Abstract

In today’s era, global issues such as climate change and overexploitation of natural resources have made impacts in our daily lives. To address these problems, Education for Sustainable Development (ESD) is an essential component to consider. One important element is to address economic, environmental and social aspects that are interlinked and mutually dependent. Thus, ESD aims to promote not only the fundamental environmental knowledge, but to empower people to deal with such dilemmas. Therefore, individuals need competences for sustainability. These can be learnt but hardly be taught. Hence, learning environments for ESD should enable individuals to develop these competences and think interdisciplinary.

E-learning addresses these challenges and offers opportunities to design effective learning environments for ESD. For instance, with the help of information and communication technologies (ICTs), e-learning can represent the mutual influence of the different dimensions of sustainability. Simulations can offer learner-centered learning scenarios, in which individuals can apply their skills in an authentic situation. This is the basis to gain competences for sustainability. Thus, we expect e-learning modules to increase the quality of the learning process.

However, prior research on e-learning modules supporting ESD is limited. A systematic approach of categorising e-learning modules into an instruction model is missing. Thus, the main goal of this paper is to present the state of the art of e-learning usage in ESD. Therefore, we conducted a literature review by analysing eleven databases, selected 35 articles and classified them according to the Analysis Design Development Implementation Evaluation (ADDIE) instruction model. Afterwards, we used this model to categorize the research methods and e-learning tools used by the selected articles accordingly. Based on this, we elaborated research gaps and future research directions.

The results show that most of the articles primarily focus on the evaluation phase of the ADDIE model. Consequently, they do not provide a complete picture of the ADDIE process of e-learning modules to support ESD. Moreover, current research does not show how to create competences as an outcome for ESD. Further research should try to give a complete picture of the e-learning modules for ESD from the analysis phase to the evaluation phase. In addition, further research should also focus on how to design learning environments for the development of competences and how to measure them.

Keywords: E-learning, Education for sustainable development, Literature review, Competence, ADDIE model.

1 INTRODUCTION

In light of the overexploitation of natural resources, climate change, inadequate working conditions in developing and emerging countries and the financial crisis, Education for Sustainable Development (ESD) is needed. ESD can help to overcome these threats, as it can empower individuals to deal with these issues [1]. Sustainability involves the economic, environmental and social aspects that are interlinked and mutually dependent [2]. In order to understand the complex construct of sustainability, competences are necessary [3]–[5]. In this context, it is challenging to include the economic, environmental and social aspects in learning modules, because competences are described as learnable, but not teachable [6]. This requires a change in the teaching processes from traditional teacher- to learner-centered pedagogies. Information and communication technologies (ICTs) and e-learning can bring a number of potential benefits [7]. For instance, they can help representing networking and mutual influence of the different dimensions of sustainability [8]. By using simulations and focusing on practical life issues in a learner-centered, virtual learning environment, individuals can combine actual practice (“learning by doing”) with reflection on what they learned from this practice (“learning by reflection”). With these kind of e-learning modules, individuals can develop competences...
for sustainability. These competences are difficult or impossible to gain from conventional learning constructs [7].

In order to design such e-learning modules supporting ESD, research needs to give guidelines on how to develop artifacts such as e-learning tools for individuals to learn about sustainability topics. Hence, it is possible to overcome the barriers of conventional learning environments [1] such as their exclusive focus on factual knowledge, which cannot be used for action in specific situations [7]. Accordingly, the purpose of this paper is to present the state of the art of e-learning usage in the ESD. Furthermore, the aim is to set up a research agenda to provide guidance for future research [9]. In line with this approach, we address the following research questions:

RQ1: What is the state of the art of e-learning modules supporting ESD?

RQ2: What are the main topics for future research on e-learning modules supporting ESD?

To answer these research questions, the remainder of this article is organized as follows: In the next section, we describe relevant terms such as ESD and key competences for sustainability as well as e-learning modules. Thereafter, we present the research methodology and study design. We illustrate the results of the systematic literature review (RQ1) by using the Analysis Design Development Implementation Evaluation (ADDIE) model. Afterwards, we discuss the findings and conduct future research directions (RQ2). Finally, we summarize our findings in the conclusion.

2 BACKGROUND

A review paper should elaborate definitions of key variables of the review [10]. In this study, key variables are Education for Sustainable Development, Key Competences for Sustainability, e-learning modules and the ADDIE model, which are defined in the following.

2.1 Education for Sustainable Development and Key Competences for Sustainability

ESD emphasizes a “transformative approach to education, encouraging the adoption of sustainability principles, ethics and values […] and the learner’s critical reflection on them” [7]. Consequently, educational goals should shift from knowledge to competences acquisition and adoption [11]. The concept of competence describes “the ability to successfully meet complex demands in a particular context through the mobilization of psychological prerequisites” [12]. Competences are needed in order to solve complex tasks in a sustainable related situation. The five key competences for sustainability are (1) system thinking competence, (2) anticipatory competence, (3) normative competence, (4) strategic competence and (5) interpersonal competence [13]. One of the most important challenges is to translate key competences for sustainability into practice [14]. In order to gain competences, experience-oriented, problem-based learning [7] and learning in real-world situations, is necessary [15].

2.2 E-Learning Modules

E-learning is a didactic approach that “can encompass all electronically supported learning and teaching” [16]. E-learning can capture a range of available tools, like web-based courses, virtual learning communities, video streaming and computer-based training [17]. E-learning modules are learning objects which are organized into modular learning contents. This includes a closed issue with a specific learning objective, to make the contents flexible [18] and independent of other learning modules. Often these e-learning modules are integrated into learning management systems.

With the help of videos, pictures and other items, e-learning modules can create virtual learning environments [7]. This supports learning to take place in an authentic context [19], which boosts the confidence of individuals in their ability to solve complex tasks [16]. Since it is based on ICT, e-learning modules allow flexible, learner-centered education [15] and independence of time and location [20], [21]. Collaboration tools, like forums, also support collaboration between learners and lecturers as well as between learners. This interaction is seen as an essential part of a successful learning experience [15]. By providing interaction software, an e-learning environment offers additional opportunities for individuals to reflect their own learning more effectively [7] and improve their critical thinking [22]. It follows that, e-learning modules are expected to be a more efficient way of learning and teaching as well as to increase the quality of the learning process [7].
2.3 ADDIE model

The ADDIE instruction model is the acronym for the Analysis, Design, Development, Implementation and evaluation phases of the instructional design process [23]. This model is traditionally used in all forms of instructional design. It includes methods for systematic planning, development and evaluation of learning materials and environments and is therefore a useful approach to promote successful learning by individuals [24]. Fig. 1 summarizes these five phases and their characteristic tasks.

![Fig. 1. ADDIE model [23], [24].](image-url)

3 RESEARCH METHODOLOGY AND STUDY DESIGN

In order to answer the research questions, we conducted a literature review [10]. We reveal how we identified relevant articles for the following analysis, by capturing the whole spectrum of literature. Afterwards, we point out, how we identify and classify relevant research papers into the ADDIE instructional development model. In the following, we present the chosen research method.

As stated in the past chapters, the aim of this article is to give an ascertainment of the usage of e-learning modules in the field of ESD. Hence, the intention is to present an overview of relevant literature. As the authors were fluent in English and German, and the predominant academic language is English, we searched English and German keywords in major scientific databases [25]. The cutoff date was on 31st of December 2016. We reviewed the titles and abstracts of 6.143 results. 6.029 articles were excluded, as they were not related to sustainability, had a different research focus or were duplicates. 114 contributions appeared to be relevant. In the next step, we analyzed the full text of the identified articles and excluded 92 articles due to too little contribution to the considered sustainability topic. After crosschecking the references and analyzing if there are newer articles, that cite the paper in our review, we identified 13 additional contributions. We stopped searching when we only discovered articles with familiar methodologies, arguments and findings [26]. Following this advice, we identified overall 35 relevant articles, which were analyzed for further study. Fig. 2 provides an overview of the applied methodology.

![Fig. 2. Research Framework.](image-url)
To provide a better overview of the emerging areas of research in e-learning modules regarding the field of ESD, we conducted a content analysis. We used the presented five phases of the ADDIE model (see Table 1) as a classification scheme and manually classified the 35 selected articles according to the ADDIE model. If an article covers more than one phase of the ADDIE model, we classified the articles accordingly. We performed the classification of the articles independently. In the next step, we compared these two classifications and resolved discrepancies during a joint verification. In addition to that, we determined for each article the research method and e-learning tool. If authors of an article used research methods or e-learning tools that we did not considered, we successively extended categories.

4 RESULTS

With respect to the descriptive findings, we begin with the presentation of the frequencies of contributions by publication year. Thereafter, we consecutively present the findings for the task characteristics of each phase of the ADDIE model, their research method and the e-learning tool that was used in the contribution. Analyzing these dimensions helps us to analyze the state of the art of e-learning modules for ESD more precisely.

Fig. 3 presents the growth in the number of articles over time. It reveals that the first relevant article was published in 2005, the beginning of the UN Decade on ESD (2005-2014). It took four years from the emergence of first articles till the observed domains gained more attention in the year 2009. The number of publications increased over time, although it is not steady.

Regarding the ADDIE model, we could identify two contributions, which focus on the analysis phase of the e-learning modules during the literature search. These studies focus on students as they present e-learning modules for ESD in the context of higher education. Moreover, they suggest that, in order to gain competences for sustainability, it is helpful to provide learning environments that improve contact and increase learners interaction [27]. When it comes to the content of the e-learning modules for ESD, topics such as energy, ethics, sustainable economy or climate change are the most common. However, there are no studies analyzing the technical requirements for the usage of e-learning modules.

We identified three contributions that focus on the design phase of the ADDIE model, especially on the instructional objectives and strategies. The educational goals prominently features competences for sustainability, such as knowledge, skills and attitudes that are appropriate to deal with sustainable dilemmas. These educational goals focus on a systematic change of thinking rather than knowledge acquisition. Hence, the design of such e-learning environments for sustainability competence development is characterized by three principles: self-directed learning, collaborative learning and problem-based learning [7]. This means learners have to take the initiative to learn about sustainability in a realistic context, if they want to successful develop competences for sustainability. In order to measure the development of competences, the assessment was the most used instructional strategy. Assessment and learning were seen as an associated and not separated process. The assessment is concerned with features such as knowledge of sustainable development and communication as well as collaboration skills [11]. Furthermore, these articles present the curricular structure and characteristics of their modules [1]. Thereby, we found that the start modules of the e-learning
systems are essentially an introduction module that provides basic information about sustainable development [11]. In the remaining modules, the focus is more on transversal issues, such as environmental ethics [15]. The modules at the end of the learning management system focus on a final discussion of central issues of the sustainability discourse and individual feedback on the modules [28].

The development phase of e-learning modules for ESD is also only partially addressed so far. In this phase, we do not witness one article addressing content development or the production of the course material. The studies, concerning the development phase, select the learning management system Moodle [7]. It offers a number of collaboration tools such as different discussion forums, tools for file exchange and a wiki [28]. According to the authors, this learning management system is useful to provide an efficient learning environment for ESD.

Two articles deal with the implementation phase. In this phase, articles primarily discuss the integration of the provided technology into the infrastructure. This integration covers the organizational integration, such as organizational development, personnel development and didactics. Furthermore, these two articles emphasize the technological integration such as flexible model access, feedback mechanisms and different roles as well as groups of users [29]. Moreover, in the implementation phase, it is advisable to include the sustainability modules in existing courses [30]. We find no endeavors in the literature for the adoption of learning management systems to the didactic concept. There are also no articles discussing about financing and technical development of these e-learning modules.

A vast majority of contributions covers the evaluation phase of e-learning modules in the field of ESD. They focus on the motivation of learners to use the e-learning tools, to learn about sustainability. Moreover, they evaluate the level of satisfaction among learners. The findings show that by creating new ways of exploring sustainable issues in an interactive way, e-learning modules can increase the motivation of individuals to learn about sustainability [15], [20], [31], [32]. One reason is that e-learning modules are based on the flexibility of access without spatial or temporal constraints. In addition, e-learning modules allow individuals to proceed with their studies in their own speed [15]. Learners are also attracted by the anticipated interdisciplinary approach [11]. By teaching more complex interrelations among environmental, economic and social dimensions, e-learning modules can promote interdisciplinary thinking, which is the basis of sustainable management [15]. When it comes to assessing individual learning outcomes, central elements of the ESD are effective learning outcome in knowledge, values and behavior [15]. Most of the studies state that within their e-learning modules most learner reach an effective learning outcome. In addition, e-learning modules have the potential to benefit the individuals’ learning experience for ESD in terms of the acquisition of skills, independent thinking, enhanced communication and the exchange of ideas [33]. Nevertheless, individuals need to make themselves familiar with the idea of self-directed learning in virtual learning environments [7].

In order to gain a better understanding of the sort of research that is being published, we analyze the research method. Case studies represent by far the most often-used research method, followed by surveys, and literature reviews. In fact, case studies are conducted in every phase of the ADDIE model, whereas literature reviews are only conducted for the analysis phase and surveys are only used in the evaluation phase. For example, authors evaluated the effectiveness of sustainability e-learning modules through learner questionnaires. As a result, in the field of e-learning modules for ESD the existent diversity of research methods is limited. Some case studies do not even meet the minimum standards of case study research, like referring to a research question [34]. For instance, the case studies often just describe the evaluation of an e-learning module. This evaluation prominently based on the acceptance of e-learning modules. In addition, the evaluation of the degree to which individuals developed competences for sustainability in e-learning modules is often based on learner’s subjective reflection.

Lastly, we identify that the web-based course subdomain has the top number of articles. Web-based courses adopted for ESD can overcome the limitations of the typical teacher-centered educational design model. They can also provide learning environments to increase learner interaction between learners and lecturers as well as between learners through collaboration tools [27]. Virtual learning communities account for fewer articles. They can also support the interaction between learners and lecturers as well as between learners and are therefore useful for ESD. Computer-based training and video streaming account for five and two articles, respectively. In these identified articles, mostly video lectures were streamed, as they can stimulate opinion and provoke debate [16]. However, most of the articles describe the evaluation phase of these e-learning tools.
We present the results of our classification in Table 1 as follows: The phases of the ADDIE model from Fig. 1 are presented in the consecutive order on top of the table. For each phase the number of articles, research methods and e-learning tools are depicted in the rows. The rows represent the research domains. The numeric values state the number of articles focusing on this issue. In the last column, we state how many articles we classify into the respected domain without multiple mentioning.

**Table 1. Research method and e-learning tools in the ADDIE model**
(Note: multiple allocations possible within one category; n=35).

<table>
<thead>
<tr>
<th>No. of articles</th>
<th>Analysis</th>
<th>Design</th>
<th>Development</th>
<th>Implementation</th>
<th>Evaluation</th>
<th>Number of Articles</th>
</tr>
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<tbody>
<tr>
<td>Case study</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>29</td>
<td>35</td>
</tr>
<tr>
<td>Survey</td>
<td></td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>22</td>
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<tr>
<td>Literature review</td>
<td>2</td>
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<tr>
<td>Web-based courses</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>18</td>
<td>35</td>
</tr>
<tr>
<td>Virtual learning communities</td>
<td>2</td>
<td></td>
<td>1</td>
<td>1</td>
<td>11</td>
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<tr>
<td>Computer-based training</td>
<td>1</td>
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<td>1</td>
<td></td>
<td>3</td>
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<tr>
<td>Video streaming</td>
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5 DISCUSSION AND FUTURE RESEARCH DIRECTIONS

In the following, we discuss the results of the conducted literature review on e-learning modules supporting ESD. Further, we work out what phase characteristics are suitable for further research opportunities. We justify our suggestions by referring to our results from the literature review focused on studies that support the ESD via e-learning.

Our findings show that most of the selected articles evaluate their e-learning modules. However, these contributions focus on the acceptance of the modules, rather than the competence development. Moreover, only four studies discuss two phases of the ADDIE model. Hence, the current contributions do not present a complete picture of the e-learning modules for ESD. Since current literature does not provide sufficient information, examination of technical requirements and learning environments for the e-learning tools supporting ESD is needed. Especially, it should be examined how to design effective learner-centered learning environments. These can illustrate authentic situations, help to overcome barriers from traditional learning constructs and support individuals to develop competences for sustainability [1]. For this purpose, further research can define key requirements and design principles for an e-learning system for ESD. A central challenge is the analysis, design and production of content, materials and teaching stimuli (texts, images, diagrams, videos) as well as the conception of the system itself. Also, articles emphasize the need for a more complete and systematic approach to holistic integration of ESD in all courses and curricula [35]. Therefore, the didactic concept of the e-learning modules for ESD needs further research. Thus, one of the central challenges is to intensify the research on the interaction in learning environments between content and individuals and among individuals. Thus, further research should focus on the e-learning course design and content to help individuals acquire competences for sustainability. So far, no studies exist that provide information about the selection process of the learning management system, its adaption to the didactic concept and its technical development to meet the needs of ESD. For this reason, future research should try a transcend research approach in order to give a complete picture of the e-learning modules for ESD from the analysis phase to its evaluation.

As described before, the most important outcomes of ESD are competences for sustainability rather than knowledge promotion. Most of the articles debate about different competence concepts as an outcome of the e-learning modules for ESD. Because of the underdeveloped theory, the practical usability is unclear [11]. Hence, there is still limited research on which competences individuals develop in the e-learning modules. Therefore, most contributions focus on some parts of competence.
for sustainability or only on the knowledge promotion. The challenge is how to translate the competences of sustainability into practice [15].

Another future research direction concerns the assessment of competences. There is still little evidence that proper assessment tools for competences in ESD exist. The existing assessment tools only use closed question formats like multiple-choice questions. Although these questions are suitable for the purpose of verifying the growth of knowledge, the development of competences, which is essential for ESD, cannot be tested by these questions [4], [36]. It follows that, research tools, other than questionnaire surveys for the assessment of competences development need to be developed [15]. Hence, assessment practices should include authentic assessment and high-quality feedback, which is critical to the development of learning outcomes. It provides an instrumental resource to help learners to acquire realistic experience [37]. In addition, assessment should be aligned with factors, such as content, educational goals, instructional design and the learning environment [11].

We find that case studies dominate the research in this field that only partly meet high quality research standards. As a result, there is a need for more explanatory studies. This kind of research could contribute evidences on how to design and implement e-learning modules for ESD. Future research should use all kind of studies, make the research question explicit and the process of data collection more detailed [34].

When it comes to e-learning tools, the majority of the tools just provide a flexible access to information, like online lectures or support the communication and collaboration (e.g. wikis) among individuals. Although many authors used web-based tools that have the ability to create an effective learning environment, most of the learning contexts do not reflect authentic contexts, which are essential to deploy skills and knowledge and for the development of competences [1]. Therefore, there is a need for future research to provide guidance on how to design and implement tools that provide a powerful learning environment for ESD.

6 CONCLUSION

The aim of this study was to identify the state of the art of e-learning modules for ESD by conducting a rigorous literature review. This resulted in a list of 35 articles (RQ1). The presented study shows that most of the e-learning modules for ESD are used in the context of higher education. These modules cover topics such as energy, ethics, sustainable economy or climate change. The educational goals are related to the competence development. In order to develop these competences self-directed learning, collaborative learning and problem-based learning are necessary. We could identify that most of the e-learning modules use web-based courses and Moodle as the learning management system. Current research shows that e-learning modules can increase the motivation of individuals to learn about sustainability by creating new ways of exploring sustainable issues. However, most of the articles regarding e-learning modules for ESD primarily focus on the evaluation phase of the ADDIE model. Consequently, they do not give a complete overview of the analysis, design, development, implementation and evaluation of e-learning modules supporting ESD. Furthermore, current e-learning modules for ESD do not reflect authentic learner-centered learning environments that are essential for the development of competences. Also, current literature does not provide information on how to design the content or the learning environments itself. Furthermore, there is limited research if these e-learning modules create competences as an outcome for ESD. Our findings show that proper assessment tools for measuring competences are also missing.

Therefore, it raises further research opportunities (RQ2). Further research should try to give a complete picture of the e-learning modules for ESD from the analysis phase to the evaluation phase. In addition, further research should focus on how to design content about sustainability and authentic learner-centered learning environments, because this is important for the development of competences. To do so, key requirements and design principles must be defined. Lastly, research needs to focus on how to measure these competences and therefore design proper assessment tools.

Despite the aim to identify the whole corpus of relevant literature, we acknowledge that it is possible that we did not include all existing contributions to e-learning modules for ESD in our study. The review is limited by the databases and keywords used. In this study, we used articles in German and English, because the authors are capable of using German and English. Furthermore, the relevance of articles and their inclusion into our study bases on our subjective judgment. In spite of that, the amount of identified publications should be a solid basis for research. Given that and the care, caution
and formal procedures used by the researchers, the limitations do not diminish the findings of the study significantly.

REFERENCES


