Bridging the Gap between Formal Education and Informal Learning: towards Evidence Based Science Education

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Abstract. *The awareness of the public understanding of science is very often linkedo the big inventions or crisis in technology. The growth of modern science centres can be traced to the resurgence of interest in the West and in the USA in particular following the launch of Sputnik. Similarly, the growth of science centres since the1990s and 2000s has been clearly been connected to two major developments in society: the crisis of scientific literacy and the visions for the information society. Rapid advances in genetic research and information technology have created new challenges for the public understanding of science. The role of universities, industries and research institutes has been crucial for creating the contents of modern science centres such as Heureka in Finland. The findings of recent research suggest that students' situational motivation can be changed to intrinsic motivation by well organised programmes linking schools to the informal, open learning environments of science centres. A survey taken among university students attests to the fact that informal learning sources such as science centres seem to have a stronger impact on their academic career choices than has hitherto been realised. Also the latest technology like Augmented Reality (AR) can be successfully form a link between formal science education and informal hands-on learning.*

Keywords. Augmented reality, Career choices, Informal learning, Motivation, Open learning environment, Public understanding of science, Science centres, Science education.

Introduction. The role of informal learning is increasing in the modern societies. This phenomenon is closely related to the growing impact of science and technology on our everyday lives. Lifelong learning needs new practical forms. According to most of the core ideologies of science centres, the essential role of science centres is: to advance public understanding of science. Science centres vary greatly in their nature, size, function and content. However, when starting a new institute, the same reasons are used world-wide: a science centre will advance public understanding of science, create positive attitudes towards science and technology, encourage young people to learn, and maximise their opportunities to try scientific applications. How much evidence do we have to prove that these main goals will be realised in the everyday functions of a science centre? Answering this question is not easy although we know from our everyday experiences that these pragmatic outcomes can be achieved. It is important to answer this question because this same question is asked with increasing frequency by the authorities, sponsors and the people who attend science centres. Because they are fairly new institutes, science centres, in particular, face this question more frequently than some other more traditional cultural institutes. The 'big picture' of the science centre field has become more clear thanks to the publication of carefully collated statistics which are comparable world wide [1]). However, additional data with the focus on educational research and learning results instead of economical and demographic statistics is needed. A science centre is a learning laboratory in two senses. First of all, it is a place where visitors can learn scientific ideas by themselves using interactive exhibit units. Second, it is a place where informal education can be studied in an open learning environment.

History of science –more than mirroring the society

The roots of science museums can be traced to the ideas of such respected scientists as Francis Bacon, Rene Descartes and Benjamin Franklin [2]. Industrialisation gave birth to the Great World Expositions. These presented the latest technical and industrial achievements but

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were also supported by art. The motivations for the expositions were often simply manifestations of nationalism [3]. The roots of most of the important science museums are to be found in the Great Expositions. Other characteristics of science museums established from 1850 to 1940 were: financial support for private collections which were made publicly accessible; a perceived need for enhanced science education; museum directors with strong and innovative characters and who had personal support at high levels in society [4].

Similarly, national museums and galleries grew up in the 1800s from a need to support the nation state and nationalism with allusions to and rhetoric about heroic wars and history. The era of rapid industrialisation, developing technology and new inventions made it possible to use technology as a tool for nationalism. International reputation was important for the state, and also important for industry and the new manufacturing companies. This dual need for the marketing of science, technology and production, provided the rationale for establishing many science museums and modern science centres. Technology and science played an increasing role in the lives of ordinary people, and came to occupy a place beside religion, the state, art and history in society.

In the USA, the background to the expansion of modern science centres in 1960s was the Sputnik phenomenon. No direct link can be documented, but the crisis in national confidence that resulted from the successful launch of Sputnik had a knock-on effect on all education in the USA. The attitude towards the study and teaching of science dramatically changed. The educational system in the USA was totally reformed [5]. Science education was seen as an element of national security. Federal governments gave resources to local school administrations for the improvement of education. The scholarship system was renewed. Some scientists were enlisted to develop new curricula and learning materials for schools and to re-arrange teacher education [6]. Resources were also directed to pedagogical development projects.

In the 1970s and 1980s there was a period when nearly identical exhibitions were built by science centres just by copying exhibit units and whole exhibitions from other science centres. The main source for this was the ‘Exploratorium Cookbooks’, which were to a large extent published for this purpose. Many new institutes still utilise this concept for their main content. It tells much about the international nature of science and science centres. The scientific principles and laws of nature are universal, and science centres are able to use the same exhibit units in different countries and cultures. However, the staff of science centres adapt their national and local features with their own ideas when choosing the content, design and programme ideas [7].

Innovative methods for creating a new type of interactive (not only hands-on) science exhibitions need a lot of resources. Money is not necessarily the main factor. The content development of these exhibitions has to be carried out in close co-operation with the best available scientific expertise. In this way, the exhibition is reliable and based on the latest knowledge in the subject area. This would not be possible without the input of universities. The value of this expertise cannot be overestimated [1]. The science centres which were initiated by national and local universities were among the most successful and innovative during the 1990s.

The development of science centres and museums must be seen against the background of the wider developments in society. The growth of science centres since the late 1980s has been clearly connected with the major developments in society, namely: the crisis of scientific literacy and the visions for future information societies. The Chernobyl accident clearly showed the inability of the media to put over technical and scientific points to the public. In addition, it highlighted the lack of meaningful and understandable scientific information given by experts themselves. On the other hand, the rapid development of genetic research and information technology of the present time closely resembles the situation in the 1960s with space and nuclear technology [8]. Most recent example of this trend is the climate research, and its role in public understanding of science.

Heureka, the Finnish Science Centre, was opened to the public in April 1989. The Science Centre Foundation behind Heureka was established by the University of Helsinki, the Helsinki University of Technology, the Federation of Finnish Learned Societies and also the Confederation of Finnish Industries and Employers. Heureka immediately became one of the major attractions in Finland. It has usually been number four, in terms of attendance, and usually number one or two among leisure attractions in Finland as measured by independent quality surveys. Heureka is renowned for its interactive science exhibitions, which consist of traditional hands-on experiments, computer and high-tech based audio-visual solutions. Interactive exhibitions related to technology and its solutions in everyday lives have been one clear trend in the content of Heureka's main and temporary exhibitions. The development of the content of these exhibitions is carried out using the best available scientific expertise of universities and relevant companies. In this way, the scientific and technological content of exhibitions is reliable and based on the most up-to-date knowledge in the respective subject areas. The Helsinki University of Technology and more than 60 high-tech companies have played a very significant part in these exhibitions.

New forms for public understanding of science and scientific literacy

The growth of science centres since the 1990s is closely related to the developments of the information society. Communicating science to the public via different media is not only a matter of giving sufficient support for scientific research and academic education in society but also a process of giving citizens their basic democratic rights in relation to scientific information [9]; [10].

The continuing world-wide trend is for a broadening of the subject range of science centres and an increasingly interdisciplinary approach to exhibition themes. One non-trivial problem that has been raised in the discussion of the role of science centres and universities, is related to the meaning of the word 'science'. In English, science generally means the natural and physical sciences and is often limited to physics, chemistry and biology. However, in German, Swedish or Finnish, the words 'Wissenschaft', 'vetenskap' and 'tiede' include the humanities, history, psychology, social science and linguistics. The modern science centre must be able to present phenomena related to all academic research. Accordingly, the content of Heureka has been planned in an interdisciplinary way. The content of Heureka's exhibitions is supported by a broad spectrum of temporary exhibition themes. Also the recent PISA-results [11];[12] are showing the importance of this relation and interaction between science and society.

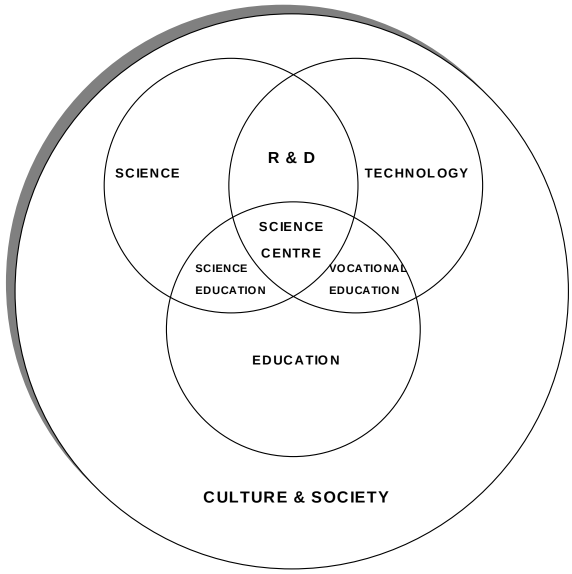

Figure 1: Science, technology, education and a science centre in relation to society and culture

To define the positions of a science centre in its relation to science, technology and education is presented in figure 1 [6]; [13]. Science education occurs at the point where science and education overlap. Science and technology combine in the area of research and development (R&D), where academic research is used to develop industrial methods. Vocational education is located at the intersection of technology and education.

In figure 1, a science centre is located where science, technology and education all meet. According to this description, a science centre features all of these three. Any exhibition, event or audience activity combines these three elements depending on the nature of the exhibition.

Science centres are no longer isolated hands-on workshops created by a couple of 'science freaks', but have become part of a larger movement promoting public understanding of science. They are influenced by not only the scientific community, but also by the other groups of society and vice versa.

Science education is not only a question of advancing technology or of demands for a scientifically qualified workforce, but it is also a question of social goals. As Coombs [14] summarised: 'The aim is not solely to produce more scientists and technologists; it is also to produce a new generation of citizens who are scientifically literate and thus better prepared to function in a world that is increasingly influenced by science and technology'.

The theory of informal learning

To advance public understanding of science, new forms of education are actively being sought. A huge amount of information especially about modern phenomena is obtained in a personal way from family, friends, peer groups. Furthermore, the roles of television, libraries, magazines and newspapers are also essential. Museums and science centres have increased the number of their visitors regularly during the last decade. Most of these forms of education can be classified as informal learning either focused on young people via informal, out-of-school education programmes or as clearly informal learning occurring totally outside of any educational institutions for young people or adults.

Informal education has often been regarded as the opposite of formal education. Even the names of the classic books - *Deschooling Society* by Ivan Illich [15] and *The Unschooled Mind* by Howard Gardner [16] - have been provocative. These books also contained harsh criticism of failures of schooling, which has alienated students from meaningful learning. Moreover, they argued that learning from informal sources was effective and motivating. These books have had a great effect to education and its research.

Since the 1990s informal education has become a widely accepted and integrated part of school systems. However, examples of theoretical or empirical research concerning informal education are rare [19, 20, 21, 22]. Recently informal learning has become a more accepted part of educational science, although there is still very little valid research for example about such a central topic as learning via the Internet [23]. The role of the Internet is a clear example of a learning source that was originally created for other purposes. The Internet is an effective informal learning source, which was first used by individual teachers and then officially by schools and other formal learning institutions. In other words the Internet can be described by the term ‘out-of school education’ meaning schools using informal learning settings and sources as a part of their curriculum.

The educational role of science centres has been regarded as more or less as self-evident. However, some classical educational theories can be detected in the principles underlying science centre education, although few educators in these institutions have been explicit in their approach. They have relied on the practical and common-sense application of loosely formulated pedagogy.

Frank Oppenheimer [17] has been quoted as the creator of the science centre pedagogy. His criticism of the passive pedagogy of science education derives implicitly from Dewey's ideas [18] expressed in his thesis: ‘learning by doing’ . The same approach can be seen in contemporary developments in science centre pedagogy: The famous hands-on principle articulated by Oppenheimer is a corner-stone of the principle of interaction in modern science centres. What Dewey and modern science centre pedagogy share is the accent on motivation, free will and the learner's own activity, stimulated but not forced.

Motivation and meaningful learning

Every-day knowledge tells us that students are eager to learn in informal settings. Field trips, schools camps, visits to industry, to a museum or science centre, or even having an art lesson in the school yard, are positive occasions in students' minds. The roots of this positive attitude are in the freedom of leaving the setting of the classroom. This free feeling arises as much from the wish to avoid school as from positive motivation towards the informal learning goal. Can the motivating effects of freedom and physical context be taken advantage of? This is an aim of science centre education. The recent research about motivation and science education also indicates the central role of intrinsic motivation in explaining many learning processes.

The Rocard-report - Science education now: A renewed pedagogy for the future of Europe [19] is describing the situation mostly in the pre-schools, primary and secondary schools while we also see the trends around the formal education. The role of informal learning is increasing in the modern societies – meaning the countries which are developing their societies by investing and creating opportunities for research, innovations, and education. The phenomenon is closely related to the growing impact of science and technology in our everyday lives. Lifelong learning needs new practical forms and the formal education can learn something from the informal, open learning environments like the science centres.

The Rocard report specifically underlines the term Inquiry-Based Science Education. One of the weaknesses of school’s science teaching has been that the studies and lessons at school are mainly deductive. There are some exceptions in some schools, but, historically the main trend in the European science teaching pedagogy has applied “Deductive approach”. In this approach, the teacher presents the concepts, their logical – deductive – implications and gives examples of applications. This method is also referred to as ‘top-down transmission”.

“Hands-on learning” is the main pedagogical principle of the science centres. On opposite to “Deductive”, it represents the “Inductive method”. This classical “learning by doing” method is something that the science centres have been pioneering in Europe during the last decades. The multidiscipline contents of modern science centre exhibitions form a unique and reliable learning source for inductive, Inquiry-Based Science Education.

Similarly, the Rocard-report requests new forms of teacher training, too: “Teachers are the key players in the renewal of science education. Among other methods, being part of the network allows them to improve the quality of their teaching and supports their motivation. – Networks can be used as an effective component of teachers’ professional development, and they are complementary to more traditional forms of in-service teacher training and stimulate morale and motivation.”

The presentation of the “Hot Air Balloon” is a classical science centre exhibit in several institutes around the world. That was one of the reasons why it was chosen as a CONNECT-case for the research and development. The idea was to gain more educational value from the exhibit by using Augmented Reality –technology added to this classical exhibit. The main pedagogical goal was to improve skills for individual observation. This was possible because by the AR-solutions certain invisible phenomenon could be made visible by animations and demonstrations. The combination of traditional hands-on learning and modern technology like Augmented Reality (AR) can create encouraging learning opp0rtunities also for the students having less-than-average success in traditional school grades [13].

Conclusions

Promoting public understanding of science and informal learning are the key elements to attract and retain the interest of greater audiences. Well planned educational programmes are needed, and without reliable and valid educational research the value of the science centres cannot be proven.

The conclusion of the research of informal science learning strongly indicates the following:

(1) The results of knowledge tests showed clear learning effects. However, the time spent in a science centre is rather short, and because of that the focus must be on the quality and not the quantity of learning. This arouses motivation as a key factor. School students having intrinsic motivation gained both better cognitive results and tended to apply deep-learning strategies in the learning process.

(2) The series of visits to a science centre appears to have a positive effect on the motivation of students in all the age groups, but the results were most positive among primary school pupils. Sixth form students’ intrinsic motivation also grew during the project. Motivation decreased among secondary school pupils, but the decrease was smaller among those students who visited the centre compared to the control group with no science centre visits.

(3) Gifted students seemed to get more motivated than others during the visits. However, by using programmes linking the school curriculum and science centre exhibitions, encouraging motivational results were also obtained for the group of students with learning difficulties.

(4) No statistically significant relation between gender and motivation was found in any of the motivation tests given.

(5) Informal learning sources such as science centres have an effect on career choices of university students.

(6) The combination of traditional hands-on learning and modern technology like Augmented Reality (AR) can create encouraging learning opp0rtunities also for the students having less-than-average success in traditional school grades.

Meaningful learning has two components. First, the content should be meaningful for the learner. Second, the learning process should be arranged pedagogically in a meaningful way (according to the age and the former knowledge and skills of the learner and by the logical structure of the topic to be taught.) All the great innovations in education have been based on putting these two principles into practice.

Science centres are firmly planted in the soil of the society that nurtures and continues to support them. The impact of developments in society, science and technology is crucial to the process of starting and developing science centres. If these institutions cannot respond to social change, and renew themselves, they may very easily loose their ideological credibility and financial support. To encourage and report results related to public understanding of science and informal learning is the main element in this process.

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