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MASTERING THE ENERGIEWENDE – A CROSS-DISCIPLINARY TEACHING APPROACH

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Abstract

Decarbonizing the electricity system has become one of the most important and urgent societal challenges for the coming years. Germany's so-called Energiewende, the energy transition from fossil to renewable energy sources, is well advanced. However, experience show that there is both an urgent and probable long-lasting need for cooperation between disciplines such as economics, engineering, sociology and computer science to master the Energiewende. While scholars already address a myriad of idiosyncratic technological and economic issues, they still tend to neglect the demand for a skillful workforce that is capable of mastering cross-discipline challenges. The IS discipline has a long tradition in interdisciplinary research and the energy system transition is inseparably linked to a smarter grid. Green IS education can therefore significantly contribute to a global Energiewende by developing teaching concepts in order to provide necessary skills and capabilities for students and young professionals. We address this challenge by presenting a cross-disciplinary teaching innovation based on the German Energiewende.

Keywords: Green IS, Smart Grid, Energiewende, Energy transition, IS education.

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1 Introduction

Information systems are going to play a key role in making today's electricity grids smarter, thus enabling the energy transition from fossil to renewable energy sources (Watson et al., 2010, p. 26). Many regions around the globe have transformed or significantly changed their energy policy. For example, California initiated their energy transition by passing the 'Renewable Energy Standard' in 2011. According to this law, all electricity providers in the state have to obtain at least 33 per cent of their electricity from renewable sources by 2020. Similarly, the European Union's "20-20-20 goals" demand a 20 per cent increase in energy efficiency, a 20 per cent reduction of CO2 emissions, and 20 per cent use of renewables by 2020. Against the background of the power plant meltdown in Fukushima, Germany passed a law in 2011 mandating that 35 per cent of energy must originate from renewables by 2020 (Kemfert, 2011). The term *Energiewende* is associated with a fundamental shift towards a greener energy policy in Germany. Due to the fact that renewable energy sources are volatile in nature – in contrast to baseload power sources such as coal or nuclear – accurate measurement, better prognosis and close control of energy needs are seen as key to cope with the growing share of distributed renewables in distribution grids (Appelrath et al., 2012, p.1). Thus, new data exchange infrastructures have to be designed and implemented for today's wholesale markets – previously designed systems for the fossil energy generation – will have to be adapted to renewables with minimal variable costs. Stabilizing grids with a higher share of renewable energy generation, by managing the demand side is seen as a promising solution (e.g. Watson et al., 2010, p.24). While fine granular electric power measurements are likely to improve consumption forecast accuracy, they also raise privacy concerns due to novel profiling options. Calls to address these energy research questions accordingly, demand the cooperation of researchers from disciplines such as economics, computer science, information systems, engineering or law. As the transformation from fossil to renewable energy sources is a task for the coming decades, energy research has to not only lay the scientific foundations but to also accompany energy policy for a prolonged period of time. Hence, one of the key challenges is to firmly embed the cross-disciplinary requirements in this process.

The IS discipline is well suited to contribute to this task (e.g. Corbett, 2012; Watson et al., 2010, p.32). First, IS can bridge the gap between the different disciplines as a result of its long tradition in interdisciplinary research. Second, the design of automated information exchange in smart grids is seen at one of the key challenges in smart grids (Appelrath et al., 2012, p.1; Kerschbaum et al., 2011). Against the background that system design, business process management in general and human interaction with information systems are core topics in IS research, the IS discipline has the potential to substantially contribute to the transition of our energy systems. IS scholarship possesses a large set of theoretical concepts and methodologies. Consequently, a still mostly neglected contribution to *Energiewende* lies in IS education by preparing students and practitioners to develop adequate capabilities, i.e. cross disciplinary teamwork, increasing their understanding of the complexity of energy transition. This enables them to carve out the potentials and limits of current technologies and solutions against the political and economic context and recognizing the specific role of IS. We address this challenge of the *Energiewende* as IS research and teaching agenda by offering a seminar, presenting a cross-disciplinary pedagogical innovation for students who seek a career in an energy related job-position. Due to the required foreknowledge, it is intended as elective course on a graduate level. Our aim is to encourage participants of different scientific disciplines, accompanied by different underlying perspectives, to work on a topic of the energy domain and find a common solution. In order to achieve that, a basic knowledge regarding the methods and views of the respective scientific discipline is needed.

The remainder of the paper is structured as follows: First, we briefly describe several issues that arise with the implementation of the *Energiewende* in Germany, the specific role of IS and its implication for education. This is followed by a short overview of our conceptual teaching approach encompassing related-work and requirement identification. The next section provides the design of the cross-disciplinary seminar (including the organization and program) based on our findings. After a brief description of the evaluation methodology, we aim to share our experiences by highlighting perceived strengths and weaknesses of our concept. Finally, we outline the lessons learned and the portability of our teaching approach for other IS educators.

2 *Energiewende* as IS Research and Teaching Agenda

As the transition from fossil to renewable energy sources – the *Energiewende* – is a task for the next decades, energy research has to not only lay the scientific foundations but to also accompany energy policy for a long time. Hence, one of the key challenges is to firmly embed the cross-disciplinary requirements of the *Energiewende* in IS research and curricula.

It is only recently that IS research has begun to deal with environmental sustainability topics to a significant degree (Elliot, 2011), whereas works on so-called Green IT and Green IS have particularly gained momentum (e.g. Watson et al., 2010). Overall, the number of IS publications on smart grids, smart metering, demand side management or demand response approaches or data-privacy is still small but quickly growing (e.g. Strüker and Kerschbaum, 2012). With regard to textbooks the choice is very limited. Watson and Boudreau (2011) provide an 'energy informatics framework' as an excellent tool to analyze the potential and actual role of IS in the frame of the *Energiewende*.

However, as IS scholars we cannot wait until IS textbooks and IS energy research are broadly available. The urgency of climate change and our social responsibility should motivate us to create a new IS curriculum on the *Energiewende* right now. The lack of IS research as a starting point is in particular no excuse, because it can be compensated with a strong link to industry experiences and current activities. As Elliot (2011) argues, scholarly contributions should in general not be limited to research: Higher education aiming to prepare graduates for careers in all stakeholder areas could and should make a significant contribution by a strong relation to concrete and daily problems. With regard to the transformation of our energy system, the challenge for IS scholars therefore is to focus curricula and educational outcomes on (a) cross-disciplinary problem-solving skills, (b) specific energy-domain knowledge (e.g. in industrial & energy economics, machine-to-machine communication, IT-security and privacy-enhancing technologies, meter data management, data analytics, consumption forecasts or enterprise application software) and (c) strong interpersonal communication and learning capabilities.

2.1 IS Expectation Gap: Academic Preparation vs. Industry Requirements

Independent from the context of Green IS, keeping pace with the high-velocity of turbulent change within the IT industry is generally difficult for IS researchers and particularly IS teachers (Davis et al., 2005, p. 980-981). Hence, it is not surprising that several studies reveal significant perception gaps between IS academics and practitioners (Lee et al., 1995; Lee et al., 2002), ill-matched curricula with business needs (Lee et al. 1995, p. 316) or lagging responsiveness to market needs (Bullen et al., 2009, p. 137-138). While both sides call for closer collaboration and communication between universities and practitioners in order to close this gap, IS scholars emphasize the mission of higher education: a pedagogical innovative provision of state-of-the-art research findings and a broad spectrum of skills instead of pure job training (Lee et al., 2002, p. 53-60). Over the past two decades, changes such as the dot.com bubble, global outsourcing of IT functions, technological developments have led to a reconsideration and revision of future IS professional skills and a continual revision of existing curricula (Lee et al., 2002, p. 55-60; Topi et al., 2010, p. 6-7).

In response to these developments, an increasing number of studies address the question of the evolving IT skills required from graduates and the development of curricula to enhance and sustain the education of young talents for both practice and IS research community (Goles et al., 2008, p. 183-187). Although business is still a core domain for IT professionals (Abraham et al., 2006, p. 1150), it has expanded beyond this realm as IT-enabled innovations such as the Internet and ubiquitous computing technologies become more and more important in a number of domains outside business, such as urban planning, law biology/ecology or environmental studies (Sendall et al., 2011, p. 3; Topi et al., 2010, p. 9-10). Considerable restructuring efforts driven by these changing stakeholder needs and expected graduate skills can be observed e.g. in North America as well as in Europe: Topi et al. (2010) published a comprehensive revision of the curriculum for IS undergraduate programs with a focus on high-level capabilities needed by IS graduates. These capabilities are based on a set of knowledge, skills and domain fundamentals and server as a guiding principle for the curriculum development. Also in Europe, where a standardization and harmonization of higher education is still taking place, a variety of restructuring educational projects are noteworthy. Examples are the curriculum for Business Information System Design in Scandinavia (Carlsson et al., 2010) or (WKWI/GI, 2007) in the German context, which also builds on a capability-driven pedagogical model but emphasizes the specific role of design in science and education.

2.1.1 Critical educational needs for students and professionals

Allied to existing differences regarding scope and focus, current curriculum model revisions are driven by the changing needs of IS graduate capabilities. In a recent survey by Bullen et al. (2009) different "requisite skills" of IT professionals were explored. As technical as well as non-technical skills are important for success in practice, IS graduates need some competency in both types of skills to advance in their careers. Interestingly, studies about the projected importance of different IS capabilities ranks non-technical skills such as communication and global teamwork (Carlsson, et al., 2010, p. 537; Goles, Hawk, and Kaiser, 2008, p. 189-190) as the most crucial in the future. Also, the recommendations by Topi et al. (2010, p. 16-17), assume that understanding and improving organizational processes is a key capability. In this context, organizations and their employees often failed to consider environmental and sustainable problems in business processes. These issues have been seen to play an important role for their decisions and behavior in everyday work, although increasing rates of IT implementation make them capable to increase production and therefore more responsible for questions of environmental sustainability (Jenkin et al., 2011, p.1)

IS graduates need some understanding of the important role Green IS would play in addressing sustainability in organizations. The task pertains to training sustainability knowledge workers, who are aware of their influence on a sustainable development. A strong relationship to concrete and daily problems is important, as effort driven considerations may result in discrepancies between the individual intention and actions undertaken regarding environmental topics. IT can become more and more embedded in organizational structures and what enables its use for sustainable development. In order to do so, knowledge about how IT and employee-level relationships promote this task on an organizational level is crucial (Jenkin et al., 2011, p. 28-34). These capabilities should recognize the variety of specific career tracks and therefore be broad enough to allow individual specialization. Hence, so-called high-level capabilities, which are more abstract and stable than knowledge and skills (Goles, Hawk, and Kaiser, 2008, p. 182; Topi et al., 2010, p. 16-18), are not limited to a specific domain. Such capabilities include the ability to identify and understand IT-enabled opportunities, resulting information requirements, issues of globalization and fundamental reconsiderations of designing and managing architectures. Thus, the specification of these high-level capabilities allows the inclusion or exclusion of several sets of methods and techniques.

2.1.2 Technical and Economic Knowledge

Due to the fluctuating renewable energy generation, future electricity distribution grids will entail trade-offs between market efficiency and security of supply. Tensions between engineering and economic approaches also manifest, for example, in choosing the communication infrastructure in smart grids: While engineers want standardization and high volume, economists aim for competition at every level in the commercial model. Finding solutions to these kinds of trade-offs requires knowledge at least in two core areas of the IS discipline: information technology and economics. Accordingly, IS students should acquire technical and economic fundamentals, i.e. knowledge for instance in industrial & energy economics, smart objects/ machine-to-machine communication, IT-security and privacy-enhancing technologies. Although information systems are not the primary focus of the paradigm shift towards renewable energy, it is instrumental for gathering and sharing data for the purpose of coordination and therefore of strategic importance. As a result, students need basic skills in data analytics to assess, for instance, the potential of detailed energy consumption data for an ecosystem of new energy and energy related services. The energy industry is already far behind concerning IS advances. Therefore, the transition toward smart grids creates far-reaching opportunities for technical and economic educated graduates in the electricity sector. Utilities are aware of this issue and have already recognized the great demand for IS skills in their domain (Corbett, 2012, p. 5).

2.1.3 Interpersonal and Communication Skills across Disciplines: Avoiding blind spots

As the success of the energy transition is challenged by a multitude of economic, technological and societal issues, it is crucial for graduates to develop cross-disciplinary capabilities to work closely together and acquire knowledge and skills beyond their own core discipline. Trade-offs such as new business opportunities versus privacy and ethical issues or the optimization of economic welfare versus physical and technical boundaries illustrate the need for a multi-disciplinary approach to the topic of smart grid. Multi-disciplinary learning outcomes promise to unearth new and differing questions and issues, drawing on multiple methods and knowledge to address them and finally develop the capability to synthesize or integrate these differences (Lee et al., 1995, p. 323-331; Repko, 2008). However, cross-disciplinary learning is often challenging due to different perceptions and expectations, particularly varying knowledge and methodical base. For this reason, another aim of our seminar was to improve interpersonal and communication skills, which may become more important for IS students (Goles, Hawk, and Kaiser, 2008, p. 180; Carlsson, Hedman, and Steen, 2010, p. 529).

3 Course Design and Implementation

Today, the *Energiewende* in Germany is a very urgent issue that is mainly dominated by governmental and industrial actors requiring political, technical and economic solutions that can be applied in the near future. Therefore, we garner insights from leading actors within this transition: The starting point of the teaching concept was therefore a cross-disciplinary lecture series on current specific topics. For this purpose, experts from industry (representatives of international enterprises) and academics (computer scientists, engineers, IS and philosophy) presented pressing problems and options concerning the energy transition. The cross-disciplinary theme is also reflected by the academic background of the educators involved in the seminar. Seven full-professors from different areas such as Computer Science, Economics, IS, Engineering and Philosophy agreed to collaborate and supervise the students on a specific topic. Each educator was further committed to acquire an expert as guest researcher to minimize organizational efforts. The responsibility of the professors also included the role of a "mentor", who supervised a student working group and therefore allowed for individual assistance and more interactive support.

Bioinformatics and Systems Biology	Ethics / Philosophy
Business Economics	IS / Business Informatics
Computer Science	Microsystems Engineering
Environmental Studies	Renewable Energy Management

Table 1. Disciplines involved

The students were further asked to work closely in a team to (a) develop a research paper on an elected topic and (b) present their results to the audience at the end of the course. The rationale behind was twofold: We aimed to provide the students enough freedom to research in a field of their interest, while also allowing them to negotiate and discuss the scope and structure of their contribution together as a team. We expected that such team and project-based work simulates the requirements of real-situation in business and related domains in a very realistic manner (e.g. Abraham et al., 2006).

Beside IS and economics, we further invited students from related disciplines such as Computer Science, Ethics and Engineering to participate in our course. When we formed the groups working on a common topic, we integrated students from different disciplines. Table 1 presents an overview of academic backgrounds of the 32 participating students:

Table 2 briefly summarizes the teaching modules and expected learning outcomes. Due to space limitations, we provide a deeper discussion of the intended capabilities in Section 4.

Teaching module	Guest lectures	Workshop
Approach in order to enable the following capabilities	• Experts from industry and academics present problems from their specific perspective	• Under the supervision of an expert mentor students in small groups discuss one aspect • Finalizing a group work research paper and provide a problem-solved recommendation • Presentation of the student group work to public audience with different expertise
CAP1: Cross-Disciplinary Work	• Analyzing current problem areas from different perspectives • Insights from practice • Building additional capabilities through multi-disciplinary teaching experience	• Problem- solving in a team • Project-based working environment • Developing rhetorical skills • Transfer of research-services beyond the classroom
CAP 2: Interactivity	• Time for discussions with the guest lecturers	• Presentation of the individually acquired results to the whole group, subsequent feedback and debate • Close and interactive learning experience with professors (face-to-face)
CAP 3: Interpersonal Learning and Problem-Solving	• Further solution processes and new mindsets can emerge from the experience of the experts	•Simulation of the real-situation requirements in business • High level of freedom and flexible working environment •Varying ways of thinking and methodical approaches synthesize to one common result
CAP 4: Teamwork	• Preparation and follow-up of new topics in a team	• Writing of a common research paper in a group • Negotiation and Discussion about the scope and structure of the contribution • Different expectations about the *Energiewende* have to get harmonized
CAP 5: Presentation	• The participants get an opportunity to attend lectures from experts, what enhances their own presentation skills	• Presenting to an audience with heterogeneous knowledge and expectations is a challenging task
CAP 6: IS specific Skills / Methods	• Guest lecturers from the IT domain and economics	• Problem formulation skills: Formulating of a relevant IS and energy-related topic •Ability to analyze and review data

Table 2. Overview of the teaching approach intended outcomes.

3.1 Program of cross-disciplinary lecture series

The first lecture by a researcher in the field of distributed power supply included an introduction of various technologies for an intelligent power supply, smart meters and alternative storage options. Subsequently, a chief technology officer of a large Japanese technology company gave a broad overview of current and planned corporate strategies against the background of the political dynamics in Japan. He provided insights about Japan's strategic energy plan and the significant cultural and operational differences. During the third lecture, a computer scientist and electrical engineer demonstrated the importance of demand-side management for a more efficient use of renewable energy. As a complement to the previous lecture with a technical focus, a representative of a global market leader in enterprise software emphasized economic issues from the perspective of a software provider. Here, potential new business models and positioning strategies of a software provider were outlined and discussed. In lecture four, an IS-researcher gave an overview of the vision of the so called "Internet of Energy" (Appelrath et al., 2012, p. 1-2) and its following economic and regulatory challenges. The last practical insights were provided by a board member of global supplier of industrial energy equipment. In his lecture, he described the development of the electricity supply system and the associated challenges such as the political framework conditions for the energy transition in Germany, projected energy production costs and subsidies as well as possible pitfalls. The role of solar power technologies in the global energy transition was highlighted by a material scientist and engineer. Finally, a professor of philosophy and ethics introduced a new perspective into the lecture series by discussing ethical and philosophical issues arising in a modern industrial society.

3.2 Student Group Work and Student Level

The topic of the guest lecture served as basis for the following student teamwork. They chose their selection via an online-form and were then assigned to one of the seven topics groups. Furthermore, we considered diversity and multi-disciplinarity when finishing the group assignments. Each team was assigned to a corresponding guest speaker mentor. To reduce organizational efforts and to allow a maximum of flexibility for both students and educators, all groups were organized independently. Our intention was that the students needed to reach an agreement regarding the research topics and the organization of the tasks (which also involved scheduling of the group meetings). The mentor on the other hand supervised the group by continuous feedback such as recommending literature, clarifying terms and helping with the structure of the paper.

Scenario 2025 – Future Energy-Mix in Baden-Württemberg	New Business Models in the Internet of Energy
Gas Storage as a Key toward the Energy-Transition in Germany?	Demand-Side-Management – Challenges and Opportunities
Demand Side Management in public dormitories with Dynamic Pricing	Data Protection and Privacy Issues in a Smart Grid

Table 3. Topics of the student groups

4 Evaluation

4.1 Methodology

The event evaluation was composed of both a standardized questionnaire and a comprehensive evaluation report. This combined approach was designed to provide numerous reviews, as well as a more comprehensive, critical analysis of the event. A standardized collection of key aspects of the event was made, assessing all 32 students, while only a selection of six students (one from each group) created a final report. The final report allowed the students' subjective experience, motivation, and satisfaction to be expressed in more detail.

The standardized questionnaire contained close-ended questions on the guest lectures, the learning climate, teaching methods, organization, effort, or quality of the teaching material provided. We used a Likert scale (Burns and Bush, 2010) with ratings equal to the German grade system ranging from 1= excellent, 2 = good, 3 = satisfactory, 4 = borderline until 5 = very poor. Open-ended questions about naming major strengths and weaknesses of the seminar were also used. In order to avoid socially desirable answers, the questionnaires were recorded anonymously. As part of the final evaluation report, six students additionally reflected on their experiences and subjective impressions and provided important impetus for improvements in future events.

4.2 Results

The first part of the questionnaire referred to the perceived quality of the guest lecturers. We asked all students to answer the following question for each guest speaker: "How do you rate the overall quality of the particular contribution to the course?" The resulting quantitative ratings of the eight guest lecturers (from 1= excellent to 5= very poor) can be seen in Figure 1. The best rated speaker received an excellent rating (1.4), the worst evaluation result was satisfactory with 3.0, while the average of all lecturers note a generally good performance with 2.3 points.

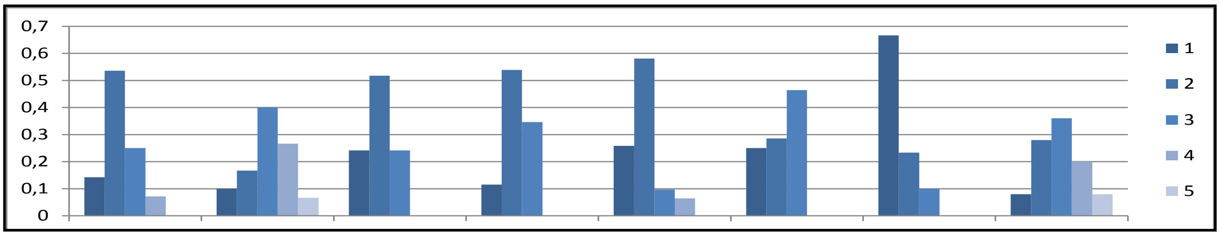

Figure 1. Rating Distribution of the eight Guest Lecturers

4.2.1 Organization and educational approach

The second part related to several aspects of the module (see Table 4). Any question about the organization (structure and support), learning methods, skills and learning climate were measured by the same Likert scale (from 1= excellent to 5= very poor). The results indicate a predominantly positive evaluation with an average of 2.2. In particular the opportunity to interact proactively with professors was well rated, at 1.6. The workload, measured with an adapted scale (ranging from 1=difficult to 5=too light), was rated on average as 3.31 (=complete adequate). A similar result was achieved for difficulty of the course, which earned an average rating of 3.1 (=just right).

Aspects of the module	**µ**	**∂**	**Aspects of the module**	**µ**	**∂**
Structure & Integration: Was the composition of the module well structured?	2,26	,89	Content & Skills: How do you rate the contribution this module made regarding the development of your knowledge and skills for your future career?	2,03	,71
Teaching & Learning Methods: Were teaching and learning appropriate given the goals of the unit?	2,10	,75	Learning climate: Did you get motivated and was your interest raised?	2,00	,86
Quality of references/materials: How was the quality of support material?	2,23	,92	Workload: How was the amount of subject-matter treated within the available time?	3,39	,84
Participation: Was there sufficient room for interaction between lecturers and students	1,58	,72	Difficulty: How difficult was the module in regard to your previous knowledge?	3,1	,83
Overall Grade: Which overall grade would you assign to the whole module	2,23	,76	Scale 1-6: 1= excellent, 2 = good, 3 = satisfactory, 4 = borderline, 5 = very poor Scale 7: 1=excessive, 2= slightly too much, 3=completely adequate, 4= easy to handle, 5=too light Scale 8: 1=too difficult, 2= moderately difficult, 3=just right, 4=moderately easy, 5=too easy		

Table 4. Standardized Questionnaire Results

In the third part of the questionnaire we asked respondents to name the seminar's strengths and weaknesses. Here, the interdisciplinary nature of the event was praised as were the interactions with non-specialists and the opportunity to look at the complexity of energy systems from different perspectives. Furthermore, the opportunity for discussion was considered positive. In the above shortcomings and suggested improvements are demonstrating conflicts with preferences and goals of students with different backgrounds: For example, some participants wanted a more technical focus while others criticized the emphasis on information technologies and the smart grid and wished for a greater inclusion of social, philosophical, and economic prospects. Table 5 summarizes the responses together concisely:

Strengths	**Suggestions for improvement**
Good opportunity for students from different areas to work together.	Give more technical vision, not just social aspects of the energy transition.
Presentations in different disciplines.	Better introduction for mentors.
Very complex and interesting topics.	Focus was mainly on IT/Grid, give more diverse presentations (economics, politics, …).
Expert guest lecturers.	Give more applied aspects of energy transition.
Almost all presentations were good or very good.	Clearer description of what is expected from students and how the seminar is evaluated.
Inclusion of societal/philosophical aspects of energy transition.	Better timing.
Good discussion after presentations.	Give more topics, not just seven.

Table 5. Strengths and weaknesses of the seminar

The aforementioned evaluations provided us further insights about the learning experience of our cross-disciplinary teaching approach. One identified need for IS graduates is the acquisition of certain capabilities, which are required from graduates to be prepared for successful practical/ academic work.

The *Cross-Disciplinary Work (CAP1)* was enabled by the teaching module in various ways. Guest lecturers from different disciplines presented a broad variety of energy related topics to the audience and analyzed them from their own point of view. The workshop consisted of mixed groups, what allowed the integration of more diverse perspectives and presentations to an audience with a wide spread level of expertise. The participants appreciated the cross-disciplinary character of the module, what is shown by the following statements of the respondents (R.):

R2: "We perceived the multidisciplinary nature of this module as a real strength: It was exciting to see how students from other disciplines extended the perspectives on energy systems and what questions arise here."

R4: "During my previous studies I was never confronted in any other seminar with such a great professional and experiential diversification of the group members. But it was this interchange of ideas with students from another field, without the skills and knowledge I already acquired but with fundamentally different perspectives about the topic, the problems arising and opportunity for innovative approaches to problem-solving."

Nevertheless, the multi-disciplinary focus was a challenge for all students involved, but after the successful completion of the seminar it was perceived as a valuable asset for gaining new insights. As an example, one participant describes his experience as follows:

R1:"The different needs and expectations about the Energy turn-around didn't only refer to the actual group project but also to the complexity of necessary processes in general. This initially led to difficulties in the working approach, but the value of these diversities emerged with the progress of the course and the group work. I got the impression that we could all usefully add our existing knowledge according to our disciplines."

The Guest Lecturers encouraged the *Interactivity (CAP2)* with time for detailed discussions after their talk. A face to face learning experience integrated the mentor into the working-process, in this way they were able to give feedback and help with the structure of the paper. However, several students expressed their needs for better preparation and supervision of mentors:

R1: "Professor G.S. and his assistant Dr. J. S. were always available and gave useful comments about the organization and presentation of our work. […] However, it became obvious that the supervising team had no comprehensive knowledge on these particular energy technologies."

R4: "The group work was supervised by Dr. C.W. from the engineering department. The meetings were very cooperative and characterized by an open way of dealing in each issue of the group members. A little more initiative from the beginning of the supervisors would have helped because of the complexity of the task and the inexperience of the students. Apart from the initial difficulties, the mentors have taken their role as teacher and supervisor seriously and very satisfactorily. "

R3:"Our work was supervised by Professor G.L. Due to the novelty of the seminar the task was unclear and thus caused confusion within the group at the beginning of the team project. After these initial difficulties and the resulting unproductivity our group was able to independently choose a good and useful topic and structure."

Learning and Problem Solving (CAP3) is an important capability for mastering the challenges of the *Energiewende*. We offered a project-based working environment and encouraged the groups to organize independently to solve a problem together. That enabled high levels of freedom and a flexible working environment:

R5: "*The different needs and expectations about the Energy turn-around didn't only refer to the actual group project but also to the complexity of necessary processes in general. This initially led to difficulties in the working approach, but the value of diversity emerged with the progress of the course and the group work."*

R2: "The exchange with students from other courses was interesting and has simulated a typical project situation. The need to find a research topic as a group without specific requirements by the teacher also increased our satisfaction with the teaching approach as it was not only perceived as a responsibility but also as a higher level of freedom."

But also initial difficulties in communication and an advantageous learning outcome (team work, diversity) are made clear in the statement of another participant:

R6:"Among other reasons, the intra-group discussions in our group work were not only constructive and beneficial but sometimes also debilitating. Each participant has had a different opinion on the issue of energy systems[…]."

The *Teamwork (CAP4)* aspect of the seminar consisted of the writing of a common research paper and the challenge to harmonize different expectations about the *Energiewende*:

R5:"It was quite clear that the different members of the group (economics, computer science, microsystems engineering) had high interest in the topic of energy policy but with very different knowledge backgrounds."

We intended to enable *IS Specific Skills (CAP6)* with guest lecturers from the IT domain and economics in addition to the work in mixed groups on IS related problems. Some students though complained about too much emphasize on technical aspects, indicating that they request a broader diversity of topics:

R1:"The energy turn-around has been discussed from different perspectives and thus led to 'broadening horizons'. However, the technical focus of the seminar dealing very much with demand-side management and smart metering was exhausting in particular for students from other disciplines such as philosophy. In addition, other important issues of energy policy like social acceptance and motivation and ethical considerations were on the short side"

Very positively, the students also commented about the organization of the seminar. Nonetheless, due to the novelty of the teaching concept and lack of experience, suggestions were not only predictable, but also desirable. The evaluation report reflects most of the weaknesses in more detail as already mentioned within the questionnaire.

Given the strong focus of the event on the cooperation of students, the evaluation part should also end with a commentary from a responding student:

R6: "In summary it can be stated that the cross-disciplinary seminar about the energy transition offers a very valuable addition to my recent study. In particular, the emphasis on multi-disciplinarity and the opportunity for students to work and organize independently as a team makes course to a unique learning experience. The different backgrounds of the lecturers and teachers interested in sustainable energy policy were very valuable *for me. But in particular the varied perspectives about the energy transition of the other student team members challenged and shaped my existing knowledge and therefore enriched my way of thinking."*

5 Discussion and Conclusion

Starting point for the development of our teaching concept was the ongoing energy transition across the globe and the resulting challenges in multiple fields. We can see growing attention in the IS community towards sustainability (e.g. Elliot, 2011; Watson et al., 2010) and IS educators are aware of their responsibility to integrate sustainability principles into their curricula (Sendall, 2011, p. 31). However, the number of contributions on solutions for the success of the energy transition from fossil to renewable energy sources is still on an initial state but increasing and the majority of recent teaching approaches and teaching books do not reconsider adequately the topics of the energy transition yet.

To fill this gap, we developed an integrated cross-disciplinary seminar to equip students with a number of skills required for advancing their professional or academic future in the field of transforming energy systems. Motivated by guiding recommendations of current IS curricula developments (e.g. Topi et al., 2010) and recent findings in IT-enabled energy policy, we identified some aspects of the complexity of the energy transition and derived specific capabilities and skill requirements. Hence, we developed our teaching approach incorporating three modules with expected learning outcomes for students as well as teachers: (1) A multi-disciplinary guest lecture series, (2) an independently student group-work, and (3) students' presentation and transfer of contributions (cp. Table 2). The program of the guest lecture series was briefly summarized as well as the content of the students' contributions. In addition, we provided the results of our comprehensive course-evaluation in order to identify strengths and weaknesses of our approach. By contrasting the development process of the teaching concept with the evaluation results, a number of issues are worth discussing.

First, the participants of the seminar already represented a number of disciplines (cp. Table 1). However, the invitation of students from other fields such as (socio-)psychology, sociology and law could significantly enrich the amount of knowledge and skills. On the other hand, such an addition might increase coordination efforts and complicate teamwork. Second, the acquisition of industrial experts highly relies on either the previous connectivity of faculty members with industry or a sufficient budget for this purpose. While the practical insights given were perceived as valuable input for students as well as for educators, the course could in principal also focus on speakers from their faculty. Third, the course was developed for German students, who are fairly advanced in applying IS in different life domains and predominantly committed familiar with the notion of sustainable development and renewable energy. Despite that fact, some students asked for a more comprehensive introduction of the general topics about the transforming energy systems. An even more extensive introduction of background knowledge might be necessary in other countries. The seminar was not only cross-disciplinary, but also supported by professors from different faculties and departments. This requires additional organizational changes, breaking up boundaries between departments in order to form cross-departmental teaching groups and curriculum developments. Such changes call for will to collaborate and consensus. Fifth, the seminar does not only aim to raise specific skills with regard to the *Energiewende*, but also offers the development of more generic skills. This includes, for example the improvement of writing and communication skills and the ability to cooperate with students with different backgrounds. Sixth, most of our students were Germans. In a globalized economy, the ability to work across different cultures provides further opportunities but also potential challenges.

The *Energiewende* is going to be a real game-changer and it will transform the energy industry and many sectors of society. A plethora of research disciplines are called upon to contribute by developing insights and solutions and cross-disciplinary cooperation is obviously a good idea. However, interdisciplinary research tends to look not only for specific interdisciplinary solutions but also for specific and new interdisciplinary methodologies. This can lead to the risk of neglecting tools that are already available. Our cross-disciplinary approach was different as we first tried to break the identified problems down according to each discipline's typical set of solution approaches and then carefully

defined the intersections between each discipline. We are convinced that this procedure might be also promising for other IS topics such as E-health, data privacy or IS innovation, adaption and diffusion.
To conclude, our cross-disciplinary seminar is a teaching approach for those who (1) wish to advance their career in the energy-sector or either (2) who are interested in multidisciplinary learning experiences. We hope the ideas presented in the paper may galvanize the need for cross-disciplinary education and the recognition of energy-policy related topics to IS educators around the globe.

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