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Developing an Accreditation System to Recognize Competence in Mathematics Education Students in Germany

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Abstract: As acquiring skills and competences in ICTs are not fixed in university curricula in Germany yet, the ICT-skills gained by the students cannot be accredited formally. Therefore, the idea is to use an Open Digital Badge system to award the students on the one hand and to enable them to show their competences to their future employers on the other hand. The purpose of this paper is to use a South African example of how an accreditation system was applied for gained competence and to develop a similar system that has been implemented and applied on mathematics education students at Siegen University in Germany. Therefore, this paper describes a teacher professional development course where competences of teachers were recognised as they acquired specific skills and competence and this was adapted to be performed during teacher training education at the University of Siegen. The course focuses on the use of ICTs in education. The University of Siegen applies the design science research methodology to develop the accreditation system.

Keywords: Accreditation System, Open Badges, Teacher Professional Development, ICTs in Education

1. Introduction

> *"ICTs are new media, which could have the potential to transform education and student learning in developed countries, but especially also in developing countries.",* [1].

To prepare teacher training students for the use of ICTs in schools in Germany, it is necessary to create a strategy at university, to enable the students to acquire necessary competences during their studies. As acquiring skills and competences in ICTs are not fixed in university curricula in Germany yet, the ICT-skills gained by the students cannot be accredited formally. Therefore, the idea is to use an Open Digital Badge system to award the students on the one hand and to enable them to show their competences to their future employers on the other hand. *"It seems unsurprising that discussions about the value of education - particularly from elite universities - coincide with the creation of alternative forms of accreditation for intended adoption by professionals (both degreed and not) to showcase skills to improve their futures."* [2]. A broader representation of an individual's capabilities is created by the granularity associated with awarding badges for competencies, [3]. *"Digital badging has become popular to accredit individuals for a gained competence or developing skills. Simultaneously, badges are meant to provide an incentive and benefit for an individual. In Germany, the use of a unified digital badging strategy, remains an area to explore."* [4].

As a first pilot, we developed a first system for awarding badges for gained competencies in the use of ICTs in mathematics education, which could then be transformed to other subjects, as well. The purpose of this paper is to describe the development of an accreditation system at the University of Siegen (Germany) based on the experiences and opportunities identified from a project in South Africa. A project coined ICT4RED (Information Communication Technology for Rural Education Development) applied Digital Badging to validate the progress of participating teacher's professional development (TPD) during a three-year period. The experiences from this project were shared with academics at the University of Siegen in Germany and it led to the adaption and development of the validation aspects for a Master's seminar in mathematics education. The ICT4RED TPD was chosen as appropriate development basis for the accreditation system at the University of Siegen, because it is successful and innovative as it presents a practical, free, practice based (three years and 3 iterations) peer reviewed course and methodology of how teachers in rural, resource constrained contexts can be empowered and supported to integrate technology to address 21st century teaching and learning challenges.

In the ICT4RED initiative, the teachers did not have an initial digital identity (having an email address or any other digital mechanism of identity), which made it impossible to issue digital badges to them. Therefore, either paper-based badges were issued in the ICT4RED-project or the teachers first had to learn how to create a digital identity for enabling the receipt and sharing of the digital badges. In contrast to this, students participating in the course in Germany all have a digital identity as an email address is provided by the University of Siegen and all of them are also active on social media platforms and own a mobile phone and a laptop. Consequently, digital badges can be used in this context. The research question which will be addressed in this paper is:

> *How did the experiences on the use of badges in the South African ICT4RED project inform the application and development of open digital badges at the University of Siegen (Germany) for mathematics education students and what guidelines can be derived for future similar programmes?*

In this paper, the methodology that was applied in developing the accreditation system, as well as digital badges and their use within the ICT4RED TPD badging system, will be outlined. The paper will also describe the accreditation system development at the German university and how experiences in South Africa informed this developed system.

2. Objectives

The objectives of this paper are to:

- Provide an overview of what an accreditation system entails.
- Describe how an accreditation system was applied in ICT4RED and the lessons learnt.
- Describe how the experiences in the ICT4RED project informed the development of an accreditation system for a mathematics education seminar at the University of Siegen.
- Derive Guidelines for future similar programmes.

3. Methodology

The University of Siegen applies the design science research methodology to develop the accreditation system. In Design Science an existing situation is changed into a preferred one, by the user [5]. As the philosophy of Design science is pragmatism, it involves the creation of artifacts which is something created by humans usually for a practical purpose [6;7;8]. There are four different types of artifacts: concepts, models, methods and instantiations [6]. The University of Siegen's accreditation system was a method (artifact) in the form of an accreditation system to ensure that competences on the use of ICTs in (mathematics) education can be certified in a uniform and reliable way. Design Science in

Information Systems is underpinned by a socio-technical perspective where the feedback of the user is applied to improve the system [9;10]. Therefore, relevance and novelty was addressed in developing and evaluating the accreditation system at the University of Siegen. The Design Science Research (DSR) process is iterative and the artifact continually evaluated and it evolves based on various opportunities that exist. The evaluation of the artifact involves successive iterations, where it is adapted and evolved through implementations and evaluations. The accreditation system was developed as an artifact by applying the DSRM process of Peffers et al. [11]. The process of Peffers et al. [11] was applied to develop, evaluate and improve the accreditation system as it involves six steps: problem identification, objectives of the solution, design and development, demonstration, evaluation and finally communication of results. In Niehaus et al. [4] an initial prototype of a multi-channel Open Badge system as artefact was developed using the design science method. This prototype is used as basis for the accreditation system described in this paper. The intention is to refine the prototype to be able to enter the next process step of Peffers et al. [11] which would be demonstration to enable the observation of the solution.

4. Accreditation of competence in the ICT4RED TPD course

The ICT4RED initiative explored the use of Android tablets in 26 deep rural schools in the Nciba district of Cofimvaba in the Eastern Cape Province of South Africa. It involved various components of which TPD was regarded as a crucial component for its success. The aim of the ICT4RED TPD was to support and guide the development of relevant teacher knowledge and proficiency to enable rural classroom practice to portray a 21st century technology enhanced teaching and learning engagement [12]. The ICT4RED TPD consisted of 10 modules of courseware presented through a gamification strategy. It is innovative as it presents a practical, free, practice based (3 years and 3 iterations) peer reviewed course and methodology of how teachers in rural, resource constrained contexts can be empowered and supported to integrate technology to address 21st century teaching and learning challenges. The ICT4RED TPD adopted badges to award competence. Each school had a dedicated facilitator that acted as a mentor and guide to assist the teachers to apply the competence gained through earning the badges and the technology. After the TPD training, the teachers had about 3 weeks to apply the strategy for their own content, using technology in their own class. They need to record some evidence as each badge had specific criteria that was outlined, which they had to adhere to in order to earn the badge. Teachers had multiple opportunities to achieve skills and competencies to enable the achievement of a specific badge [13]. A badge facilitator evaluates the evidence provided and either awards the badge or gives meaningful input on possible improvements. Evidence on all the modules has to be presented. Only then can the participating teacher graduate and receive a badge (all the compulsory badges have to be earned). Each module is designed to not exceed 3 hours of training. Originally the thought was to award teachers with digital open badges but as the teachers lacked a digital presence at the start of the TPD and had no email-addresses, this did not materialize. Instead a paper-based sticker badging system was adopted at first [13;14]. Once teachers got an online presence digital badges were also allocated as means of recognition and a reward [4;15;16].

These digital badges were working in the following ways [4;15;16]: A badge issuer, such as a volunteer or online or offline training program, decides what criteria potential earners must be able to meet. They design and offer certifiable badges online for people who meet their badge's qualifications. Users collect relevant badges for a range of "hard" and "soft" skills and accomplishments they have accumulated. These go into a personal digital "backpack", a sort of dashboard that contains badges and allows a user to select privacy and publishing preferences. Users display badges they have accumulated on social networking sites, personal profiles, blogs, and community hubs. Mozilla says it intends to

work with "career website and credentialing portfolio and profile systems" [15] such as LinkedIn, that might also host the users' badges. In the interest of being verifiable on the web, badges will be clickable so viewers can access criteria details about them. They will feature metadata from the issuer that makes the badges a bit more complicated - but more informative - than a company or university logo image that can simply be dragged and dropped. People, who are curious about the badge holders' work and background, including potential employers, can view these identifiers and choose to learn more based on the information that the user, holder and the issuer have chosen to provide. The most important long-term benefits of the badging system in the ICT4RED TPD were its validation requirements. This is supported by Jabbar et al. [17] as well as by Muilenburg and Berge [18] who indicate that validation seems to be the biggest challenge in issuing badges whether the badge is issued digitally or not. According to Muilenburg and Berge [18] "principles of credibility" are essential to establish as it can become a subjective activity and favouritism can play a role. Competency-based learning which a badge will validate, has to reflect and validate the true meaning of the competence or skills gained. Reputation is built on valid, verified and quality judgements not just for badge earners, but also for the badges themselves and the medium of exchange within which they have to have currency [18;19;20].

Based on the experience and implementation of both a paper-based and digital badge system in the ICT4RED initiative, the University of Siegen decided to also apply a similar approach to provide an additional way to validate the competence-learning gained by their students. The students also have a badge issuer and various badges are developed to acknowledge soft and hard skills in mathematics education.

5. The University of Siegen proposed design for an accreditation system

As the first author of this paper is currently employed as deputy professor at the University of Siegen (Germany) and has been funded by the DAAD for a short-term lecturingship at the University of Pretoria (South Africa) in August and September 2017, the experiences gained at those two universities were incorporated into the development of the accreditation system for the mathematics education students at the University of Siegen.

The situation in Germany is as follows: Even though modern education in school is unthinkable without media education according to the Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany (Kultusministerkonferenz, abbreviated: KMK), the use of ICTs in teaching in scholastic standards in Germany formulated by the KMK is hard to find and if, the concrete use is not specified. On 8th December 2016 the KMK decided for a strategy on education in the digital world [21] and indicated that by 2021 every pupil should be able to use a digital learning environment and access the internet at all times, if it makes sense from a pedagogical point of view. In this context, the KMK states, that an appropriate education of the teaching staff is one requirement to reach this aim [21].

"Teachers in Germany often have to bear part of the costs of professional development activities themselves as schools only have a limited budget available for such activities." [22]. Therefore, a TPD is not easy to perform in Germany, because lots of teachers are not able or willing to participate. That is why we try to implement the TPD component into teacher training at the university, with no additional cost results for the students.

To prepare teacher training students for the use of digital media, it is necessary to create a strategy at the university, to enable the students to acquire necessary competences during their studies. Therefore, we developed a first system for awarding badges for gained competencies in the use of ICTs in mathematics education, which could then be transformed to other subjects, as well. The competences, that are supposed to be awarded, were inspired by the competence framework defined in KMK in Germany, 2016, p. 15 [21],

consisting of six competence areas: (1) Search, process and store; (2) Communicate and cooperate; (3) Produce and present; (4) Protect and act safely; (5) Problem solving and action; and (6) Analyze and reflect.

Based on this framework of KMK and the ICT4RED TPD, a course for mathematics education for teacher training students was developed at the University of *Siegen* and the University of Pretoria, the *"TPD4MathED@Uni"*[16], which is documented in Wikiversity: *https://de.wikiversity.org/wiki/OpenSource4School.*

6. Developments

6.1 State of the Art

Based on Niehaus et al. [4], where a strategy to validate a multi-channel Open Badge system at a German University informed by the use of digital badges in South Africa was developed and Platz et al. [16], where a German mathematics education TPD course based on a South African success model was conceptualized, the following accreditation system was derived: The focused course is a course on digital media in education (specialized education on teaching methodology in mathematics didactics, 15 meetings with a duration of 90 minutes) at the University of Siegen in Germany, which built on the *TPD4MathED@Uni* concept developed in Pretoria [16]. As a consequence of the *TPD4MathED@Uni*, two differently aligned course structures were united in this course: (1) By working and documenting in Wikiversity, the students act as Open Educational Resources (OER) creators who develop teaching material themselves. The idea is, that the students learn by teaching. Consequently, the first step of learning by teaching can be performed with the proposed course by letting the students develop their own *TPD4MathED@Uni* modules. This therefore acts as evidence of achieved competence similar to what the ICT4RED teachers had to show. The students also present the content to their "classmates" by sharing the developed content via Wikiversity. The next step would be to let the students (acting as teachers) test their developed modules with other students (acting as learners). On this basis, further courses can be developed fulfilling the whole process of learning by teaching. The co-creation element as well as the communities of practice from ICT4RED TPD is therefore applied here as well. (2) The teaching material, which is developed in such courses can then be directly used by lecturers or teacher trainers. The students or attendees have then the role of consumers of knowledge [16].

Through this, a community of practice is initiated which initiates the creation of an open community. The concept of open community is used as a measure to draft strategy for participative communication and for efficient knowledge management, [4]. Using this concept, already developed components of open source software and open content can be modified and adjusted. The advantage is faster development, improvement and distribution of the content, in our case, the *TPD4MathED@Uni* material. The course material can be provided free of charge. This can hopefully lead to better teaching and education of students. Consequently, competent persons can be educated in schools which have valuable ICT-skills and media competences required by employers in all areas, industrial and non-industrial. The *TPD4MathED@Uni* was supplemented by a module which consisted of the creation of digital museum exhibits for real use in a mathematics exhibition at a local museum with educational background information in the form of a "museum pattern" for teachers visiting the exhibition. The created museums pattern are work in progress and can be further edited and optimized in Wikiversity by everyone:

http://mathematikum.technikmuseum-freudenberg.de/startseite/die-ausstellung/

To generate an incentive for the students in the manner of the gamification strategy of ICT4RED, the best three exhibits were awarded with prizes and by putting them on a handout for the museum.

6.2 Future Developments

Following this module, six modules derived from the KMK competence framework [21] will be performed in a subject-specific way. With each successfully accomplished module the students will be awarded with a badge using the open source system *Badgr* (https://info.badgr.io/), which serves as achievement recognition and tracking system used to issue, organize, and share open badges. This is an advancement on the ICT4RED badges and it is more focussed on university students whereas ICT4RED was only focussed on primary and secondary school teachers who have experience in teaching in a rural context. The course will be evaluated by the students and the course concept will be presented within a committee on digitalisation of education of the University of Siegen. This is different from ICT4RED accreditation system as the teachers did not evaluate their own competence neither did their co-creation improve the ICT4RED accreditation system. Only their co-created lessons were shared amongst themselves which created the communities of practice. This was not put on a Wikiversity platform to share by all teachers in South Africa. The open source software and open content of the University of Siegen's accreditation system is also an added advantage which is an improvement on the ICT4RED accreditation system. Following this, the course and the badge system will be optimized and applied again in two courses held in the summer semester at the University of Siegen in 2018 (three phases of evaluation and improvement).

Thus, the accreditation system of the University of Siegen is an advancement on the ICT4RED accreditation system and it can constantly be improved and supplemented based on the open source content platform and open source badge system. ICT4RED was also only focussed on a rural context whereas the students from the University of Siegen are based in a more affluent setting.

6.3 Derived Guidelines

Patil & Pudlowski (2005) [23] propose a model derived from industry for quality assessment of education structures, which can be modified for the development of an open badge system as accreditation system for the University of Siegen (Germany) for mathematics education students. The model includes three different stages, the input (1), the process (2) and the output (3), where feedback (4) closes the loop and can start with (1) again. This model is applied in the following way on the TPD4Math@Uni:

Stage	**TPD4MathED@Uni**
(1) Input	**Societal Needs.** To prepare teacher training students for the use of ICTs in schools in Germany, it is necessary to create a strategy at the university, to enable the students to acquire necessary competences during their studies. **Knowledge.** ICT in education experts are needed to give high quality teacher training courses. **Technology.** Technology is chosen following the concept: Technology must drive didactics. **Ressources.** The current concept is to use open source and open content and low cost technology. The students should bring their own devices (BYOD). **Enrolement.** The pilot course design is tested at the University of Siegen, but should be enhanced to an online course using Wikiversity as plattform.
(2) Process	**Curriculum.** As acquiring skills and competences in ICTs are not fixed in university curricula in Germany yet, the competence framework defined in KMK in Germany, 2016, p. 15 [21] for schools in Germany is used as orientation to prepare future teachers to teach pupils the skills defined in the competence framework. **Learning & Teaching.** Currently learning and teaching took place in traditional courses at university. By developing an online course, long distance teaching using ICTs can be used. Furthermore, it might be helpful to analyse the media usage behaviour of learners to develop

	learning material adjusted to the individual media use of a learner. **Assessment.** Assessment of the students is done by evaluating an artifact developed by the students in the framework of a project in group work using digital media, e.g. a geocaching or museum exhibits. The process is documented in Wikiversity. **Staffing.** ICT in education experts are needed who are able to give interdisciplinary courses which link ICT knowledge with typical school curriculum contents.
(3) Output	**Results.** Open digital badges are awarded for gained competencies in the use of ICTs in mathematics education. Furthermore, the teaching material, which is developed in such courses and documented in Wikiversity can then be directly used (and edited/optimized) by lecturers or teacher trainers for future courses. **Profile.** The collection of open digital badges should help the students to build a profile which honours them as experts for ICTs in school education. Students also improve and co-create the content of the lessons in a Wikiversity open source webpage and the university accredits the digital badges to be of value to students on social media platforms as evidence of gained competence. **Emloyability.** Through the profile they built with collecting digital badges, the employability should be influenced. Therefore, awareness of the *TPD4MathED@Uni* and its digital badges has to be created in the employers.
(4) Feed-back	Feedback is currently given via university course evaluation but should also be implemented in the long term with former students who took part in the *TPD4MathED@Uni*.

7. Conclusion

In the present paper, an overview of what an accreditation system entails was provided. It was described, how an accreditation system was applied in ICT4RED and the lessons learnt. Following this, it was discussed how the experiences in the ICT4RED project informed the development of an accreditation system for a mathematics education seminar at the University of Siegen. Finally, guidelines for future similar programmes were derived.

The TPD4MathED@Uni, which is based on the ICT4RED principles is not only adjusted to local conditions of the university to support teacher training but also addresses the objectives of the KMK [21] to make every pupil able to use a digital learning environment and access the internet at all times by 2021. Both the accreditation systems of ICT4RED and the University of Siegen support the importance to deliver quality digital educational content, which provides in-depth focus on the quality and availability in multiple languages, especially targeted at educators. This can only be a success, if collaboration, co-creation and sharing takes place amongst teachers and learners in the form of communities of practice between schools, teachers and learners. This paper described the accreditation system behind a generative TPD for mathematics education at university level. It was implemented in Germany and can be used in other English- or German-speaking countries, as it is documented in Wikiversity to enable reproducibility. In order to be able to certify the students who have acquired competences in the use of ICTs in education, an open digital badge system can enable them to demonstrate their skills to future employers (e.g. school directors). These badges can be linked to their social media platforms and as it is accredited and justified by ICT in education experts it can be regarded as valuable.

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