X World Conference on Computers in Education
July 2-5, 2013; Toruń, Poland

The Application and Impact of ICT in Education for Sustainable Development

Barbara Kędzierska, *bkedzierska@gmail.com*
Pedagogical University of Kraków, Poland

Johannes Magenheim, *jsm@uni-paderborn.de*
Paderborn University, Germany

Agnieszka Kędzierska, *kedzierskagnieszka@gmail.com*
Free University of Berlin, Germany

Robert Fischbach, *fischbach@institutfutur.de*
Free University of Berlin, Germany

Abstract
Sustainable Development (SD) is an important issue for the survival of mankind and therefore without alternative. In this context Education for Sustainable Development is proposed as the preferred strategy of achieving that goal. This article provides an introduction to the concept of Education of Sustainable Development (ESD). Furthermore, it describes the concept of key competences and ICT competences that learners should achieve in order to enable them to successfully participate in ESD-related learning. In this context ICT, Digital Media and especially Web 2.0 tools are important levers to support ESD and improve the learning outcomes of the participants. Therefore, in this paper the role of ICT in ESD is characterized and a specific ESD-project, that uses ICT and Web 2.0 tools intensively, is presented. A short summary and an outlook on further research and learning activities concludes this contribution.

Keywords
education for sustainable development, Web 2.0 technologies, mobile learning, lifelong learning, informal learning, social networking, collaborative investigations, key competences in ESD, information competences for sustainable development

INTRODUCTION
According to numerous results of research, a sustainable development is crucial for the survival of mankind and to keep the miscellaneous ecological systems of earth in balance. The UNESCO stresses the importance of Education for Sustainable Development (ESD) and initiated the decade for ESD. Main topic areas for ESD are 'Biodiversity', 'Climate Change', 'Cultural Diversity', 'Indigenous Knowledge', 'Disaster Risk Reduction', 'Poverty Reduction', 'Gender Equality', 'Health Promotion', 'Sustainable Lifestyles', 'Peace and Human Security', 'Water' and 'Sustainable Urbanisation'. (UNESCO, 2013) It is important, that this initiative provides in the processes of formal, non-formal and informal learning key competences that enables actors and stakeholders in the field of SD to achieve the intended objectives. Within these learning processes, that intend to enable participants to perform lifelong learning in different action areas of SD, ICT and especially Web 2.0 tools play an im-

portant supportive role. Different studies conducted e.g. by UNESCO or EU stress the important social impact of ICT on education and the whole society especially in the fields of 'participation in Policy-Making' (e-government), 'Education and Lifelong Learning', 'Work', 'Consumption (incl. media and entertainment)', 'Health', 'Community and family', 'Creation and distributed innovation' (EU-Report, 2010). Within the 'Smart City'-concept the EU describes different future action fields, like 'smart economy', 'smart governance', 'smart environment', 'smart people' (educational system), 'smart living', 'smart mobility' that are important as well for the future development of societies in general as especially for the educational system (EU, 2011). The utilization and intelligent application plays in all these scenarios an important role.

Therefore, the role of ICT in ESD-related learning processes in these action areas, should be investigated and integrated in motivating, real-life-oriented learning scenarios. Thus, in the following chapters of this article we will not only introduce the concept of ESD and the related processes of competence achievement with ICT tools, but also introduce an ESD-related project, that tries to put the theoretical concept into practice. According to the methodical approach of Studios and Ateliers initiated by the IFIP AGORA Initiative and the IFIP / UNESCO Project ANDIL (Magenheim, 2008) a social network of practitioners and experts, working in distributed projects within different social and cultural context, but on the same ESD-related topic, should be established on the long run.

CHALLENGES OF EDUCATION FOR SUSTAINABLE DEVELOPMENT

The notion of Sustainable Development can be traced back to 1713 when von Carlowitz spoke about unsustainable usage of wood. From this moment the notion of sustainability gradually was winning more and more recognition and popularity. In 1968 the Club of Rome was founded and its activities have significantly contributed to the understanding of the term sustainability in the modern way. In 1992, United Nations organized a conference on Environment and Development (UNCED, so called 'Rio'). As one of the results of the conference the Agenda 21 was approved, a UN's program of action from Rio (signed by representatives from 170 countries), which addresses most relevant issues necessary to achieve sustainable development. Particularly, in the chapter no. 36 education, the education for sustainable development, was presented as a most powerful tool for fostering sustainable development. Another important milestone in this area was the World Summit on Sustainable Development (WSSD 2002) in Johannesburg. The conference concluded with the declaration of the 'United Nation Decade of Education for Sustainable Development' (DESD, 2005-2014). Since the worldwide implementation of DESD, this issue is increasingly perceived in society and politics. The Brundtland Commission defined in its report 'Our common future': "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The diversity of social, cultural and economical structures of the participating countries implies that the needs in many of those contexts differ significantly and that most attention should be given to the poorest ones.

Subsequently, the Outcome Document from the World Summit of the United Nations (2005) referred to SD as to 'interdependent and mutually reinforcing pillars' as to development that includes economic and social development as well as environmental protection. Later 'culture' as a fourth pillar was included. According to the strategy of SD 'think global – act local', later on many additional pillars were including, depending on the region and current local situation. For some it is relevant to include politics, for other health (as in example in India where health is one of the main issues) or personal development (other through perspective of employment). The fact that sustainable development has such a strong connection with a local situation and conditions it made it difficult to create one definition that would be applicable everywhere. ESD should concentrate on many different competences, however one of the most relevant is 'Gestaltungskompetenz' (shaping competence).

'Gestaltungskompetenz' explains the ability to apply knowledge and to recognize problems of non-sustainable development. That means that the diagnosis of the presence and futures studies are generating conclusions about ecological, economical and social development. These three dimensions are linked to each other and lead to the ability to setting priorities, making 'good decisions' (Bormann, de Haan, 2008). UNESCO considered the challenges of ESD and states that it needs: 'to integrate the principles, values, and practices of sustainable development into all aspects of education and learning' as well as that 'this educational effort will encourage changes in behaviour that will create a more sustainable future in terms of environmental integrity, economic viability, and a just society for present and future generations' (UNESCO, 2005). Reflecting these challenges many lead-agencies (including UNESCO) demand to set the focus more intensively on cross-sectional learning settings including informal and non-formal education and applying i.e. games, online education, blended learning, usage of Internet, social networks etc. Hence, the creation of an infrastructure for knowledge exchange as well as efforts to foster competences on the educational application of digital media seem to be an urgent task of ESD regarding the creation of sustainable educational landscapes.

KEY COMPETENCES IN ESD

Contemporary challenges of sustainable development apply to all areas of human activities and address social, economic and environmental issues. To meet these challenges, a society must be aware not only of the risks of negative impacts of actions but should be able to overcome current imbalances and ensure sustainable development in the future. In order to prepare young people for sustainable activities, education should shape and develop key competences that comprise generic dimensions as well as the acquisition of specialized and vocational skills.

The European Communities Commission published a document (European Parliament COM, 2005) that defines 8 areas of core competencies for lifelong education that also are crucial for education for sustainable development:

1. communicating in mother's language,
2. communicating in foreign languages,
3. math competence & basic science-technical competence,
4. computer competence,
5. ability of learning,
6. interpersonal, intercultural & social competence as well as civil competence,
7. enterprise,
8. culture expression.

The OECD Project DeSeCo published a proposal of key competence relating to the three priority areas:

1. to use tools interactively,
2. to co-operate in a heterogeneous group,
3. to work autonomously.

Besides all the competences mentioned in the documents above, ICT-related competences can be ranked on a top-level within the hierarchy of key competences (Kedzierska, 2008). Information competences, understood as a set of knowledge, skills, attitudes and efficiency are essential for an individual to diagnose when and what information is needed, to localize the information, to assess it, to effectively process and use it as well as to transfer it in a correct form with the use of properly selected tools. A person who is information competent is able to:

- determine the scope of needed information,
- access effectively needed information (also from not electronic sources),
- critically evaluate obtained information and its sources,
- include selected information to her/his own structure of knowledge,

- effectively use proper information in realization of assumed goals, both individually and as a member of a group,
- understand and include in his/her actions economic, legal, social and ethical conditionings,
- responsibly use ICT tools for acquiring, processing, presentation and communication of information in lifelong learning process:
  - integrate modern media in education: wiki, blog, Web 2.0, Web 3.0, mobile technologies,
  - independently learn through social networking, online interactive courses & experiments, online gaming & simulation.

ICT AND ESD - TOOLS AND THEIR APPLICATION

The concept of ESD and the Key- and ICT-competences, which are needed to put the related organizational and societal transformation into practice, also require rethinking our educational strategies. The glocalization as unity of global systemic thinking and local action requires changes in the educational system on the organizational level as well as on the level of learning methods and the utilisation of media.

On the organisational level the opening of schools and classrooms towards the local environment and the scientific community is necessary. Thus, formal learning in the classroom can be connected to informal learning in the local community within family, peer-groups, clubs and (public) organisations. Interested local SMEs (small and medium enterprises) can also be included and in this way become part of 'Liquid Learning Places'. On the level of teaching methods and digital media, inspiring and ubiquitous learning enhances traditional classroom learning by means of a 'Person in Place design' (see DULP Framework, 2013) and the appropriate use of ICT and digital media. Technology enhanced learning in such a didactical learning design enables student-centred, self-steered types of learning like:

- real life, problem based learning
- explorative learning in action
- learning on demand
- game-based learning and gamification
- connecting experiences and exploration of real and virtual worlds
- cooperative learning, fostering social-network building in learning communities
- learning with communities of experts (e.g. by means of City- and Association-Wikis and Blogs) in order to achieve an interdisciplinary multi-perspective view on a real-world problems
- contextual learning, that supports digital inclusion and fosters intercultural understanding, social participation and social responsibility
- and the most important aspect: creating not only social impact on a local level by means of action-oriented learning of students but also foster their understanding of global constraints of ESD.

The use of digital media can be regarded as an effective lever to address different problems of sustainable development on a local level and make their global impact visible to the students. The following table provides an overview on how digital media may contribute to ESD (E= Example).

Table 1: Digital Media and their Application in ESD

Digital Media	**Potential Learning Support in ESD**
Cognitive Tools E: Spread Sheet, Database, Text Processing, Presentation, Graphics , Search Engines	*Create, (Re-)structure, Deliver Information* E: Use of CT for creating (shared) e-Portfolios Prepare Presentation of Exploration-Results

Communication Tools E: Micro-Blogging, e-Mail, Video-Conferencing Software (Skype, FM) Instant Messaging	*Communicate and Exchange Information* E: Virtual Meetings with experts on EDS topics, Online-Meetings between Project stakeholders, IM-Communication on field trips between students
Video- and Podcasts E: Video- Audio Software	*Produce and Modify Audio- or Video-Files* E: Interviews with Persons concerned; Documentation of excursions and field trips
Animation E: Topic related interactive (net-based) Animation Software of SD constraints	*Animation of systemic constraints* E: Animation of interdependencies in energy networks
Simulation E: Generic or Topic Related Simulation Software, Dynasis, Stella	*Dynamic Simulation of potential systemic developments* E: Simulation of customer- producer behaviour and their impact on socio-technical energy supply networks
Gamification E: Topic Related social (web-based, mobile) Games, MUDs, Virtual Communities (Second Life)	*Interactive – cooperative Games dealing with socio-technical systems* E: Competition between school-classes dealing with (local) environmental issues, Integration of real-world action or role-plays, strategy-games
Mobile Learning *E: Mobile Learning Apps, Local Based Services*	*Topic related apps using local based services for the needs of exploration* E: Support of Student's field trips and excursions by means of mobile Apps, which are connected to repositories; Apps for in-house navigation, supporting individual learning paths in Museums and Science Centres
Augmented Reality E: Mobile Topic related Information/ Navigation Apps, Head Mounted Displays in In-house Environments	*Real world exploration by means of mobile apps, Exploration within Science Centres* E: Including additional visual, textual or audio-information when exploring artefacts in museums or real life objects on field trips
Students' Learning Labs E: Topic related experimental / explorative Learning Environments	*Explore complex systems and constraints (in a Science Centre)* E: Support of activity-oriented, problem-based learning of students by using ICT-based experimental Learning environments (e.g. socio-technical aspects of power supply)
Cloud Computing Tools E: Mendeley, Delicious, Dropbox, Google Drive	*Support of shared knowledge achievement in distributed groups and learning communities* E: Co-operative topic related resource and people tagging, collaborative knowledge achievement, collaborative working and learning in locally distributed groups
Learning Management Systems E: Customized Moodle, Integrated Web 2.0 Tools (koaLA)	*Support of (shared) knowledge achievement and cooperation in learning groups* E: LMS with Web 2.0 Tools (APIs) can be used as co-operative generated repositories in distributed and mobile learning environments, repositories for individual or group-related e-portfolios

Web 2.0 Tools E: Wikis, Blogs, Micro-blogs, Tagging Software, Personal Learning Environments (Widgets, Apps)	Cooperatively generate, exchange, communicate, assess information E: Co-operative generation of topic related content, fostering content awareness and social awareness within a learning community
Social Learning Platforms E: Group Specific or Generic Social Software, LinkedIn, Ning, Facebook, Mahara,	*Support of social awareness and social network building* E: Supporting cooperation in and between groups of a common project, including external experts and stakeholders (search for resources and expertise)
MOOCs E: EdX, Class2Go, Coursera	*Massive Open Online Courses of international top Universities* E: (Parts) of MOOCs can be used to improve the expertise of stakeholders in an ESD-project, Further Education of involved teachers

The following condensed description of an ESD-project, that is actually realized at the UPB (University of Paderborn) in cooperation with the HNF (Heinz-Nixdorf-MuseumsForum), one of the Worlds biggest Computer Museums, provides an example how ICT can support ESD according to the concept characterized above.

EXAMPLE: USING DIGITAL MEDIA FOR ESD

In a students' learning lab (coolMINT) within the museum SD-related modules are offered. The students will be able to visit the Lab for project-oriented explorative learning with their teachers and classes but also individually. The visits will be prepared and reflected during pre- and post-visit phases in the schools together with the teachers. Explorative learning also takes place outside the classrooms and the museums during explorative real-world missions of the students. Students' learning results will be documented and reflected in individually and collaboratively created e-portfolios. For the needs of cooperation and social network-building a social learning platform with Web 2.0 tools is provided. Besides students, teachers, parents and representatives of schools, local decision makers, representatives of SMEs, bigger companies and domain specific experts are involved in these learning activities. Topic related guided tours in the museum and field trips with mobile devices and elements of augmented reality are as well offered as energy 'prosumer' simulations and games. The missions comprise real world action of the students causing social impact and intend to change personal and family lifestyles towards sustainable development issues.

Content- Modules in coolMINT

The ESD Scenario orientates on SD-topics and objectives introduced in the EU initiative 'Smart City' of the future. The Scenario Specific Domain is on Socio-technical Information Systems (SIS) for Sustainable Development, Socio-Technical Awareness Networks and Sustainable Use and Production of Renewable Energy. The respective modules will be offered to the visiting students within the Student-Lab. (coolMINT) of the HNF. Every module is linked to the preparatory classroom work in the pre-visit phase. The students will work with the materials and media of the modules according to the agreed mission design during their visit in the HNF. During a following post visit phase in the classroom at schools the results of the HNF visit will be wrapped up and incorporated in a common students' project. The results of several projects can be presented in a future students' exhibition in the HNF. Every module can be graded according to the learning prerequisites of the students'. The modules (M1-M3) will provide the students with a local and global

perspective on energy supply and energy consumption as a socio-technical system, considering the flow of information and energy according to the system's state and the behaviour of the involved human actors.

M1: Intelligent Energy-Management of a House (MicroModule)
(Socio-technical Information System {SIS} on Micro Level)
Interactive simulation of different consumer behaviour and energy supply scenarios, use of technical equipment.

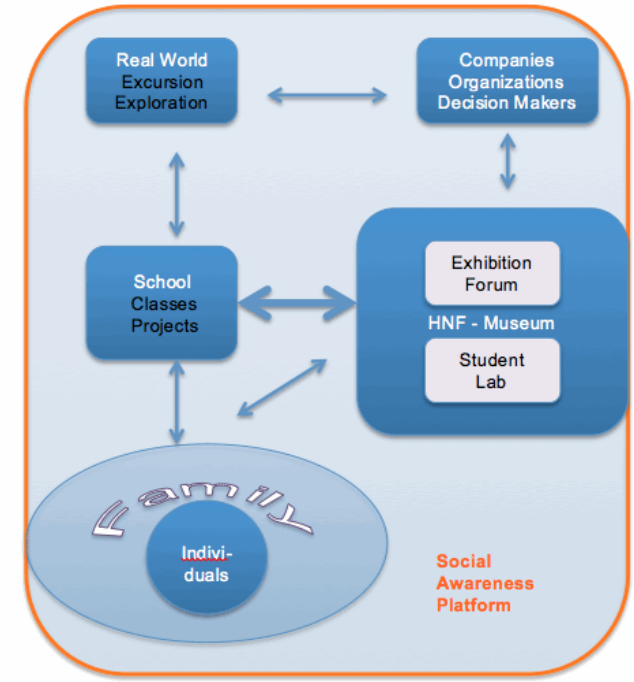
M2: Intelligent Energy-Management for a Local Neighbourhood (MesoModule)
(*Socio-technical system {SIS} on Meso Level*)
Interactive simulation of a local consumer/producer energy networks (neighbourhood).

M3: Intelligent Global Energy Networks (MacroModule)
(Socio-technical System *{SIS}* on *Macro Level*)
Interactive simulation of global consumer/producer energy networks (large scale networks).

Missions and Mission Design

The HNF offers in cooperation with UPB a student lab with three topic related modules, a topic related exhibition and a Forum as a 'Market-Place' (AGORA) for communication and exchange of ideas with different stakeholders. The scenario will contribute to sustainable education by scaffolding social awareness networks for sustainable development in the area of renewable energy. In order to address the specific needs of the students' target groups a group-related mission design is required. The specific mission design describes for the respective class of visiting students the sequencing and the requested aspiration level of the module and the assigned exploration of the exhibition. Thus, according to an agreed mission design between the stakeholders, a learning pathway for visiting classes will be defined, that not only links pre-visit, visit and post-visit phases of the mission but also offer individual students the opportunity to enhance their knowledge achievement during additional individual visits (e.g. with peers, parents etc.) in the HNF later on.

Figure 1: ICT support of ESD in the UPB-Scenario



Phases of Formal Learning

Before the visit of school classes in the HNF / student lab (pre-visit phase) the students will get access to the HNF/lab platform in order to include the offered preparatory learning materials and media for their classroom work according to the specific mission design. During the HNF visit the classes can work with the offered modules in the student lab coolMINT and also will be able to visit the exhibition on ICT and sustainable development with an adapted, topic specific guided museum tour (including competitive elements like treasure hunt, use of augmented reality, use of mobile devices). A following post-visit learning phase may also include real-world excursions at problem related sites in their local community and additionally may include the visit of companies. The results of all the learning phases the HNF will be summed up and incorporated in a common students' project. Every participating student will also document his/her learning activities in an individual e-portfolio. The results of several projects can be presented in a future students' exhibition in the HNF and will also be published on the social platform. Thus, local national and international cooperation and social networks will be established.

Teacher Training

HNF/UPB will offer a topic related teacher training for interested teachers that includes on site workshops with the teachers. The teacher training should provide scientific and didactical information related to the offered modules concerning relevant aspects of sustainable education, socio technical information systems and sustainable energy management. Especially, strategies should be addressed during the workshop about how classroom activities can lead to the change of real life habits of the involved students, their families and persons in their social network.

The HNF Forum

The forum will serve as a market-place for topic related information exchange that contributes to the scaffolding social awareness networks and triggers real life impact on a local level. Different activities are planned, which will be closely linked to the virtual social awareness platform:

- *Special Guided Tours for interested groups to the HNF exhibition on ICT and sustainable development*
- *Topic Related Public Panels and Workshops* tailored to the needs of different target groups
- *Students Academy Student summer and winter schools*
- *Topic related competitions*
- *Regular Common Closed Workshops with locals stakeholders* for the needs of coordination of local activities
- *Dissemination: Forums /Networks with other Museums / Organizations*

Scaffolding of Social Awareness Networks

Since many years the HNF and UPB maintain relationships to schools in Paderborn, in the state of North Rhine Westphalia (NRW) and in other parts of Germany. There are lot of school classes who register to a (guided) visit in the HNF. Thus, the HNF-UPB scenario will incorporate this social network and offer schools the participation in the project. The events in the HNF Forum and the accompanying activities on the social awareness platform will be used to trigger action for sustainable development on the local level and to transform the result of learning processes of the participating stakeholders into real practice of a changing life style. An accompanying formative evaluation will contribute to the improvement of the processes.

CONCLUSIONS AND FURTHER WORK

In the article we have shown, that ICT can play an important supportive role within ESD. During the learning processes in ESD-projects, students and other stakeholders can not only achieve competences, which are important for the local and global sustainable development, but also key competences and ICT competences. Accompanied by empirical action-oriented research in an on-going process of formative and partially summative evaluation, an incremental improvement and development of the lab will be fostered. The evaluation covers not only the evolutionary improvement of the ICT-tools by means of usability assessment and analysis of human-computer interaction but also the research on competence achievement and the observed social impact (KPIs: Key Performance Indicators). Actually the cooperation with other interested partners (Universities, Museums) has been initialized within an European Network (antARnet) of similar projects. Nevertheless, we have to be aware of the different regional implementation contexts for such projects. The concept of glocalization demands the consideration of the specific regional conditions of sustainable development for the respective regional projects. Nevertheless, the evolving regional projects may benefit from each other by exchanging common and specific experiences according to the IFIP AGORA approach of Ateliers and Studios.

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Biographies

Barbara Kędzierska is a professor for Education at the Pedagogical University of Kraków. Her primary areas of research and teaching are ICT in education, LLL, new forms and methods of learning, education for sustainable development, key competencies for LLL. She is a member of IFIP, Polish Informatics Society (PTI), coordinator of polish group of polish pedagogical universities' representatives for e-learning methods in preparing teachers.

Johannes Magenheim is a professor for Computer Science Education at the Institute of Computer Science at the University of Paderborn. His primary areas of research and teaching are CSE, E-Learning and Knowledge Management. He is member of different working groups of the German Informatics Society (GI), member of IFIP WGs 3.1 and 3.3. and the German National Representative to IFIP's TC3.

Agnieszka Kędzierska M.Eng. in Environmental Engineering Researcher at Free University of Berlin Expertise: Environmental Education, Waste Management, Education for Sustainable Development, Innovative Teaching Methods, Methodology in Non-formal education and Facilitation. Interests in Social entrepreneurship, Innovation and Leadership

Robert Fischbach: BA in Educational Studies & Governance Studies, MA in Research and Development in Social Organizations. Research Associate, Project-Manager and Lecturer at the Free University of Berlin, Department of Educational Futures Studies. Recent projects were about Local Social Networks among ESD-actors, evaluation of the national research strategy within ESD, evaluation of the train-the-trainer program "ESD Leadership Training" of the Federal Ministry of International Development. Interests: Educational Reform, Local Educational Landscapes, Education for Sustainable Development.