ESD training for university teachers: which is more effective, the face-to-face or digital format? Results of an intervention study

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Abstract
Purpose – This paper aims to analyze the extent to which education for sustainable development (ESD) training enhances university teachers’ professional competence and whether it has the same effect in the digital as in the face-to-face format.

Design/methodology/approach – A training concept was developed based on the professional action competence model. Between 2018 and 2021, 19 training sessions were conducted with 183 university teachers: ten in face-to-face sessions and nine in the digital format. Questionnaires were administered before and after the training to determine its impact.

Findings – Overall, the training proved to be effective. There was a significant increase in professional knowledge and self-efficacy after the training, but there was no change in motivation. The face-to-face and digital formats proved to be equally effective.

Research limitations/implications – The long-term effect of the training could not be determined.

Practical implications – There should be regular ESD training and coaching for university teachers.

Originality/value – There has been little research on the effectiveness of ESD teacher training, and no comparison between the face-to-face and digital approaches exists. It has been possible to train a relatively large number of university teachers from a wide range of subject areas, about two-thirds of whom have had no previous ESD experience.

Keywords Education for sustainable development (ESD), Professional competence, University teacher, Academic staff training, Digital training, Higher education for sustainable development (HESD)

Paper type Research paper

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1. Introduction
Global challenges necessitate changes in all areas of education. Thus, Sustainable Development Goal (SDG) 4.7 of the 2030 Agenda sets the goal of structurally anchoring education for sustainable development (ESD) by 2030. The World Program for Action “ESD for 2030” calls for the training of multipliers in all sectors of education as one of five areas of action: “Educators in all educational settings can help learners understand the complex choices that sustainable development requires and motivate them to transform themselves and society” (UNESCO (United Nations Educational, Scientific and Cultural Organization), 2020: 36). In their introductory article to the special issue “Professional development in HESD,” Mula et al. (2017) emphasize the great importance of the education of university teachers. This is because they teach students who will go on to become decision-makers in all areas of society. Mula et al. (2017) and Scherak and Rieckmann (2020) agree that there are few international ESD professional development programs for university teachers. Recent studies in Germany show that higher education for sustainable development (HESD) is neither sufficiently implemented in degree programs nor are university lecturers adequately prepared (Holst and von Seggern, 2020). There are only a few didactic university courses on ESD, and they are not (yet) implemented in existing structures (Holst and Singer-Brodowski, 2022). Internationally, impact studies on these offers are even rarer, as Scherak and Rieckmann (2020) point out. Furthermore, the few evaluations of university teacher programs have only been carried out with a small number of already ESD-savvy participants. In the following, a project (duration: 2018–2021) is presented, in which a specially designed ESD training program is conducted with 183 university teachers in 19 courses, and its impact is analyzed through a pre–post evaluation. Owing to the COVID-19-pandemic, the training had to be converted to a digital format halfway through the project. This provided an opportunity to further compare the effectiveness of the traditional face-to-face and digital formats.

2. Theoretical foundations

2.1 Competence models for education for sustainable development multipliers
Training academic staff in ESD requires an examination of the intended competencies to promote. In this regard, both the existing (H)ESD-related and professional competence models for teachers are crucial. Teachers play a dual role in these training programs because to guide and empower learners, teachers themselves need to be empowered and equipped with the knowledge, skills, values and behaviors required for this transition (UNESCO (United Nations Educational, Scientific and Cultural Organization), 2020).

After reviewing the relevant competence models (e.g. Brundiers et al., 2021; Wiek et al., 2011), it is decided to use the de Haan (2008) model of “Gestaltungskompetenz,” which is best known in Germany, with its 12 sub-competencies based on the OECD key competencies. Accordingly, the training was designed to be competence-oriented. However, more attention has been paid to systemic competence, as emphasized by Wiek et al. (2011), than to the de Haan (2008) model. The most recent international model, “A Rounder Sense of Purpose” (RSP) (Vare et al., 2019), was not yet available at the start (2018) of the project described herein. However, as it is based on previous models, it does not offer any fundamentally new competencies.

2.2 Professional teaching competence
The existing competence models for ESD multipliers neglect the cognitive domain; however, empirical studies have shown that ESD experts consider conceptual knowledge to be the most important competence that multipliers should have (Hellberg-Rode et al., 2014). The pedagogical literature generally points to the importance of content knowledge (CK) and pedagogical CK (PCK) (e.g. Kunter et al., 2011) with regard to the quality of teaching. Melles
(2019) also highlights the need for university teachers to engage with the different perspectives of SD and ESD as well as the didactic question of how to translate SD into ESD. Similarly, Mula et al. (2017) emphasize that the initiatives aim at educational change in ESD and not simply at embedding content on sustainability in learning opportunities. Bellina et al. (2020) develop the theory-based characteristics of ESD-oriented university teaching that correspond to the principles of ESD didactics.

The model of teachers’ professional action competence is well known in pedagogical and didactic research (e.g. Kunter et al., 2011). This competence is seen as a prerequisite for successful teaching in schools. It can also be applied to higher education. The success of teaching activities is essentially determined by specific cognitive professional knowledge. This especially includes CK and PCK. Professional action competence is complemented by non-cognitive aspects such as motivational, volitional and social competences (Weinert, 2001). This also includes self-efficacy, which plays a special role in ESD (e.g. Reinke, 2021). Reinke (2021) attempted to formulate a specific professional action competence for ESD (cf. Figure 1). This model, together with de Haan’s (2008) model, was used in the present study as a basis for both the conception and scientific evaluation of higher education didactic offers. Particular attention was paid to conceptual knowledge about SD and ESD as part of not only CK but also PCK.

3. State of research

3.1 Training of university teachers

Although there are some international approaches to ESD training for university teachers, we are far from structurally embedding ESD into higher education (Mula et al., 2017; Scherak and Rieckmann, 2020). Kieu et al. (2015) found sustainable development topics in the curricula of five teacher training colleges in Vietnam but no corresponding methodology. Based on expert interviews, Etzkorn (2019) concludes for Germany that there is a lack of training for university lecturers, and that teachers’ awareness and didactic skills have not been sufficiently developed. This assessment is supported by an extensive Australian study (Christie et al., 2015). Mula et al. (2017) list some recent approaches to implementing ESD in higher education curricula and analyze them according to their strengths and weaknesses. They draw three conclusions from their analysis:

- Training should be competency-based.
- Training should not be a one-off event and should be institutionalized.
- Training should reflect a whole-institution approach.
Within these implications, they emphasize the importance of inter- and trans-disciplinary collaboration as well as student participation and empowerment.

Very few studies have focused on the effectiveness of ESD training. Barth and Rieckmann (2012) reported comparatively early on a project they developed together with a university in Ecuador. The program comprised seven modules and 720 h within one year, but it was only completed by 18 university teachers who were interested in it. The qualitative analysis of a focus group interview and the final reports showed that the training not only led to competence development in teaching but also supported the transformation of the entire university. Similar results were obtained by Amado et al. (2017), who conducted a one-month case study in Ethiopia with 21 participants.

As Scherak and Rieckmann (2020) note, the various competency models mentioned above have not been widely used in the present studies. Therefore, they conducted courses in higher education didactics, based on the RSP model. In doing so, they explored the competencies that participants considered necessary and how they could be developed. Over a period of two years, they offered various workshops in which 30 university teachers participated. The evaluation was based on a focus group interview with six people and a self-assessment questionnaire completed by nine people. The results showed that all 12 competencies of the RSP model were considered important, but the respondents felt that the potential to build them in the 3–4-h workshops was limited. The authors also saw a problem in the fact that they could only attract a few people who were already in favor of ESD.

In an earlier publication (Hemmer et al., 2022a), the authors reported the results of the first project part of this study. They analyzed the effectiveness of ten face-to-face training sessions involving a total of 81 university teachers, but the publication did not include the second project phase with the nine digital events. For the face-to-face events, a significant increase in professional knowledge could be demonstrated, but not in non-cognitive aspects.

### 3.2 Digital formats

While there is an increasing number of articles reporting on experiences in student ESD events, only a few have analyzed the effectiveness of digital formats (e.g. Ahel and Schirmer, 2023). However, there is still a lack of experience with digital formats in the field of academic staff training. De Kraker et al. (2017) analyze the value of the European Virtual Seminar on Sustainable Development (EVS) as an opportunity for professional development in ESD at the university level and describe the use as expandable. Weselek et al. (2022) have developed a digital professional development platform based on the RSP model with different modules to enable university lecturers to carry out autonomous professional training. However, there is little experience and no empirical evidence vis-à-vis working with the platform. Hemmer et al. (2022b) described how they overcame the COVID-19-related challenge of transferring the training activities described here from a face-to-face event to a digital event, without having definite results on its effectiveness.

### 3.3 Summary of the current state of research and research questions

In summary, only a few studies have been conducted on the ESD training of university teachers. They have involved a small, usually already enthusiastic number of participants. They achieved very different results, mostly with longer training durations and by using different survey instruments. The question arises as to how effective training can be designed with a realistic amount of effort, which can also reach a larger number of participants and not only teachers who are already highly committed.
Because of the limited state of research, no hypotheses have been formulated. However, the following research questions derived from theoretical principles are explored in detail in this study:

**RQ1.** How effective is the training in terms of professional competence (CK and PCK), motivation and self-efficacy?

**RQ2.** What influence does the format (digital versus face-to-face) have on the outcome?

**RQ3.** How do different personal factors (age, gender, ESD experience and involvement in an ESD project) influence the outcome?

### 4. Methodology

#### 4.1 Design and realization

The training was delivered in a face-to-face format between October 2018 and March 2020 and digitally from September 2020 to July 2021 due to the COVID-19 pandemic. Both formats lasted 8 h in total.

The face-to-face sessions were held at eight different Bavarian university campuses. The digital training was advertised at all Bavarian universities. After the training, the participants were offered coaching to provide further support for implementation in their own specialized teaching if desired. Coaching was used by 17 (9.3%) participants. It was not included in the effectiveness research.

#### 4.2 Sampling

A total of 183 university teachers from over 50 different sub-disciplines (see Section 5.1) participated. Sufficient data are available from 175 participants for both survey periods t1 and t2. In the face-to-face format, data of ten training sessions with 81 participants, and in the digital format of nine training sessions with 94 participants, could be analyzed. Participants were informed that the research was being conducted to accompany their training. The questionnaires were anonymized.

#### 4.3 Measurement tool

Participants completed a questionnaire at the beginning and end of the training sessions. Filling out the questionnaire took approximately 15 min. The questionnaire was developed according to the competence model described above (c.f. Figure 1).

It covered the following areas:

- professional knowledge (CK, PCK, (nine-item scale and two open-ended questions);
- motivation (ten-item scale);
- self-efficacy (eight-item scale); and
- personal data.

The response scales were designed as four-point Likert scales. All the three scales are printed with all items and the response scales in the corresponding results Section (Sections 5.2–5.5). Section 5.3 also lists the wording of the open-ended questions.

The professional knowledge scale and the open-ended questions were designed by the team. They focus on the conceptual understandings and central terms of SD and ESD, not only on the mere knowledge of terms but also on the ability to explain the concepts/terms (see answer scales in Sections 5.2–5.4 and Reinke, 2021).
The measurement instruments were validated by ESD experts at two workshops. In the team and in these workshops, especially, the scale for CK and PCK and the open-ended questions were discussed, further developed and prepared for a pilot test, which took place with master’s ESD students. The motivation (Kunter et al., 2011) and self-efficacy scales (Schmitz and Schwarzer, 2002) have already been developed and used in other studies (Reinke, 2021) and are adapted here for the HESD field.

4.4 Analysis methods
A nine-item scale was used to investigate whether changes in participants’ CK and PCK could be achieved through the training. The list of items is shown in Table 1. Principal component analysis was used to test the factor structure of the professional knowledge scale. This confirmed the two previously suspected factors of CK and PCK. The homogeneity and validity of the motivation and self-efficacy scales were tested in a same way.

To test for significant differences between the first and second measurement points, $t$-tests for dependent samples were conducted for the individual items and scores on the CK and PCK as well as self-efficacy and motivation scales. To investigate the influence of the teaching format (face-to-face vs digital version) and time of measurement, a two-factorial analysis of variance (ANOVA) with repeated measurements was performed. To examine the influence of independent variables, single-factor variance analyses were carried out.

The answers to the open-ended questions were categorized and scored by three people so that they could be included in the statistical analysis.

4.5 Description of the intervention
Both variants of the training, face-to-face and digital, lasted for 8 h and took place synchronously. The contents and methods of both training variants were essentially the same. However, the digital format requires methodological adjustments (see below; also, Hemmer et al., 2022b). Both formats are based on the ESD understanding of the World Program of Action [UNESCO (United Nations Educational, Scientific and Cultural Organization), 2020], the professional action competence model and de Haan’s (2008) competence model. The aim of the training program was to encourage and support participants in implementing ESD in their professional university teaching programs. Therefore, the focus was on the development of CK and PCK, motivation, self-efficacy as well as system competence and reflection competence. The structure, contents and methods of the intervention were commented upon and supplemented in two ESD-expert workshops (see Section 4.3).

The face-to-face event lasted for one day. After participants were introduced, a short film clip of Severn Cullis-Suzuki’s speech at a Conference in Rio de Janeiro in 1992 was shown as a prelude. This entry clarified that sustainable development was necessary. Following a constructivist approach to education, participants were then asked to sketch their individual ideas about sustainability on paper. These pre-concepts were presented and clustered by participants. To encourage reflection, participants were then asked to discuss whether they would also apply the previous methods in their own teaching. Such reflections also took place after the subsequent training phases.

In the following keynote lecture, some sustainability concepts from the current scientific discourse were critically presented. The individual sketches of participants were also included. After a break, the transition to ESD occurred. In this three-part impulse lecture, the basics of ESD were presented and discussed. The first part included a brief outline of how ESD emerged and a selection of conceptual understandings (including UNESCO and Buen Vivir). This was followed by a discussion of other educational concepts, such as environmental education and global
learning, and their relationships with ESD. After this input, participants became active and assigned the characteristics of ESD using map-laying techniques. An example of climate change is then used to show the added value and multidimensionality of ESD. The second part of the lecture introduced international and national framework conditions, as well as the current situation of ESD, especially in universities. The SDGs and their significance with regard to ESD were also discussed. The presentation ended with a brief introduction of the whole institution approach (WIA) in universities and its relevance to ESD. The third part of the lecture was dedicated to the ESD-oriented design of university teaching. First, important elements of ESD-oriented didactics – competencies, contents, methods and media – were presented in an overview (Bellina et al., 2020; Hemmer et al., 2022a). It was made clear that methods and media played an important role in promoting competencies. Two examples – climate change and migration – were used to further explain how these four elements could contribute to ESD orientation. Finally, a tool for ESD-oriented planning was presented that, in addition to orientation on the four elements, referred to student participation in teaching, the importance of a holistic approach (cognitive, affective and actional) and lifeworld orientation. After a break, participants worked in small groups to develop outlines for their own teaching, which were then briefly presented and discussed in the plenary.

Subsequently, selected methods to promote system competence (e.g. concept maps, SDG cubes) were practiced in small groups. Their potential and limitations for university teaching have been the subject of plenary discussion. Finally, a reflection of the entire training was conducted.

The online event was divided into three sections (2.5 to 3 h each over 1.5 to 3 days): sustainable development, ESD with selected examples and discussion of participants’ application examples. The transition from the face-to-face to the digital version required some minor methodological changes, such as the increased use of film clips (Hemmer et al., 2022b). The own ESD-oriented lesson planning was particularly emphasized in the digital version by being set as an individual homework between section 2 and 3; as the latter did not usually take place on the same day, there was more time available for it than in the face-to-face module.

5. Results

5.1 Statistical description of the implementation and the sample

Of the participants, 33% were male, 62% female, 5% did not provide information. Most respondents were between 30 and 39 years old. According to the subdivision of sciences of the OECD (2007), the participants who answered this question (n = 110) came from the following scientific fields: 50% social science, 24.6% humanities, 12.7% natural science, 9.1% medical and health science, 2.7% engineering and technology and 0.9% agricultural science. The composition of the two groups (d = digital n = 52, f = face to face n = 58) differed markedly: social sciences d: 38%, f: 60%; humanities d: 33%, f: 17%; natural sciences d: 15%, f: 10%; medicine and health sciences d: 8%, f: 10%; engineering and technology d: 6%, f: 0%; agricultural sciences d: 0%, f: 2%.

A total of 40 respondents (24%) indicated that they had previously been involved in a project related to ESD with their organization or institution, and 126 respondents (76%) indicated that they had not. In the total sample, 54 persons (35%) indicated that they had already dealt with some aspects of ESD in their teaching, while the majority of respondents, 102 persons (65%), had not yet done so.
5.2 Professional knowledge: content knowledge (CK) and pedagogical content knowledge (PCK)

In the following, both descriptive and inferential statistical results are presented for the CK and PCK scale, which provide information about the effectiveness of training for professional knowledge (CK + PCK).

The general scale of CK and PCK consists of nine items, the CK subscale consists of six items and the PCK subscale consists of three items (see Table 1). The respondents could choose between four levels of responses on a four-point Likert scale, ranging from 1 =

<table>
<thead>
<tr>
<th>Item</th>
<th>First time of measurement</th>
<th>Second time of measurement</th>
<th>n</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CK</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Millennium development goals</td>
<td>2.03 1.04</td>
<td>3.07 0.74</td>
<td>144</td>
<td>10.92</td>
<td>0.000</td>
</tr>
<tr>
<td>SDGs</td>
<td>2.48 1.09</td>
<td>3.45 0.90</td>
<td>147</td>
<td>8.39</td>
<td>0.000</td>
</tr>
<tr>
<td>Agenda 21</td>
<td>2.47 0.92</td>
<td>3.03 0.81</td>
<td>144</td>
<td>6.36</td>
<td>0.000</td>
</tr>
<tr>
<td>Circular economy</td>
<td>2.74 1.05</td>
<td>3.08 0.91</td>
<td>147</td>
<td>4.06</td>
<td>0.000</td>
</tr>
<tr>
<td>Planetary boundaries</td>
<td>2.71 1.01</td>
<td>3.25 0.95</td>
<td>148</td>
<td>5.57</td>
<td>0.000</td>
</tr>
<tr>
<td>Strong sustainability</td>
<td>2.44 1.01</td>
<td>3.32 0.91</td>
<td>144</td>
<td>7.75</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>PCK</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System thinking</td>
<td>2.80 0.98</td>
<td>3.40 0.81</td>
<td>148</td>
<td>7.16</td>
<td>0.000</td>
</tr>
<tr>
<td>Competence orientation</td>
<td>3.14 0.96</td>
<td>3.42 0.89</td>
<td>142</td>
<td>3.51</td>
<td>0.000</td>
</tr>
<tr>
<td>“Gestaltungskompetenz”</td>
<td>2.70 1.03</td>
<td>3.26 0.92</td>
<td>123</td>
<td>5.15</td>
<td>0.000</td>
</tr>
</tbody>
</table>

**Source:** Property of the authors
“I have not heard of it” to 2 = “I have heard of it, but I could not explain it to others” and 3 = “I have a rough idea of it” to 4 = “I am familiar with it, so I could explain it.” The mean scale scores for the total scale and the CK and PCK subscales (see Table 2 and 3) were calculated from the item scores.

The descriptive results of the face-to-face and digital sample are presented in Table 2. A two-factor ANOVA with repeated measures was carried out to check whether there was a significant difference between the face-to-face and digital samples with regard to the CK and PCK scales and their subscales at first time of measurement (t1) and second time of measurement (t2). There was no significant difference between the classroom and digital samples regarding the results for both scales together (F(1) = 0.267; p = 0.606), on CK (F(1) = 0.013; p = 0.911) and on PCK (F(1) = 1.132; p = 0.289).

As there are no significant differences between the face-to-face and digital groups, the results for the total sample are presented (Table 3). The descriptive values at t2 for the CK and PCK scales are consistently higher than those at t1. To check whether the scale scores were also statistically significantly different, a t-test for paired samples was performed. The descriptive values and results of the t-tests are shown in Table 3. There were also highly significant differences for both the subscales and the total scale. Thus, a significant increase in CK and PCK was achieved among participants through the training.

Using dependent samples t-tests, there were also highly significant differences between t1 and t2 for all nine items (cf. Table 1).

5.3 Professional knowledge: open-ended questions
Changes in CK and PCK were assessed not only by means of the quantitative scale presented above but also by means of additional open-ended questions.

The first question relates to participants’ conceptual knowledge of sustainable development, which participants in the face-to-face seminar are asked to answer in writing before and after the seminar: “A student asks you what ‘sustainability’ or ‘sustainable development’ means. Please provide some key points you would use to explain this.” Figure 2 shows the results for both subsamples, which are categorized based on the keyword answers using the six-eye principle.

In both samples, the understanding of sustainability comprises too few dimensions and is one-dimensionally oriented toward environmental aspects in a large proportion of participants at t1. The dimensions of justice are mentioned less. Only a small minority refers
to the interconnections between the dimensions. Comparing the two samples, it is noticeable that although these tendencies are the same, they are weaker in the digital sample.

In both samples, a marked increase in the dimensions mentioned by the participants can be observed at t2. This has been accompanied by a clear decrease in the one-dimensional understanding of sustainable development, which includes only ecological aspects. After the intervention, approximately one-third of the respondents in both samples also see the links between the dimensions. Thus, the intervention has led to participants having a differentiated understanding of sustainability.

The second open-ended question relates to the conceptual knowledge of ESD. Participants at both measurement points were also asked thus: “Global learning—Education for sustainable development—Environmental education: Briefly describe how these three concepts are related.” This question was answered by 56 persons (f = face-to-face format) and 53 persons (d = digital format) in the two subsamples at measurement times t1 and t2.

While at t1, only 6% (f) and 18% (d) of participants answered the question correctly, that is, described environmental education and global learning as subareas of ESD, at t2, 70% (f) and 81% (d) were able to classify the three terms correctly. This classification is the official standard in the German-speaking world. The two subgroups tended to answer the question in the same way but differed in their respective percentages. The intervention led to a clear expansion of ESD understanding in both groups regarding the question asked.

5.4 Motivation
The motivation scale consisted of ten statements (items) that respondents could tick on a four-point scale ranging from 1 = “disagree” to 4 = “agree.”

The descriptive results for the face-to-face and digital samples are presented in Table 4. The results of the ANOVA show no difference between the face-to-face and digital samples on the motivation scale (F(1) = 0.063; p = 0.802).

Because there was no significant difference between the face-to-face and digital samples on the motivation scale, further analyses were performed using both samples together. The descriptive statistical results for the ten items are presented in Figure 3. The individual items were checked using a t-test. No significant changes were observed for eight items, but significant changes were observed for two items. Significant improvements were achieved for the item “I enjoy teaching content related to sustainable development” (t(113) = 2.00, p = 0.024) and for the item “Education for sustainable development is an important concern for me” (t(141) = 2.65, p = 0.000).

For the motivation scale, a mean scale score was calculated for the first and second time points based on all individual items. An examination of the descriptive scores showed that

<table>
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<tr>
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<th>First time of measurement</th>
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<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Face-to-face</td>
<td>3.48</td>
<td>0.40</td>
</tr>
<tr>
<td>Digital</td>
<td>3.49</td>
<td>0.51</td>
</tr>
</tbody>
</table>

Source: Property of the authors

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Table 4.
Descriptive results for the scale motivation for the face-to-face and digital samples.
participants’ motivation increased minimally from t1 (M = 3.48) to t2 (M = 3.53). However, the dependent samples t-test shows that the difference between t1 and t2 is not significant (t(146) = 1.29, p = 0.099). However, the baseline score on the motivation scale was rather high prior to the intervention.

Looking at the descriptive means of the individual items, it became clear that the seminar could achieve a slight increase for most of the items.

5.5 Self-efficacy
For the items of the self-efficacy scale, respondents could answer on a four-point scale from 1 = “disagree” to 4 = “agree.” The scale consists of nine items, each related to ESD or action competence.

### Table 5. Descriptive results for the self-efficacy scale

<table>
<thead>
<tr>
<th>Item</th>
<th>First time of measurement</th>
<th>Second time of measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>I find ESD topics interesting.</td>
<td>3.45</td>
<td>0.52</td>
</tr>
<tr>
<td>Sustainable development is important to me.</td>
<td>3.61</td>
<td>0.37</td>
</tr>
<tr>
<td>I enjoy teaching content related to sustainable development.</td>
<td>3.39</td>
<td>0.53</td>
</tr>
<tr>
<td>Too much political weight is attached to sustainable development.</td>
<td>3.07</td>
<td>0.54</td>
</tr>
<tr>
<td>Education for sustainable development is an important concern for me.</td>
<td>3.87</td>
<td>0.49</td>
</tr>
<tr>
<td>Students have little interest in sustainable development issues (inverted).</td>
<td>3.32</td>
<td>0.51</td>
</tr>
<tr>
<td>I feel responsible for implementing education for sustainable.</td>
<td>3.49</td>
<td>0.54</td>
</tr>
<tr>
<td>Through ESD in teaching, I want to convey values to my students that</td>
<td>3.57</td>
<td>0.51</td>
</tr>
<tr>
<td>ESD methods can enrich my teaching.</td>
<td>3.67</td>
<td>0.49</td>
</tr>
<tr>
<td>ESD deepens the content of my teaching.</td>
<td>3.82</td>
<td>0.47</td>
</tr>
</tbody>
</table>

**Source:** Property of the authors

### Table 6. Descriptive and inferential statistical results of the total self-efficacy scale (total sample)

<table>
<thead>
<tr>
<th>Item</th>
<th>First time of measurement</th>
<th>Second time of measurement</th>
<th>n</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-efficacy scale</td>
<td>3.35</td>
<td>0.54</td>
<td>146</td>
<td>3.025</td>
<td>0.003</td>
</tr>
</tbody>
</table>

**Source:** Property of the authors
The ANOVA shows no significant difference between the face-to-face and digital samples at t1 and t2 for the self-efficacy scale ($F(1) = 0.030; p = 0.863$). The descriptive results for the face-to-face and digital samples are presented in Table 5.

The results for the total sample are presented in Figure 4.

![Descriptive statistical results of all items of the total self-efficacy scale (total sample)](image)

**Source:** Property of the authors

The $t$-test revealed a significant difference between t1 and t2 for four items. This affects the following:

- “Through my teaching, I contribute to students rethinking their actions/behavior” ($t(126) = 1.93, p < 0.05$).
- “Through my teaching, students become multipliers of sustainable development” ($t(114) = 1.88, p < 0.05$).
- “I am confident in teaching ESD-oriented courses” ($t(130) = 4.82, p < 0.01$).
- “The exchange with colleagues about new ESD concepts serves me as an important feedback/confirmation for action” ($t(112) = 2.56, p < 0.05$).

For the other items, there was no significant difference between t1 and t2.

For the self-efficacy scale for all items, an examination of the descriptive data in Table 5 shows a slight increase in self-efficacy at the second time point. The dependent samples $t$-test shows a significant difference between the first and second measurement points. Thus, participants’ self-efficacy was significantly increased by the ESD training (cf. Table 6).

Significant differences between t1 and t2 could be achieved not only for the total scale but also for the four individual items (see above).

### 5.6 Influence of teaching format

Using a one-tailed $t$-test, there was a small difference when examining the formats individually in terms of their effect. For the CK and PCK scales, the face-to-face format achieved a slightly greater increase in learning progress between t1 and t2. For the self-efficacy scale, there was a slightly greater increase between t1 and t2 for the digital module.

However, as described in more detail in the sections above, the testing with a two-factor ANOVA with repeated measurement (the two factors are “teaching format” and “time of
measurement”) showed that the factor “teaching format” with the characteristics “face-to-face version” and “digital version” had no significant influence on the variables “CK and PCK,” “motivation” and “self-efficacy.” Therefore, the face-to-face and digital versions proved to be equally effective.

5.7 Person-related factors of influence

In the following, the influence of personal data on individual scales and their changes are presented.

Data analysis using a one-factor ANOVA did not reveal any correlations between these scores and the factors of gender, age and general work experience at the university. The personal data for which correlations are found are listed below.

5.7.1 Education for sustainable development teaching experience. In the questionnaire, the participants were asked, “Have you ever dealt with partial aspects of ESD in your teaching?” A repeated measures ANOVA was used to test the influence of ESD teaching experience on CK and PCK. While general university teaching experience had no influence, ESD teaching experience was found to have a highly significant influence (F(1) = 17.618, p = 0.000). Furthermore, the interaction was also significant (F(1) = 5.648, p = 0.019). Thus, the increases in CK and PCK were higher for those without ESD teaching experience than those with ESD teaching experience.

First, motivation is already quite high in both groups at t1. However, the repeated measures ANOVA shows that there is a highly significant difference between the groups with and without ESD teaching experience in terms of motivation (F(1) = 17.864, p = 0.000). Thus, people with ESD teaching experience are significantly more motivated than those without ESD teaching experience at measurement times t1 and t2. The interaction between ESD teaching experience and time of measurement is not significant (F(1) = 0.501, p = 0.480). This indicates that the increase due to training does not differ between the two groups.

Self-efficacy is already relatively high for both groups at t1. The repeated measures ANOVA shows that people with and without ESD teaching experience differ significantly from each other in terms of self-efficacy (F(1) = 11.867, p = 0.001). However, the interaction between ESD teaching experience and time of measurement of self-efficacy expectancy is not significant. Thus, it has no significant influence on the increase in self-efficacy, whether or not there is previous experience of ESD teaching.

5.7.2 Commitment to an education for sustainable development-related project. In the questionnaire, the university lecturers were asked, “Are you involved in an ESD-related project with your organization/institution?” The two-factor ANOVA with repeated measures shows that the between-subjects factor “institutional ESD commitment” has a significant influence on the levels of CK and PCK (F(1) = 6.456; p = 0.012). Furthermore, the interaction between the time of measurement and ESD engagement is also significant (F(1) = 5.608, p = 0.019). This means that individuals without ESD engagement in their institutions have a greater increase in CK and PCK as a result of the ESD training than those with ESD engagement.

For the motivation scale, the results of the repeated measures ANOVA also show that the commitment to ESD in one’s own institution has a highly significant influence on its level at measurement times t1 and t2 (F(1) = 8.910; p = 0.003). However, the interaction is not significant (F(1) = 0.973; p = 0.326).

The group involved in an ESD-related project shows a higher self-efficacy (M = 3.57) at t1 than the group without involvement (M = 3.27). Notably, ESD involvement also has a significant influence on self-efficacy at t1 and t2 (F(1) = 5.888; p = 0.017). Thus, individuals
with ESD involvement have significantly higher self-efficacy expectations at t1 and t2 than those without. In addition, the interaction between ESD commitment and time of measurement is also significant. The increase in self-efficacy through the ESD training is greater for people without ESD commitment in their own institution than for those with ESD commitment in their own institution.

6. Discussion
This study investigates the extent to which ESD training improves the professional action competence (CK, PCK, motivation and self-efficacy) of university teachers and whether it has the same impact in the digital as in the face-to-face format. Furthermore, the factors influencing this effect were analyzed.

6.1 Discussion of the implementation and the sample
With 183 participants, participation in the training was good compared to similar studies (e.g. Amado et al., 2017). Participants represented a wide range of subjects. Only one-third of the participants had already implemented ESD aspects in teaching, and only one-quarter were active in an ESD project. This showed that it was possible to attract a broad spectrum of university lecturers, including those with no affinity for ESD, a concern that could not yet be met in earlier studies (cf. Scherak and Rieckmann, 2020).

6.2 Effectiveness in relation to professional action competence
6.2.1 Content knowledge and pedagogical content knowledge (scales and open-ended questions). At t1, the respondents’ knowledge in both subfields (CK and PCK) is low. University teachers are not aware of the essential terms. This result is supported by the results of the two open-ended questions. Here, it can be seen that the respondents have uncertain and different conceptual understandings of SD and ESD, which do not justify a multidimensional understanding. Etzkorn (2019) comes to similar conclusions for university teachers based on expert interviews. Reinke (2021) also identifies deficits in conceptual understanding with very similar open-ended questions, but among teachers at schools.

The intervention significantly increased university teachers’ knowledge in both areas (CK and PCK) and formats. This result is also supported by the answers to the two open-ended questions. Here, we can see that, in both formats, understanding the concept has clearly become more multidimensional. Comparing the results of a few other intervention studies (e.g. Amado et al., 2017; Barth and Rieckmann, 2012) with those of this study, a certain effectiveness can be identified as a common feature. However, there are limitations to the comparison because other studies worked with a much smaller and more homogeneous number of subjects, as well as much longer interventions and qualitative methodologies.

Notably, CK and PCK are important prerequisites of teaching quality (Kunter et al., 2011). However, more knowledge alone is unlikely to be meaningful enough to claim that university teachers have sufficient competencies to integrate ESD into their subject teaching. However, the results show that it is possible to impart important basic knowledge to build these competencies. Within the framework of the intervention, clearly more and very differentiated knowledge was imparted, and the building of competencies was supported at many points (cf. Section 4.5); however, we decided not to use other, more detailed measuring instruments to keep the test duration low.

6.2.2 Motivation and self-efficacy. These two scales focus on non-cognitive areas of professional action competence and have already been used in previous studies. Therefore, a critical view of the measurement instrument is not as necessary as that of the cognitive
scale. The fact that the motivation of the participants is relatively high at t1 is surprising, considering that, in contrast to Scherak and Rieckmann (2020), participants come from very different disciplines that do not necessarily have an affinity for ESD. This may be related to the current relatively high social interest in sustainability. Unsurprisingly, the intervention did not lead to a further increase in motivation. On the one hand, it is difficult to influence non-cognitive areas, especially with shorter interventions, and on the other hand, it is known that it is difficult to achieve further increases in motivation if relatively high levels are already present at t1 (e.g. Lloyd et al., 2017).

With regard to self-efficacy, participants already achieved relatively high values at t1. However, at t2, the values were significantly higher. To the best of our knowledge, results from other studies are not available. The fact that the training led to a significant increase in self-efficacy was totally unexpected, given the relatively short duration of the intervention. This shows that participants have the confidence to change their teaching in an ESD-oriented manner.

6.3 Influence of teaching format
There were no significant differences in any of the above-stated scales between participants in the two formats at t1. The factor “teaching format” also had no significant influence on the changes in “CK and PCK,” “motivation” and “self-efficacy.” Thus, the face-to-face and digital versions proved to be equally effective. While some studies have demonstrated the effectiveness of ESD events with students (e.g. Ahel and Schirmer, 2023), we know of no quantitative intervention studies on digital training with university teachers so far. This study confirms its effectiveness. This encourages the use of digital formats to further disseminate ESD in higher education. However, it should be noted that the digital format used here was synchronous and highly interactive (see Section 4.5). Whether an asynchronous offering can achieve similar results is questionable and opens up perspectives for further research.

6.4 Person-related factors of influence
The results showed that only two factors were statistically relevant: ESD teaching experience and commitment in an ESD-related project. The increases in CK and PCK are higher for those without ESD teaching experience or ESD commitment than for those with such experience or commitment. People with ESD teaching experience or ESD engagement are significantly more motivated than those without at t1 and t2; however, the increase due to training does not differ between the two groups. It had no significant influence on the increase in self-efficacy, regardless of whether or not there was prior experience in ESD teaching. However, for people without ESD commitment, the increase in self-efficacy through training is greater than for those with ESD commitment in their own institution.

To the best of our knowledge, no empirical study has investigated the influence of these two factors on ESD training. It should be critically noted that in this survey, participants had a quite different and insufficient understanding of what ESD meant at t1. This is also indicated by the answers to the open-ended questions. However, the increases show that all participants benefited from the ESD training. It also shows that ESD training is useful for teachers of all subjects in both formats.

7. Conclusions
In the following, the procedure and results of the study are reflected against the background of the three recommendations of Mula et al. (2017): 1) Training should be competency-
focused. 2) Training should not be a one-shot event and should be institutionalized. 3) Training should reflect a systemic WIA, that is, it should be transformative.

(1) The training described here was explicitly competency-oriented. Significant importance was attached to CK and PCK. It is questionable whether the scale and the two open-ended questions, with their strong focus on conceptual knowledge, sufficiently cover this area. Notably, CK was a necessary foundation, but it was clear that a particular difficulty for the participants was applying the theoretical knowledge gained in the training to their own professional teaching. The increase in self-efficacy suggested that this was at least partially successful. However, the demand for coaching has shown that quite a few were still uncertain about how to link it to their own subject-specific teaching. It would have been desirable to evaluate other ESD competencies, such as the ability to reflect, that were repeatedly promoted during the training. This could be a subject for future research.

(2) The training was not originally designed as a one-shot event. Three modules were planned: basic, advanced and coaching. However, due to the COVID-19 pandemic, the advanced module had to be dropped. Coaching, which was used by just under 10% of participants, should be offered as a follow-up in any case. One-shot events have proven to be less effective in other contexts; however, they make it possible to involve a larger group of participants. The institutionalization of further training in higher education didactics, as called for by Mula et al. (2017), was achieved to some extent with the study presented here because it was credited toward the certificate in higher education didactics, and thus, more participants could be recruited. However, obtaining this certificate is neither compulsory nor is choosing ESD training as part of the certificate.

It should be noted that the results presented here only demonstrate the short-term effectiveness of the training. However, long-term effectiveness is still desirable and could be a subject for future research.

(3) The training did reflect a WIA, but this was not the main focus of the training because it was designed to be a cross-university training program.

Mula et al. (2017) also emphasize the importance of inter- and transdisciplinary collaboration and student participation. The training presented here, nevertheless, explicitly aims to integrate ESD into subject-specific teaching. This seems necessary to reach students from all disciplines. However, both teams conducting the training (geography education and psychology) and the groups of participants were interdisciplinary. This led to not only exciting discussions but also challenges in transferring the results to one’s own subject-specific teaching. Transdisciplinary aspects were not the subject of this training. The participation of students was part of the lecture on ESD and part of the implementation of participants’ own teaching example.

References


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