SUSTAINABLE EDUCATION TECHNOLOGY DEVELOPMENT - A CASE STUDY OF SUSTAINABILITY OF EDUCATION

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Abstract
The purpose of this paper is to explore the relationship between education for sustainability and sustainability of education. The methodology of the paper is a long-term case study of the development of an "educational exchange" system amongst the member universities of an international association. The result of the analysis indicates the importance of understanding the knowledge development processes of the use of educational technologies, applications and frameworks, and the evolution of the sustainable development of education technologies. Besides, the case study shows the opportunities and challenges of a community-based development approach. The paper answers a call for more empirical research on the relationship between education for sustainability and sustainability of education. Improving the understanding of this relation improves the possibilities for sustainable education technology development.

Keywords: Education Technologies, E-Learning, Sustainable development, participatory design, infrastructure.

1 INTRODUCTION
The promises and challenges of E-Learning, Learning Management Systems (LMS), and Information Communication Technologies (ICT) are at the top of the agenda of the United Nation's (UN) sustainable development goal for high-quality education (SDG4). The premise of this paper is that to realize sustainable high-quality education through technology development, a sustainable development process is, in turn, needed. In other words, education for sustainability connects to the sustainability of education [1].

This paper reports on a longterm case study of an e-learning "educational exchange" system under development in the International Association of Maritime Universities (IAMU). To meet the demands of the inherently global and rapidly developing maritime industry, the 61 worldwide member universities of IAMU have a long-term ambition to take advantage of e-learning technologies to pool their resources and develop education together, as well as to create opportunities for students to collaborate and learn together.

This paper explores how the sustainability of education can be understood as an educational and technical knowledge development process?

The following section 2 gives an overview of the premise of education for sustainability and sustainability of education with reference to the work of UNESCO and SDG4. Section 3 introduces Participatory Design (PD) and the notion of "infrastructuring" as an analytical framework to understand knowledge development with respect to the sustainable development of education. Section 4 describes the research methodology of the case study. Section 5 and 6 present the results of the analysis of how the IAMU educational exchange system relates education for sustainability, respectively sustainability of education. Section 7 concludes the paper and discuss the results.

2 EDUCATION FOR SUSTAINABILITY AND SUSTAINABILITY OF EDUCATION
The empirical case relates to the opportunities and challenges of sustainable education recognized by the UN's educational and scientific organization, UNESCO. According to UNESCO's [2] report “Rethinking Education” the aspiration of sustainable development requires us to resolve common problems and tensions and to recognize new horizons. Education must find ways of responding to such challenges, taking into account multiple worldviews and alternative knowledge systems, as well as new frontiers such as the advances of digital technologies. Digital technologies are recognized to have a fundamental and transformative impact on how we access information and how we communicate with each other [2].
Through a literature scoping review Stepanyan, Littlejohn, and Margaryan [1] find that the notion of sustainability concerning E-Learning technologies is often used as an umbrella concept that brings together diverse terminologies and various strategies. The domains of education for sustainability and sustainability of education are often subsumed in the broader notion of sustainability in an educational context. Education for sustainability focuses on sustainability through educational solutions in what can be related to the UN's sustainability goals and the UNESCO [2] report. Sustainability of education focuses on the implementation of sustainable forms of “successful” practice through educational development, leadership, and innovation [3]. This includes a range of interrelated research areas of sustainable E-Learning regarding, for example, resource and quality management, educational attainment, and professional development and innovation. Based on the results of their literature scoping review, Stepanyan et al. [1] call for more empirical research that elaborates the relation between these two dimensions. The results of this paper answer this call, with a focus on development processes for the sustainability of education.

3 PARTICIPATORY DESIGN AND “INFRASTRUCTURING”

The UNESCO report and associated working papers provide overall guidance on the development process of sustainable education. While this guidance is not very detailed, it does indicate that there are important implications for sustainable education of the design, implementation, and framing of educational policies; that these need to be inclusive, both in their formulation and in their implementation, if education is not simply to reproduce inequalities and social tensions; and that a participatory process is needed that takes into account a diversity of contexts and knowledge ecosystems.

In this paper, PD and the notion of "infrastructuring" are used as an analytical framework for understanding the knowledge development processes needed to develop sustainable educational technologies indicated by UNESCO [2].

At the core of PD is taking a diversity socio-technical knowledge ecosystems into account in the design and development of Information Communication Technologies (ICT). Of relevance for the analysis of this case study, Bødker, Kensing, and Simonsen [5] indicates three areas of knowledge development needed in PD: knowledge of technical options; knowledge about work practices; and knowledge and about new ICT usage.

The notion of "infrastructuring" develops the understanding of PD processes as a procedural, ongoing, and multi-relational activity, which unfolds over extended periods of time [6]. In this respect, Pipek and Wulf's [7] framework of infrastructural layers of work and technology development is of relevance to this research study in examining how PD processes link the development of standards, applications, and in-situ development.

4 METHODOLOGY

This paper is based on a long-term case study of an initial development project and a following community development approach of a new “education exchange” system in IAMU.

- For this case study, the initial development project was documented and analyzed from the specification and approval of the project charter by the IAMU International Executive Board in 2013; throughout a first phase that centered around development based on the specifications in the project charter; and finally a second phase of development completing the project in 2015, where 5 of the 21 IAMU IEB members universities worked with the project team to further improve the functionalities of the system as early adopters. The project activities included surveys, reviews, workshops, and prototype development and are further detailed in the following section 5. For this research study, the project documentation and artifacts generated from the project activities have been analyzed, including the resulting technical system. Also, the author in his capacity as a faculty member at one of the IAMU member universities participated in the project activities and kept a research diary also to document informal events to triangulate the formal records of the development.
Of relevance to understanding sustainable development issues, the development of the IAMU educational exchange system has been tracked and documented also after the initial project ended. The continuous development of both application and framework development of the educational exchange system has been based on a community development approach. A combination of community development and funded project development is a common development approach in IAMU where seed money is provided for, for example, project-related travel and where third-party expertise is needed, but where the primary development is carried out by the member universities themselves based on a voluntary community-based approach. Following the launch of the educational exchange system in 2015, the author has tracked: 8 different developments of e-learning application and learning activities and resources on the IAMU educational exchange system through documenting developing activities; the coordination work carried out by the IAMU secretariat (including the contracting of third-party service providers to host and maintain the system); and presentations and workshops at the IAMU annual general assembly.

Klein and Myer's [8] principles for interpretive field research has been used to understand the reliability of the empirical research and transferability of the results of the analysis: the combined documentation of the initial project activities and ongoing community-based development activities has provided a comprehensive empirical material that has allowed moving from individual events to a holistic understanding where common denominators could be understood and triangulating. In addition, new perspectives on the documentation have been gained by following up project events with key project stakeholders for triangulation purposes.

5 IAMU EDUCATIONAL EXCHANGE - EDUCATION FOR SUSTAINABILITY

This section gives an overview of how the IAMU educational exchange system relates education for sustainability, as a preamble to presenting the analysis of how the development process relates sustainability of education in the following section.

The IAMU educational exchange development project resulted in a new system based on the Open Source LMS and E-Learning system Moodle, also integrating an open technical standard called Learning Tools Interoperability (LTI) that enables the integration of e-learning activities and resources in a standardized way across major LMS and E-Learning systems in a plug-and-play manner.

Figure 1 shows an overview of the technical results in three parts: (1) The educational exchange system enables sharing learning activities and resources, such as e-lessons with recorded lectures and assessments and databases, which have been created in the e-learning systems of the respective IAMU members or in a central IAMU e-learning system; (2) Shared learning activities and resources can be found by other IAMU members in an "educational exchange" portal, which indexes and categorizes shared materials; (3) Finally, shared learning activities and resources can be used by other IAMU members either through IAMU's central e-learning system or from within their own e-learning systems. Entire courses can be shared, as can individual learning activities and resources, which in turn can be integrated into other courses.

By the beginning of 2018, eight E-Learning applications with learning activities and resources have been developed in the IAMU educational exchange system framework, including current MET topics as Scenarios for Simulation, Safety and Culture, Ballast Water Management, Navigation in polar waters, Maritime Cyber Security Training, and an IAMU Engineering Content Database.

This description gives an overview of how the IAMU educational exchange system educationally and technically provides education for sustainability. It does not, however, relate the development of the education. How the IAMU educational exchange system was sustainably developed is the topic of the following section.
6 IAMU EDUCATIONAL EXCHANGE - SUSTAINABILITY OF EDUCATION

The sustainability of education is the primary analytical focus of this paper. The results of the analysis of the initial development project and the following community-based development approach of the IAMU educational exchange system is reported in this section. As is described in section 3, the analysis focuses on knowledge development to understand sustainable development of education technologies, using PD and "infrastrucuring" as an analytical framework. The analysis is divided into three parts: Knowledge development about the use of educational technologies, Knowledge development of applications and frameworks, and Knowledge about evolution.

6.1 Knowledge development about the use of educational technologies

The analysis of the IAMU educational exchange system case shows the relation between technology and knowledge creation with respect to sustainable development. In this vein, the proficiency of the IAMU educational exchange system cannot be understood by the educational provisions of the technical system alone, but need to be understood based on the proficiency to develop the knowledge required to develop the system.

The technical framework that was used for the IAMU educational exchange system is illustrative of this relation. The IAMU educational exchange system was facilitated by the availability of Moodle, an Open Source LMS and E-Learning framework that comes with comprehensive technical provisions of functionality to develop learning activities and resources. In fact, it can be recognized that without the readily availability of a technical framework that did not require customized programming to work, it is questionable if the IAMU community would have been able to allocate enough resources to develop the educational exchange system. However, at the same time, the analysis shows that the availability of a technical framework does not equal the knowledge to use it. In this way, the analysis shows that the knowledge development process during the initial development project was instrumental in
building up the knowledge required of how to use the (technically readymade) Moodle framework. This development process included an iteration between

- Surveying the IAMU members to gain input of the needs of the system and to identify early adopters of the prospective new system;
- A review of the technical provisions of Moodle;
- Workshops between the project team members, early adopters from the different IAMU member universities, and the IAMU secretariat;
- The development of prototypes using existing but classroom based IAMU subject delivery and assessment plans and materials as input;
- The presentation of proofs-of-concept at two annual IAMU general assemblies where IAMU member participated and could provide input to the course of the development;

This development process enabled building up knowledge of different technical options based on the provisions of the technical framework in relation to educational needs. This, in turn, enabled the creation of new knowledge of how to develop and deploy the educational-exchange system, in addition to the technical education system in its own right. It is recognized that this relation between technologies and knowledge creation is a fundamental principle of understanding sustainable development of educational technologies.

6.2 Knowledge development of applications and frameworks

The analysis furthermore highlights the need to understand the relation between the educational and technology development of e-learning applications and their underlying frameworks. This realization was accentuated by the community-development approach of the IAMU educational exchange system.

After the initial development project of the educational and technical framework had ended, the development of e-learning applications on the IAMU e-learning educational exchange system was based on a community-based and end-user development approach. In this case, the technical framework Moodle enabled instructors themselves to develop their own e-learning applications with learning activities and resources. These learning activities and resources included syllabus structures, interactive exercises, reading materials, and interactive exercises. In total, eight e-learning applications have been created.

A number of these developments of e-learning applications, however, caused issues when being transferred to the IAMU educational exchange system for general use, and thus becoming part of the educational and technical framework. The analysis gives evidence to a number of such issues

- Converting educational materials that have been developed for an individual MET institution for generic use by all MET institutions. This, for example, both concerned case studies that are used in educational materials that are primarily relevant for a specific MET institution, and translation of educational materials into English. One example was a subject with educational material concerning a topic on ship navigation that a MET instructor wanted to “hand over” to the educational exchange system. There was, however, no one with the pedagogical expertise or resources on the receiving end that could develop the course into a useful format for general use in the IAMU community.

- Another related issue concerns maintaining E-Learning activities and resources in the educational exchange system. Examples were documented about MET instructors raising concerns about an ongoing responsibility to support “their” educational materials in the educational exchange system. This both concerned the need for updating the materials and supporting teachers and students who wanted to use the materials.

As these examples allude to, the application and framework relation becomes an additional dimension of educational and technical knowledge development. In the analysis of the empirical material, it was also found that this was a relevant dimension to highlight in respect to the community development approach. Community development is associated with voluntary development commitments. The examples show the necessity, but the difficulty of maintaining the knowledge and technical frameworks that surround community development approaches. In this way, based on the premise of application and framework development, there might be a mismatch between the immediate technical results of the system and the know-how for long-term sustainable development of the system.
6.3 Knowledge about evolution

The final premise of the analysis concerns the knowledge of the evolution that links educational and technical knowledge development, on the one hand, and application and framework development, on the other hand.

As described, the new knowledge that was required in the initial development project to develop the IAMU educational exchange system framework was a combination of bringing together knowledge about the general educational needs of the IAMU community, knowledge about technical framework options, and testing applications through workshops using prototypes and proofs-of-concept. In the following community development, the experiences of issues in handing over and maintaining e-learning applications pushed the need to develop new solutions in the underlying technical and educational framework. These examples both give evidence to how the evolution of new knowledge about the IAMU educational exchange system happens in the interface between educational and technical knowledge, and knowledge about applications and frameworks.

When starting the documentation and analysis of the IAMU educational exchange system during the initial development project, the importance of stakeholders with knowledge about the strategic educational needs or knowledge about the technical framework options were highlighted. The possibility of tracking the IAMU educational exchange system development over time, however, showed that knowledge about evolution is a key premise to understand long-term sustainability. At the same time, the one who was key to developing this knowledge was unexpected both to the initial development project and to herself. The analysis shows how a secretary at the IAMU office gradually built up knowledge about the intersection of the different knowledge dimensions and has become a key actor in sustaining the community development approach of the IAMU educational system. This also denotes what knowledge is crucial to the sustainability of the system. It was not, for example, the input of knowledge about the latest technical framework options to make cutting-edge functionality available. Instead, the analysis highlights how it was situated and every day - and often implicit - knowledge to bring these perspectives together in the evolution of the system that is crucial to sustainable development. This is something that is easy to overlook.

7 CONCLUSIONS

The IAMU educational exchange system shows the relation between education for sustainability and sustainability of education [1].

The educational topics developed in the IAMU educational exchange system relate education for sustainability: given the inherently global maritime industry, creating a common educational topic on safety and culture, for example, targets the aspiration of taking multiple worldviews and alternative knowledge systems into account in education as set forth by UNESCO (2015) and SDG4. Similarly, given the rapid technology development and the environmental and safety issues facing the maritime industry, pooling resources to develop educational topics such as Maritime Cyber Security Training or Ballast Water Management is in line with the aspiration of ensuring inclusive and equitable quality education.

At the same time, the IAMU educational exchange system shows the relation to the sustainability of education and UNESCO's (2015) call for an inclusive and participatory development process that takes into account a diversity of contexts and knowledge ecosystems. In this respect, the community development approach based on end-user development is relevant, where the technical framework allowed instructors with educational knowledge to, themselves, develop their e-learning activities and resources. This can be recognized as an inclusive development approach where instructors from IAMU member universities around the world could contribute with their educational knowledge. Furthermore, the analysis gave evidence to how the sustainability of education can be understood as a process of educational and technical knowledge development:

- **The participatory process of education and technology knowledge development**: An understanding of the sustainability of education technology needs to go beyond the technical provisions of a technical system alone. A knowledge development process resulting in new knowledge of how to combine educational knowledge, on the one hand, and knowledge about technical options, on the other hand, is key to the sustainable development of education technologies. This finding develops Bødker’s et al. [5] framework of knowledge areas that are needed in the participatory design in an educational context.
• **Layers of framework and application knowledge development**: At the same time, it was highlighted how educational and technical knowledge development needs to take place both in regard to applications and frameworks. This distinction is of relevance to community-based development approaches where it was shown how it can be difficult for instructors to develop their applications for general use in a common educational and technical framework. This understanding relates Pipek and Wulf's [7] framework of the participatory process of knowledge development in layers of standards, method-driven application, and in-situ development referred to as "Infrastructuring" [6].

• **The evolutionary knowledge development process**: finally, the importance of the evolution of educational and technical knowledge to the sustainability of education was shown. And how this knowledge is situated in the interface between educational and technical knowledge and knowledge about applications and frameworks. The analysis, furthermore, showed how located, every day, and often implicit knowledge - in this case, possessed by a secretary - become key to the sustainable development of the educational technologies. Sustainable education technology development, in this way, becomes characterized by an ongoing state of being constantly "in the making" [9][10].

The empirical case presented in this paper is part of a more extensive research study where three long-term case studies are tracked to understand the development of sustainable education and education technologies. The results contribute to the construction of a complete analytical framework that is intended to support both researchers and practitioners in the development of sustainable education mediated by technology.

**REFERENCES,**


