part of their normal lab costs. The institution considers the participation of university teachers as advisors to be part of the internal academic formula for measuring teaching quality and workload. This makes the programme economically sustainable with a very limited additional budget of less than €10,000 for nearly 200 students.

Pedagogical framework

The camp was conceived from the point of view of *praktikum* initiatives in which students have short stays in working places. In particular, we have considered the frame of research

groups in our university as a working environment. The learning model applied to present the scientific and technological contents to the students was conceived in terms of *project-based learning* and *learning by doing*. As far as possible two or three students at most are assigned to a project. This permits the students to get really involved in developing the projects, and also the presence of other secondary school students prevents them from feeling alone with the university teachers.

We also conceive that participation in the camp should be quite entertaining and not too heavy for the students. The camp is held during the last week of June, once the students have finished their academic year in the high school. Students document the projects using blogs and to present the final report for each project using a video recorded like the videos that the UPV university teachers in their university courses. This is done using a proprietary tool known as Polimedia (Polimedia, 2015). As a result of the projects, 137 videos were recorded and uploaded to the campus’s YouTube channel (Praktikum UPV YouTube channel, 2015). The blogs with details regarding the development of the projects are accessible from Praktikum UPV blogs (2015). Furthermore, a list of pedagogical proposals based on these projects and presented by the high school teachers of the students were compiled in Conejero, Albors, and Vivancos (2015).

Evaluation

Once the camp is finished, the students are questioned about their internship via an online poll. In 2012, 143 of the 185 participants (77.3%) answered the poll. A total of 90% of the participants that answer the poll evaluated the experience as good or very good. The impact of the camp is also measured in terms of enrolment. Nearly 70% of the students participating in the camp enrol in a UPV degree programme within two years, even though some of them are

Comentado [.3]: Please clarify. Do you mean "and the presence of other secondary school students prevents them from feeling alone with the university teachers", YES or, "and the presence of university teachers prevents them from feeling alone on the project"? NO

Comentado [.4]: Please clarify. Is this 90% of the participants who answered the poll? YES

also accepted by another public university in the same city. The majority of students that do not enrol in our institution either choose a degree on health studies, mainly Medicine, that is not offered by our institution or enrol in a university that offers the opportunity to obtain a double degree (this option is not yet considered by our university).

Acknowledgments

The Praktikum UPV Camp has been powered from the Vice-Rectorate of Culture and Student Affairs. It has also been partially supported by FUNCAE. We are greatly indebted to Mr. Fernando León, manager of the FUNCAE, for his support that permitted the success of this initiative. We, as designers and organisers of the programme at the university, want to thank the coordinators at all of the schools, teachers at the university and at the secondary schools, and of course, all the students that have participated in the camp, who are the leading actors of all this work.

Stockholm University summer school—outreach activities through experimental projects

Agneta Norén and Henrik Mickos

Objectives

This summer school programme started at a time when student numbers were still quite satisfactory, and the initiative was founded due to a strong interest in building bridges between high school and research environments. The initiative emphasised using hands-on activities and finding a format beneficial for the school target group and the academic departments involved (Chan et.al. 2011). Two different types of organisational structures evolved—one that takes care of financing and teaching structures and another that takes care

of the issues of how to reach the schools and students and how the activities can be aligned with the school curricula.

One goal was to enable the students to meet scientists in a situation where the students' project lab work could be integrated as a part of ongoing science. This would hopefully lead to deeper knowledge and positive attitudes towards natural science. As hands-on activities are extremely useful for introducing young people to the world of science, the activities were designed by active researchers and PhD students who incorporated techniques and current scientific knowledge (Ekstrom and Mosher 2000; Mekelburg 2010; Sheridan et al. 2011). Additionally, equipment and experiments not normally available in the schools were used. The importance of conveying criteria for scientific credibility (by peer and lecturer reviews) was yet another point to be taken into consideration. Finally, the difficulties in evaluating the direct effect of the outreach activities demanded a quick and easy way to monitor if the students ended up at our university.

Target group

The target group consists of high school science students within the Stockholm region (30–35 schools per year). Students at this academic level are chosen due to the closeness in time for them regarding their potential future university studies. Students are required to have for some practical lab experience that had been achieved through natural science education. The high school teachers are equally important, and at least one annual meeting for teachers is held in order to get feedback.

The students sign up based on their own interest, and the positions are distributed by the use of a lottery procedure rather than by grades (Charpin 2011). This gives everyone an equal chance to participate regardless of grades and socio-economic environment. The following

direct contact with people in research is unique and inspires many of the students to pursue further studies.

Description of activity

The summer school runs annually as a two-week project where 126 second-year high school students are distributed across the science faculty at Stockholm University in research groups from chemistry, physics, biology, and geoscience. It is both an on-campus and field station activity. There are 800–900 applicants for the 126 positions every year. The mentor/PhD student is the key person for each group, since he or she is responsible for designing the two-week lab project for the students using the framework of his or her own scientific research project. This allows the participants to get in contact with experiments that can be integrated into a bigger picture/research context and creates an atmosphere of being in touch with the actual science going on at the university. One key approach is the message that is to be based not on normal course lab experiments but on investigating the unknown, i.e. it is to be research based. The summer school programme includes lectures given by young scientists in areas that connect to the students' age group. The purpose of the lectures is to present role models for the high school students, challenging the stereotypes of scientists that are prevalent in public views. The PhD students present to the summer school project leader how their research will be used in the two-week project. As shown from other outreach projects (Houck, 2014), enabling students to get close to science is a successful part of the summer school's design. Hands-on experiments were the basis for most of the projects, showing the importance of observations (Tamburini, 2014), good controls, experimental setup, and how results are interpreted (see table 1 for examples of projects).

Table 1. Examples of research-related summer school projects.

Project assessment

Following a scientific outline for the construction of the project conveys the need to maintain a level standard for the project that includes background knowledge and scientific credibility (e.g. how to show the validity of the experimental setups and further interpretation of the results). A written report is reviewed by a mentor and handed in to the student’s high school for review and grading. In the Swedish school system, extensive project work is part of the curriculum for the last year of high school. For many of the participating schools the students are allowed to use their summer project as part of this assignment. This has created an additional driving force that benefits both high school and university. High school teachers grade the reports, but the university mentor acts as a reviewer beforehand. Peer reviews are given on the final day when oral presentations are performed in smaller groups (Topping 1998).

Comentado [.5]: It is not clear how this parantheses applies to the sentence. What is this an example of? Should it be, "e.g., the students must show the validity of the experimental steps and further interpretation of the results"?

In addition, the meaning of the phrase "further interpretation" (vs. "interpretation") is unclear.

Distribution and impact

The summer school is introduced during the spring through face -to-face meetings in almost every school in the region, which means that this activity is wide spread regardless of the school’s social environment and status. Therefore this project can be considered a university outreach activity that reaches students with very mixed social backgrounds.

The overall goal to increase the interest and engagement in science among the participants is very difficult to monitor in a directly correlating way. Each year we handed questionnaires out to the participants, both students and supervisors (see supplement). Scores are between 1 and 10 and we can show tremendously good scores (values within the upper quartile). A search in the Stockholm university student registration system (Ladok) shows an average of

Comentado [.6]: Please verify that this will be included in the final publication.

Comentado [.7]: The meaning of this sentence is unclear.

1. By "Scores are between 1 and 10", do you mean "participants rate their experience on a scale of 1 to 10, with ten being the highest"?
2. By "we can show tremendously good scores", do you mean the average scores are tremenedously high?
3. By "(values within the upper quartile)", do you mean the average score is 7.5 and above?

14% (per year) of former participants are present in our university science courses (based on 5 years of summer school participants, with 126 students per year).

Funding

The project is supported financially by the Science faculty at Stockholm University, and the budget includes the costs for administration, salary to supervisors, consumables, travel/accommodation (for the field-based project), and funding for the introductory school visits.

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