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M.Sc. in Digital Technologies in Heritage Conservation. Sustainable mission for education in heritage

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Abstract. This paper will focus on three topics regarding sustainability and heritage. It reflects on the effects on the long-term maintenance and improvement of heritage buildings through energy-efficient interventions. It also addresses how the mindful use of resources and energy in the refurbishment of historic buildings can contribute towards the preservation of finite resources and the environment for future generations. Furthermore, the current state-of-the-art in long-term preservation, aided by new data collected through digital technologies in heritage conservation is discussed. The paper concludes with the presentation of a new Masters' programme in Digital Technologies in Heritage Conservation and its development, and poses the question can an efficient knowledge transfer to future stakeholders by higher education be achieved in order to further the development in sustainability and gain new impulses in the responsibility for cultural heritage.

Keywords – digital technologies; heritage conservation; masters' program; long-term data preservation; energy-efficient refurbishment;

1. Introduction

This paper contributes to the discussion on sustainability strategies in heritage conservation in order to safeguard our cultural and material heritage for future generations.

Furthermore, it reflects on using training and education to promote the adoption of sustainable approaches in built heritage. Arguments will be presented in relation the Sustainable Development Goals (SDGs) as outlined by the United Nations [1] and the SBE21 Website[1].

The seventeen SDGs are part of '*Transforming the World: Agenda 2030 for sustainable developments'* which were adopted in 2015. Museums [2] and world heritage sites [3] have subsequently begun to adapt the proposed goals for their strategic planning for the coming years.

This paper will concentrate on the following research questions regarding sustainability in relation to Digital Technologies in Heritage Conservation:

I.   Can the mindful use of our resources and improved energy efficiency in the refurbishment of heritage buildings contribute towards the preservation of our heritage and also of finite resources for future generations, in a time of climate change?

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[1] https://sbe21heritage.eurac.edu/ Conference on Sustainable Built Heritage in 2021 at EURAC research (accessed 01.03.2021).

II.   Can ICT (Information and Communication Technologies) be a core factor in reaching sustainable heritage data and heritage information and its long-term preservation?
III. Can an efficient knowledge transfer in higher education, delivered by a new masters' program, encourage responsibility for cultural heritage and sustainability in future stakeholders?

2.   Sustainability and heritage, climate change and energy efficiency: stakeholder and policy development

SDG Goal 7 asks for energy efficiency, and subgoal 7.3 addresses heritage conservation and the built environment. Even if energy consumption of historic buildings is higher than a new build, the sensitive optimization of energy efficiency in heritage buildings is a clear challenge

Wedebrunn [4] points out, that '*cultural heritage is both a local and global concern and that it thus requires a mode of engagement that involves continuity and change, that practical assessment from the standpoint of craftsmanship and history may be augmented by theoretical methods when it comes to deciding on a building's universal and local values.*' Actually, '*cultural heritage is not about restrictions*', but about '*identifying the complex values*'. They ask for a negotiation space [5], both for listed and unlisted buildings, and for both heritage and energy authorities, in order to live up to the particular and specific values of a heritage building. Wedebrunn [4] also explicitly points out the need for education in this area and the need for further discussion.

That the heritage community has moved to a pro-active approach, aimed at becoming part of the sustainability dialogue, is shown by the establishment of the ICOMOS Scientific Committee on Energy Sustainability and Climate change[2] in 2012. It serves as a body of international experts and provides a forum for discussion in applied energy conservation and sustainability principles in the conservation of heritage places. The second big sign of policy development was the launch of the Climate Heritage Network[3] in 2019, where international experts engage in a number of working groups, preparing to give a voice to cultural heritage both at COP21 (Paris Climate Conference 2015) and the European Green Deal.

The Climate Heritage Network points out the inherent multi-generation, circularity and re-use approach. These points are also stressed by the SDGs in the efficient use of natural resources and avoiding waste, refurbishment, re-use of resources, recycling and upcycling, SDG 12.2 and 12.5 [6]. It must be our goal to refurbish our heritage stock with the right conservation-compatible measures, to raise the overall energy demand (i.e. intervention plus operation), and bring costs down to make refurbishment more economical than a new build (see studies quantifying this from Historic Environment Scotland, English Heritage and Norway). At the same time we need to maintain comfort and preserve the charm and character of the heritage building [6] – as well as both material and immaterial heritage values. The scope must be to increase buildings' life cycle duration by careful analysis of use, active protection of resources by heritage conservation and the long-term maintenance of heritage buildings by careful interventions. A good approach requires an open mind, a holistic approach and dialogue between experts of different disciplines to find the optimal solutions [7].

In the European Cultural Heritage Green Paper [8] the authors point out that given the threat climate change poses to both people and cultural heritage worldwide, *Europe's cultural heritage needs the European Green Deal to succeed*, and at the same time the *European Green Deal needs cultural heritage to succeed*, as the latter has a - to date nearly untapped - potential to drive the necessary deep transformative processes to a fair and inclusive transition. Cultural heritage anchors people to places, creates cohesion, and connects people to enable common action – climate action. And cultural heritage is built on the principle of inter-generational equity, circularity and re-use.

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[2] https://iscescc.wordpress.com/documents/ (accessed 01.03.2021)
[3] http://climateheritage.org/launch-2019/ (accessed 01.03.2021)

With the launch of the New European Bauhaus[4], the president of the European Commission has recognised and underlined[5] that the European Renovation Wave is not just an environmental or economic project, but a new cultural project. The Architects Council Europe and Europa Nostra both welcomed the initiative and stressed the importance of cultural heritage in the new movement, being the historic cities an inspiring framework for the co-creation and offering models and practices that are sustainable and resilient by nature[6]. This dialogue will require contributions from professionals in all sectors. In particular, it will need conservation experts who are able to communicate with technology specialists and vice versa.

The new masters' program in Digital Technologies in Heritage Conservation, described in section 4, is educating this new expert stakeholder. Of the 90 ECTS allocated to the modules, 20 ECTS can be gained in building physics for heritage buildings (i.e. ca 22%) and can be complemented with 10 ECTS in structural engineering and simulation as well as 10 ECTS in the monitoring and digital system analysis of historic buildings (also ca. 22%).

Figure 1. Students practice with the thermal infrared camera on historic buildings of Bamberg old town during their on-site practical (Photo: M.Hess 2021).

Figure 2. Students and tutor A. Luib evaluate the recordings of historic buildings performed with the thermal infrared-camera. (Photo: I.Garbe 2021)

3. ICTs as a core element to reach the SDGs, sustainability of heritage data

In developing the computer science part of the curriculum of the M.Sc. Digital Technologies in Heritage Conservation, we were led by the following considerations:

Information and communication technologies (ICT) constitute a core element of strategies for reaching the SDGs. Toja and Toja (2016) [9] refer to SDG 4 (quality education) and SDG 11 (sustainable cities and communities) as areas where digital innovation has significant potential to contribute to sustainable solutions. On the other hand, digital technologies may also appear as a risk factor in the context of some goals, notably climate action (SDG 13). Well aware of this issue, research in the field of green and sustainable computing has concentrated on energy consumption and the carbon imprint of data centres and networks (e.g. Zakarya et al. 2017 [10]). While it is difficult to overstate the importance of green IT technologies, it is unlikely that digital heritage scientists and practitioners are going to make large contributions to innovations in green ICT services. There is, however, an important aspect of

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digital technologies where contribution from digital heritage science is critical, namely the design of sustainable information life-cycles that are tailored to the needs of heritage preservation.

The computer science part of the curriculum reflects this understanding. We are convinced that digital heritage scientists should be trained to become more than just proficient users of digital methods. They should acquire skills that enable them to address all phases of the information life-cycle from data capture and pre-processing to information modelling, curation, distribution, and the long-term preservation of information. Heritage conservation has specific requirements for paradata annotation of data processing [11] or information management stemming from digital humanities practices [12]. Approximatively 22 % of the program's total workload (20 from 90 ECTS credit points) are devoted to these contents. They are taught by faculty members from computer science whose research activities lie in the areas of media and cultural informatics.

Overall, the structure of the computer science curriculum has proven its value. Hess et al. (2018) [13] describe the courses' learning objectives and the details of their contents. We limit ourselves to a brief overview of the structure and concentrate on the main lesson learned from running the program. All students follow a general introduction to computing in their first semester and opt for elective courses in their second and third semesters. It is in the introductory course that the students become acquainted with issues such as the data life cycle, software costs and the social impact of ITC, which Gordon (2010) recommends for education in sustainable development in computer science [14]. Students acquire a deeper understanding in the elective courses. Currently, the curriculum offers the following options:

- object-oriented programming (2nd semester)
- web technologies (2nd semester)
- digital libraries and social computing (3rd semester)
- media informatics (3rd semester)
- computer graphics and animation (3rd semester)

The main lesson learned from running the program is a better insight into the heterogeneity of the skill sets our students arrive with. Although the curriculum was devised for students with different learning biographies and interests, we underestimated the scale of the differences. Students with a background in the history of arts, for instance, are unlikely to have received any training in computing methods at all. This contrasts with graduates from civil engineering, who may have devoted as much as a whole year (60 ECTS) to subjects firmly grounded in digital methods. We found that the students who have had little contact with digital methods, experience more difficulty in in transferring generic solutions to application scenarios from the heritage science. As a consequence, we adapted the courses by designing additional training material specifically aimed at those students. This concept has been implemented in both the introductory and elective courses.

4. Sustainability and higher education in the new programme M.Sc. Digital Technologies in Heritage Conservation

In light of the need for qualified stakeholders at the intersection of heritage and technology, a new Master of Science in Digital Technologies in Heritage Conservation was established in 2017, offered jointly by the University of Bamberg and the University of Applied Sciences and Arts in Coburg[7]. The course is described in more detail in [13] and [15]. The curriculum has been drafted to equip students with the skills required to serve the interconnection of heritage and sustainability.

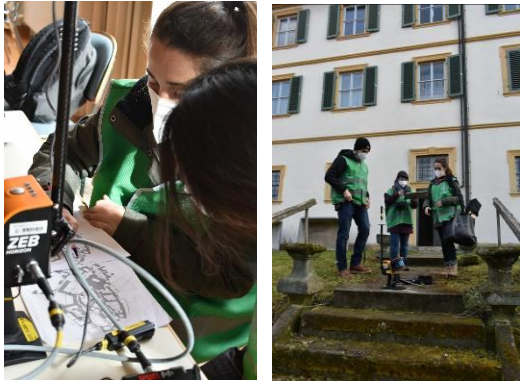[7] https://www.uni-bamberg.de/en/ma-dthc (accessed 01.03.2021)

Figure 3. The tutor C. Ferreyra and students plan and conduct surveying with 3D laser scanning based on SLAM technology around Bamberg Cathedral (Photos: I. Garbe 2021).

Figure 4. A 3D terrestrial laser scan and spherical targets are prepared by students at one of the main portals of Bamberg Cathedral. (Photo: M. Hess 2021)

4.1   Social commitment and sustainability

The focus of the program is the assessment of the as-built, its material properties and the associated ageing behaviour of historical buildings, and similar aspects applicable to other heritage objects. In addition, students will get learn the significance of cultural assets as knowledge stores, historical sources and components of regional identities. Through their expertise, students will be able to explain the significance of cultural heritage and actively contribute to a fruitful dialogue in society. Students will be able to make sound decisions in the field of digital technologies in heritage conservation in a responsible and democratic public spirit and thus contribute to the preservation and protection of cultural assets.

4.2   Practical qualification towards professional expertise

The program equips students with the skills necessary for to evaluate and develop solutions for technical and structural processes in building and damage recording, building condition analysis, planning of repair and maintenance measures, as well as the development of intelligent monitoring concepts.

Students will be able to practically apply a variety of digital technologies and heritage conservation methods. These include:

- Digital imaging and modelling for heritage conservation (described in more detail in [13])
    - Digital object recording (optical 3D imaging) and data processing, digital modelling of 3D spatial data and data analysis (see Figures 1-4 from sensor-practicals on-site)
    - Spatial modelling and H-BIM (Historic Building Information Modelling) for heritage buildings
- Digital Archiving for Digital Humanities
- Conservation sciences for cultural heritage and the protection of cultural assets
- Structural engineering, model simulation and static analysis for structural engineering
- Building physics assessment and refurbishment
    - Hygrothermal assessment & damage prevention, physical principles and quantification (see Figure 5)
    - Energy and carbon emissions, also considering the life cycle of buildings
- Monitoring and digital system analysis
- Informatics in cultural studies (described in section 3).

Figure 5. Measuring the water uptake of a façade in-situ during the application week in the hygrothermal testing lab at EURAC Research in Bozen/Italy. (Photo: A. Troi 2019)

4.3 Scientific qualification

On completion of their studies, students will be able to engage with a range of topics (for example, surveying and analysis procedures, imaging processing and computer science) and to analyse and reflect on these topics critically. In lectures, seminars and practical application weeks, students will have actively applied a variety of digital recording, monitoring, modelling, analysis, archiving and ICT-based knowledge dissemination procedures in the interdisciplinary field of heritage conservation. Students will be able to transfer the knowledge acquired to a range of application areas from engineering-construction practice.

4.4 Employability

Engineering and architectural offices are urgently looking for students with qualifications at the cross-roads of heritage and technology. The M.Sc. qualification enables students to take on jobs in the fields of engineering, architecture, heritage conservation, museums and archives. Due to the international orientation and teaching content of the programme, students will be able to participate in expert discussions, and work in international projects, institutions and companies.

Students will be qualified to compile workflows in a task-oriented and solution-oriented manner and to understand the full range of their application, sustainability and networking possibilities (e.g., integration of a workflow H-BIM into the management of heritage buildings).

4.5 New stakeholders with sustainable knowledge

The programme's emphasis on practical exercises and the transferability of methods and encourages the long-term retention of knowledge, something which has already proven useful in other courses [16].

Students will also have the flexibility to adopt and adapt to new methods and technologies in their future employment. Proficiency in digital procedures will allow students to critically evaluate new scientific methods, ICT-perspectives and novel digital heritage technologies, and develop new approaches and solutions to problems in heritage. As a result, students will contribute to the integration of technological processes in heritage conservation and cultural asset protection.

4.6 Future developments of the masters' program

The M.Sc. programme for Digital Technologies in Heritage Conservation has been running for three years, and lessons have been learned from the feedback of both students and tutors [17]. More students are enrolling every year, and optimisation is required to allow for a greater choice in studies.

All students should have the option to catch up with knowledge they have not studied in their undergraduate programs (for example architectural history for building engineers, and basic engineering principles for art historians).

It is also our goal to offer students more targeted opportunities in advanced courses so that they can respond as specifically as possible to the needs of their preferred employment area.

Therefore, the concept of the course is currently under revision and more options are being opened up in order to offer our heterogeneous group of students more possibilities to sharpen their personal profile.

5.   Conclusions

Current discussions on sustainability are seen as an ethical discussion and a fundamental topic that has an impact on everybody´s life. Research institutes approach the topic from the perspective of transformative forms of sustainability, goals and future viability [18].

   A clear trend can be seen in an increasing number of policy groups and networks, who have the aim to develop - and implement - strategies for sustainability and energy efficiency in heritage, in order to extend **buildings' life cycle** in, for example, a time of climate change. Digital innovation and ICT has significant potential to support sustainable solutions in heritage conservation and heritage sciences, but urgently requires the **design of a sustainable information life cycle**.

   Both aspects need to be integrated by a set of informed stakeholders possessing a new educational profile that bridges the gaps between heritage and technology. The new Masters' program of the M.Sc. in Digital Technologies in Heritage Conservation addresses this educational need. The transformative effect of educating the next generation with both sustainability and heritage conservation in mind, will ensure the viability of heritage preservation in the future.

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