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Innovative Teaching and Learning Formats for the Implementation of Agroforestry Systems—An Impact Analysis after Five Years of Experience with the Real-World Laboratory "Ackerbaum"

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Abstract: Since 2017, the Eberswalde University for Sustainable Development (HNEE) offers transformative learning modules in their curricula, which are called ITL—Innovative Teaching and Learning formats. Student tutors change into the role of teachers and organize lectures, excursions, and assignments at the Real-World Laboratory "Ackerbaum"—an agroforestry system in the federal state of Brandenburg, Germany. Students can learn about agroforestry systems, participate in research, and take practical action. The examination of the module is a scientific report linked to the experimental area. In this study, an attempt was made to verify the quality and impact of teaching formats in the ITL via the analysis of 53 reports created by 170 students as well as surveys among participants. For this purpose, indicators were formulated that capture the quality of scientific methods and the contribution to higher education for sustainable development. Students and tutors appreciate the open working atmosphere and the possibility to actively participate in the course; many leave the module motivated. Some even move toward transformation in agriculture professionally as, e.g., consultants in the field of agroforestry. As a transformative institution, HNEE offers with ITL a rare opportunity for practical application, scientific methods, and transdisciplinary collaboration with different stakeholders to work on future models to change today's agriculture.

Keywords: agroecology; education for sustainable development; interdisciplinarity; transdisciplinarity; transformative science; forestry

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1. Introduction

Many agricultural regions around the world are threatened by climate change, with existing regional data already indicating significant shifts in local temperature and precipitation regimes [1,2]. In addition, agriculture is linked to the continued degradation of natural ecosystems, further contributing to long-term sustainability concerns [3]. Sustainable transformations will need to simultaneously minimize further ecological damage while adapting to changing climatic conditions. Given the high diversity of global agricultural landscapes, this calls for flexible, system-based research and policy approaches which account for place-specific contexts and trade-offs when generating management options for farmers [4,5]. Meeting sustainability and resilience challenges will moreover require farmers to understand complex agro-ecological processes, take on active roles in farm management, and to apply adaptive skillsets [6–8]. This is particularly the case for heterogeneous and biodiverse farming systems such as agroforestry systems, which are defined as the deliberate inclusion of trees in livestock or annual crop production systems [9]. Agroforests can include silvoarable (crop-based) and silvopastoral (livestock-based) systems and are characterized by high multifunctionality [10].

At present, the implementation of agroforestry practices across Central Europe remains limited despite growing recognition of their potential benefits in the context of climate change and land degradation [11,12]. This may be driven by interacting socioeconomic and political factors and is likely compounded by limitations of supporting scientific knowledge [13] and biases or gaps in training curricula [14]. Higher education institutions are central agents of change driving sustainability transitions, as they contribute to shaping the knowledge and skills of farmers, researchers, and policy makers [15–18].

An important goal of education for sustainable development (ESD) is the development of key competencies to drive societal transformation processes that meet the UN's 17 Sustainable Development Goals (SDGs) [19]. The strategic need to incorporate sustainability concepts and skills in higher education is gaining recognition [18]. New pedagogic approaches are needed, and characteristic changes in teaching and learning will arise, as shown in Table 1 [20].

Table 1. This table shows the approaches to transformative pedagogy in the sense of the ESD criteria, (Education for Sustainable Development) [20].

Predominantly Prevalent in the Present Higher Education System	**Needed in the Future for Education for Sustainable Development**
Disciplinary perspective	Inter- and transdisciplinary approaches
Reproduce knowledge	Generating knowledge
Pretending to be teacher-centered	Student-centered and self-determined
Receptive	Reflective
Individual learning as competition	Collaborative synergetic learning
Cognitive learning	Holistic learning: head, hands and heart
Epistemic monism	Epistemic pluralism

As well, in the federal state of Brandenburg in Germany, universities are contractually mandated to integrate education for sustainable development into their curricula [16]. This is also relevant for farm practitioners, who may benefit from adaptive skills acquired through Innovative Teaching and Learning formats (ITL), which combine theoretical and practical learning approaches.

Agroforestry in a Real-World Laboratory

Successful ESD initiatives should integrate appropriate methodological approaches with central didactic principles: self-organization, self-determination, co-determination, participation, interdisciplinarity, transdisciplinarity, and practical orientation [20–23]. The implementation of these principles in a Real-World Laboratory offers the opportunity to combine research and learning objectives under field conditions.

Interdisciplinarity thrives through the interaction of students from different disciplines with each other, with tutors and with mentors. This is supported by direct cooperation with non-scientific stakeholders. Another focus is the transdisciplinary and practice-oriented exchange through joint data collection and analysis in the field, investigations in the laboratory, and assignments in planting and caring for the woody plants. In addition to excursions in the region and (online) lectures by experts, the importance and state of the art of modern agroforestry systems are conveyed. In small groups, the participants work on theoretical and practical questions about the study area. As a result, the assignments of these groups serve to document the results on an ongoing basis and to further develop the "Ackerbaum" study site.

The students also gain insights into the transformation processes of the agricultural and food system. The students can help shape the educational process, the approach is participatory, self-organized as well as self-determining or co-determining. An important part of this self-organization in the ITL is the organization and implementation of the module by student tutors.

The tutors' tasks include the further development of module content, inviting experts, planning excursions, coordinating public relations work and leading the working groups. To promote these processes, the students are supported by lecturers who take on an advisory and moderating role. In parallel, the quality of teaching is evaluated and adjusted at regular intervals through surveys of the module participants in order to continuously improve the module.

The ITL is included in HNEEs curricula of several Bachelor and Master programs as an elective module at HNEE, with a duration of one semester and 6 ECTS credits. It therefore has a theoretically unlimited duration, which allows for permanent observations.

The complexity of transformation processes demands their exploration outside controlled laboratory conditions. Real-World Laboratories are needed. They are influenced by many factors that can never be fully controlled. Since Real-World Laboratories not only generate knowledge but also apply it, they represent a special hybrid form of experimentation. The Real-World Laboratory is thus a powerful tool of transformative research [24]. In cooperation with the local farmer and the university, the "Ackerbaum" study site aims to test methods for transformation toward a more sustainable agriculture. It further contributes to existing research gaps regarding place-based knowledge of temperate agroforestry systems [12] through the establishment of permanent field experiments.

The aim of our analysis was to investigate the social and pedagogical impact of the ITL by systematically evaluating student reports. The research question was to analyze how far the criteria of education for sustainable development are fulfilled in our approach of the ITL. It was hypothesized that the ILL fulfills various ESD criteria and thus contributes to the development of design competence among the students. When these criteria would not be fulfilled sufficiently, this would give us information on where to focus on in the further development of the ITL and the module in our curricula.

2. Agroforestry in Germany

In the 18th and 19th century, different forms of agroforestry practices were common across middle Europe. With the mechanization of agriculture, more and more trees were banned from farmland [25]. However, there has been recent increased interest in agroforestry as farmers and scientists realize the broad benefits of those systems [26]. Alley cropping, considered a modern agroforestry system, refers to alternating rows of planted trees and arable crops, which enable farmers to run farm machinery in parallel lanes [27]. Hedgerows, consisting of shrubs and/or trees, are generally planted as windbreaks or field boundaries [28]. The German Association for Agroforestry (DeFAF) collected 108 voluntarily registered agroforestry projects in Germany. Of these, 35 of them, including "Ackerbaum", are silvoarable projects [29]. The "Ackerbaum" study site shows the possible benefits of agroforestry systems with modern cultivation methods. The aim is to demonstrate the benefits and possible changes of agroforestry systems to support the advice of practitioners in agriculture. In addition to the HNEE, other institutions in Germany are also active in practice-oriented agroforestry research. The University of Gießen is investigating experimental approaches in three agroforestry systems in cooperation with a farm, and the Julius Thünen Institute is conducting research on two experimental areas of 10 hectares and 30 hectares, which are managed in short rotation coppice [29,30]. Agroforestry is also represented in the curricula of different study programs across Germany, e.g., at the Universities of Göttingen and Munich [31]. However, the "Ackerbaum" study site presents a unique approach as it integrates dual research and education goals.

3. Materials and Methods

3.1. Study Site

The "Ackerbaum" study site includes two different alley cropping systems as well as a newly established hedgerow on agricultural land. The first alley cropping system combines tree rows of 6 different species for high-value timber as well as willow clones (*Salix* spp.) in short rotation and fruit bearing shrubs. The second alley cropping system consists of willow clones in short rotation for future onsite compost source production. Finally, the hedgerow includes different tree and shrub species and was planted with two objectives: protection from wind erosion and enhanced biodiversity.

Located about 50 km north of Berlin, the study site lies in the federal state of Brandenburg, Germany. The site elevation is 50 to 55 m above sea level. With an average precipitation of 572 mm/m^2 per year (1981–2010), and a mean annual temperature of about 9 °C [32] climatic conditions are predominantly continental. The agricultural area has a total size of about 30 ha [32], of which the "Ackerbaum" study site as described above accounts for ca. 6 ha [33]. The site consists of loamy sand, and the soil type is classified as brown soil from sand or parabrown soil from loamy sand over clay [32].

Both alley cropping systems were established in December 2017. The layout and setup of the system was developed by students based on several Bachelor theses [32,34,35]. Tree rows for the production of high value timber were planted in 8 parallel rows, with a distance of 38 m in between and a total length of 1.400 m. In total, 339 trees of 6 species were planted in plots of each three trees per specie: wild pear (*Pyrus pyraster* (L.) Burgsd.); tree hazel (*Corylus colurna* L.); service tree and wild service tree (*Sorbus domestica* L. and *Sorbus torminalis* (L.) Crantz); sessile oak (*Quercus petraea* (Matt.) Liebl.) and red oak (*Quercus rubra* L.). Furthermore, 225 fruit-bearing shrubs were planted in between the tree plots: in sum, 75 chokeberry shrubs (*Aronia melanocarpa* (Michx.) Elliott) and 150 sea buckthorn shrubs (*Hippophae rhamnoides* L.). Additionally, the hedgerow consists of 300 native shrubs and small trees and was established in spring 2018.

3.2. Evaluation of the Social and Educational Impacts

Quantitative Content Analysis of the Reports

In order to evaluate the multiple impacts of our ITL, a quantitative content analysis was conducted to capture the effectiveness of the lessons as well as its social and educational impact on the students [36,37]. The analysis focused on 53 student reports, written as an assignment of the ITL in 2017–2021. All reports generated between the start of the winter semester 2017–2018 and the end of the winter semester 2020–2021 were included in the evaluation. The impact of teaching was assessed using indicators in two categories. As scientific orientation is one of the central features of Real-World Laboratories [24], indicators related to scientific relevance (A) were selected. The pedagogical dimension of the teaching approach was reflected in the choice of the indicators (Higher Education for Sustainable Development and Real-World Laboratory (B)). Therewith, a total of ten indicators were defined, which represent the quality criteria for our ITL [37].

In class A, seven indicators were defined: the content indicators *validity*, *objectivity*, *reproducibility*, *methodology* and *reflection* as well as the formal indicators *citation* and *bibliography*. Class B includes 3 indicators: *practical approach*, *interdisciplinarity* and *transdisciplinarity*. In the analysis of the reports, a rating was assigned for each indicator. The scores were based on a classification reflecting high (1), medium (2) and low (3) quality. The overall results of all reports were then summarized in average values for each indicator; all scores were mean arithmetically. To ensure the objectivity of the evaluation, all reports were double rated independently by the authors. In a comparison, differences were discussed and standardized. Subsequently, the interpretation of the results took place.

The class A-indicators are of particular interest for the evaluation, even though they are actually considered the standard for scientific work. Since many of the module participants are only at the beginning of their studies, it should be examined to what extent the system knowledge important for transformative science as well as the research orientation as the goal of a Real-World Laboratory could actually be achieved [24].

(A) Scientific Relevance Indicators.

- *Validity:* In order to describe the degree of accuracy with which the characteristics to be tested were examined, this indicator was used [38]. It is important that a targeted approach takes place [39]. For student reports, validity was assessed by examining the inclusion of clear initial objectives and research questions and by assessing their match with reported results.
- *Objectivity:* This indicator was included to assess whether scientific results were presented on a factual, neutral, and unprejudiced basis in the reports, in other words to evaluate whether results were notably influenced by personal opinions, preferences and feelings, and emotional, unclear, judgmental and distracting argumentation [38]. To evaluate objectivity in the reports, we examined the language and argumentation used. For instance, texts using "I-form" or "we-form" in a very informal way in their argumentation received low ratings [40].
- *Reproducibility:* One requirement for a sound scientific study stipulates that under the same framework conditions, repetition of experimental steps should lead to the same or similar results [39]. To obtain reproducible results, it is therefore crucial to select suitable research instruments and to conduct the survey accurately [38]. Logical reasoning built on a transparent and sound argumentation leading to valid conclusions is also of central value [39]. Research insights should be comprehensible to third parties so that readers can reach the same conclusion [41]. Here, reproducibility was assessed based on clarity of the research question and the logical construction of the described research processes.
- *Methodology:* To quantify transparency regarding research process, logical argumentation, results, and conclusions, this indicator was selected [39]. In addition, originality, an important "driver" for the inception of new ideas, constitutes as a significant measure for scientific quality [39,40]. As a pilot project, our ITL integrates a wide variety of unconventional methodological approaches, integrating interdisciplinary approaches. The methodology indicator evaluated the suitability and reproducibility of methodological design.
- *Reflection:* For critical evaluation, a central component of scientific research, this indicator was chosen [39]. It is important that researchers arrive at relevant results, classify their findings theoretically and discuss their applicability and problem-solving ability. Given the practical orientation of students´ work, individual reflection is considered an important factor for further development of the "Ackerbaum" study site and the ITL. The indicator specifically evaluates the inclusion and extent of separate critical discussion sections within the report.
- *Citation:* This indicator, as well as *bibliography*, was used to assess the honesty, clarity, and verifiability of the student´s work. Honesty refers to the accuracy of texts and correct attribution of citations to credit the work of other authors [39]. Findings, arguments, and suggestions from other sources used must be disclosed through references in the text and the list of sources [41]. This further informs assessments of verifiability, as properly cited statements are both verifiable and falsifiable. The citation indicator assessed the uniformity, comprehensiveness, and style of references.
- *Bibliography:* In addition to the indicator *citation*, the use of a *bibliography* system throughout a text supports the clarity of the presented work [39]. The bibliography indicator evaluated the completeness and formatting of the reference list in comparison with citations used in the text and selected citation style.

(B) Higher Education for Sustainable Development Indicators.

- *Practical approach:* Within the ITL, in the context of higher education for sustainable development, the applied processing of practice- and project-oriented questions has a high priority for the continuous evaluation and further development of the study site. *Practical approach* was evaluated based on the practical relevance or expected contributions of research questions for concrete activities on site.

- *Interdisciplinarity:* This dimension was identified as a core component for ITL and was promoted through facilitated cooperation between students from different degree programs and subject areas. *Interdisciplinarity* was evaluated based on the degree program affiliations and subject area specializations within voluntarily created student groups, using the lists of participants from previous semesters (winter semester 2017–2018 to winter semester 2020–2021).
- *Transdisciplinarity:* Higher education for sustainable development implies transdisciplinary work in which the process of problem solving is carried out by actors from the academic context and practice partners together. This indicator was evaluated based on the number of external contacts referred to within the student reports. We recognize that this measure does not directly fully reflect transdisciplinarity; nevertheless, as it reflects the process of integrating transdisciplinary thinking into the teaching–learning process, it was valuated as a preliminary stage of transdisciplinary work.

(C) Further Indicators.

Another aspect of higher education for sustainable development is the involvement of student tutors in the teaching and learning process. The impact and quality of self-organized ITL teaching by tutors was captured through a survey of 9 former tutors. They were asked about their role in ITL, the acquisition of competences, the establishment of future and career-relevant contacts, and the most important challenges. As well, a thesis [42] investigated the teaching quality within the program in terms of learning experiences perceived by students and their interaction with tutors and professors.

4. Results

The evaluation of the 53 reports was carried out along the described method separately for all quality criteria. A total of 170 HNEE students from eight degree programs took part in the module over a period of seven semesters. On average, there were about 28 students per semester, 51% from the Department of Forest and Environment and 49% from the Department of Landscape Management and Nature Conservation. More than half (55%) of the students were male and 45% were female, aged 20 to mid-30s. Nationality was not recorded, but since the language in ITL is only German, it can be assumed that only participants from Germany took part in ITL.

(A) Scientific Relevance.

For the seven indicators used to evaluate the scientific quality of the reports (class A, see Table 2), average indicator ratings across all reports were in the high-to-medium range (ratings scores between 1.42 and 1.79); the highest rated indicator was *validity*, and the lowest rated indicator was identified as *citation*. In the evaluation of the content-related quality criteria of scientific work, more than half of the reports received high ratings in the areas of *validity*, *reproducibility*, and *methodology*. Exceptions were the evaluation of the indicators *objectivity* and *reflection*, which were rated in the medium range. The evaluation of the formal indicators *citation* and *bibliography* also tended toward medium ratings. We note that reports with an overall low rating often scored low in the evaluation of several indicators.

Table 2. This table shows the assigned scores of the 7 indicators in class A based on the qualitative assessment of 53 student reports.

Indicators	Share of Reports with High Quality (Score: 1)	Share of Reports with Medium Quality (Score: 2)	Share of Reports with Low Quality (Score: 3)	Average Scoring	
Validity	61%	35%	4%	1.42	high
Objectivity	40%	45%	15%	1.75	middle
Reproducibility	55%	36%	9%	1.55	middle
Methodology	57%	36%	7%	1.51	middle
Reflection	43%	40%	17%	1.74	middle
Citation	43%	34%	23%	1.79	middle
Bibliography	49%	36%	15%	1.66	middle

- *Validity:* In the evaluation, 61% of the reports proved to be of high (1) validity. Meanwhile, 35% of the reports were medium (2) validity, and 4% (3) were cut off as low validity. This results in an average value of 1.42, which places the overall rating of the validity indicator in the high range.
- *Objectivity:* The evaluation of the objectivity indicator showed that 40% of the reports were of high (1) and 45% (2) were of medium objectivity. On the other hand, 15% of the reports were rated as low (3). In the overall evaluation, the reports scored 1.75. Thus, the reports tended to be of a medium standard in the overall evaluation.
- *Reproducibility:* In the category of reliability, 55% of the reports were rated as high quality (1) and 36% were rated as medium quality (2). Meanwhile, 9% (3) of the reports were rated as low quality. Within the reliability indicator, this results in an average value of 1.55. Overall, the reports are in the middle range between high and medium quality.
- *Methodology:* The evaluation of the category methodology shows that 57% are in the high (1) quality range and 36% are in the medium (2) quality range, while 7% of the reports were classified as being of low (3) quality. The indicator has an average value of 1.51. All of the reports are thus in the middle range between high and medium quality.
- *Reflection:* Self-reflection was found in 43% of all reports. In 40% of the reports, only a medium/medium standard of self-reflection was achieved, and in 17%, there was only a poor one. For the indicator reflection, the average value is 1.74. Thus, the overall evaluation tends to a medium standard in the reports.
- *Citation:* A complete and correct citation was found in 43% of all reports. In 34% of the reports, only a medium/medium standard was achieved and thus not uniformly cited. A citation with gaps and errors was found in 23% of the reports, which thus correspond to a poor standard. For the citation indicator, the average value is 1.79. Thus, the overall evaluation tends toward a medium standard in the reports.
- *Bibliography:* A complete bibliography was present in 49% of the reports. An incomplete bibliography and thus only a medium rating were achieved in 36% of the reports. An incomplete or unscientific bibliography was found in 15% of the reports, which thus corresponds to a poor standard. The average value for the bibliography indicator is 1.66. The overall rating thus tends toward a medium standard in the reports.

(B) Higher Education for Sustainable Development.

For the three indicators used to evaluate relevance in terms of education for sustainable development (class B, see Table 3), average indicator ratings across all reports were on average lower than for class A indicators, and they ranged from high to low (ratings scores between 1.26 and 2.60). The highest rated indicator was *practical approach*, and the lowest rated indicator was identified as *transdisciplinarity*.

Table 3. This table shows the assigned scores of the 3 indicators in class B based on the qualitative assessment of 53 student reports.

Indicators	Share of Reports with High Quality (Score: 1)	Share of Reports with Medium Quality (Score: 2)	Share of Reports with Low Quality (Score: 3)	Average Scoring	
Practical approach	74%	26%	0%	1.26	high
Interdisciplinarity	40%	19%	41%	2.02	middle
Transdisciplinarity	13%	13%	74%	2.60	low

- *Practical approach:* In the evaluation of the indicator practice-oriented working methods, 74% of the reports are rated as high quality (1). In the medium range, 26% (2) of the reports can be classified. There are no reports in the low-value range. The result is an average value of 1.26, which means that the overall rating is in the high-quality range.
- *Interdisciplinarity:* In the case of interdisciplinary cooperation, 40% of the groups had a mixture of subject areas as well as degree programs, and 19% only had a mixture of subject areas. In 41% of the groups, there was neither mixed cooperation between the degree programs nor the departments. The average value of 2.02 can thus be assigned to a medium standard.
- *Transdisciplinarity:* In 26% (high and middle) of the reports, contact was made with stakeholders in the non-university sector. Within these reports, the range of external contacts is from three to fourteen individual persons. In the remaining 74% of the reports, no further external contacts were included.

(C) Further Indicators.

The intended goals of the module could be achieved with the chosen approach: In the survey of course participants conducted by Gerpen [41] in the winter semester 2017/18, the responding students (19/25) indicated that they very strongly or strongly associated the module with terms such as research-based learning (89%) or competence-based learning (84%). Similarly, 90% of the students assumed that they would keep what they had learned in the module in mind even after completing their studies. They felt able to continue their education independently (89%) and were motivated to become active in the field of agroforestry (68%). In general, 79% of the students agreed that they preferred such a form of learning to traditional lectures, and they would choose to participate in the module again even if the workload would be higher (64%).

To evaluate the ITL, a survey was conducted with former tutors. The nine participants from the fields of study Forestry (1), International Forest Ecosystem Management (4), Landscape Management and Nature Conservation (2), Organic Farming and Marketing (1) and Eco-agricultural management (1) were 23 to 33 years old and predominantly (6) male. There were two tutors per semester. The tutorial continues the approach of the ITL and maintains on the one hand scientific standards but on the other also offers new freedom for the development of the students without the presence of professors. The tutors can experience a change of perspective in their position, from student to teacher, and practice the role of mediating or mentoring. The acquisition of skills, such as effective problem solving and scientific work, was predominantly seen as valuable.

Time management, the small financial budget, and the handover to new people in charge were perceived by the tutors as clear obstacles. The wish for long-term expert support was expressed several times. The development of a database and a tutor guide would help, as would the obligation to lead the tutorial over two semesters, alternating so that one tutor already has one semester of experience.

The majority of the tutors draw great successes from the tutorial in the form of contacts with each other, with students and other actors in the field of agroforestry, as well as personal milestones and confirmation. Some have aligned their professional careers after this experience.

5. Discussion

The high proportion of the indicator *validity* within the reports could be due to the fact that concrete objectives and research questions were often specified for the work, or these were developed together with the supervisors. The existence of these simplified goal-oriented processing and supported the achievement of measurable and successful results. To ensure quality, the specification or supervised development of objectives and research questions should be maintained and expanded in the future.

The indicator *objectivity* constitutes a particular challenge for students, with a large proportion of reports receiving low ratings in this aspect. The separation between personal experience within student groups and project-specific results is perceived as rather difficult.

The indicator *reproducibility* was partly difficult to fulfill within the investigations in the reports; this may be related to the nature of the "Ackerbaum"-based research, as variability in influencing factors was difficult to control for under field and related conditions. For example, changes in supervisors, unclear time management or changing group constellations made high adaptability and sudden organizational changes necessary, making spontaneous changes indispensable.

This dynamic was also noticeable within the indicator *methodology*. The methodological approach evolved from semester to semester, with elements discarded and adapted and new aspects included over time. In some areas, this led to diverse, sometimes difficult to compare and discontinuous series of results, confounding long-term monitoring on the trial site. Based on these outcomes, the development of standardized methodological procedures for the core topics of the model project will be the focus in the future.

The indicator *reflection* should be more anchored in the guidelines for the design of a scientific paper. Papers that also contain a paragraph on self-reflection would allow for better comparisons over long periods of time. In a module organized by students, it is important to be able to better assess and evaluate the methods developed and applied in research.

The indicator of *citation* should show whether the basic rules of scientific writing have been understood by all participants. For this, formal and technical aspects of correct citation must be taught. An introductory lesson in scientific writing and presentation is now part of the module; supervision of students' scientific work is strengthened.

For the indicator *bibliography*, as well as for the indicator citation, the basic rules of scientific writing should be taught more intensively. This will help to establish the standard for writing scientific papers. Recurring errors in the reports indicate a lack of prior knowledge. These include incomplete bibliographies, missing sources that are quoted from or referred to in the text, or their identification in the text.

Across these seven indicators for scientific relevance, average ratings were in the high-to-medium range, with low ratings particularly evident for the indicators *reflection*, *citation*, and *bibliography*. For a significant number of students, the "Ackerbaum" reports were the first written assignment within their studies. These students may have been faced with a combination of minimal experience with scientific methodologies along with a high expectation of personal responsibility. This could be one reason for relatively low scoring reports in the areas of *objectivity* and *reflection* as well as for formal criteria. We further note that reports with higher ratings in those areas were predominantly written by students in higher semesters, including Master-level students, suggesting that increased experience with academic contexts may have led to improved skills.

Central for the further development of teaching is that the students receive clear guidelines and increased support for processing the reports. An important aspect is the specification or joint, supervised development of an adapted and clear objective and research question. In addition, standardized methodological approaches for recurring surveys should be specified, and the method design should be clearly communicated to the students and thus be reproducible. For surveys outside the core topics of the module, a supported development of differentiated methods should take place with the tutors and module leaders before the survey.

Generally, we assume that these findings were only marginally influenced trough the coronavirus pandemic (COVID-19): during that time, university operations were kept online, in presence or hybrid, adapted to the applicable regulatory requirements to maintain ITL operations. Excursions and practical work could be conducted outdoors in small groups, maintaining the minimum distance. ITL interaction could be built up to a smaller extent only, as group forming was more difficult with online lectures and as people did not know each other and could not meet at the beginning. However, the work results generally depend strongly on the motivation in the respective student groups; changes and differences in motivation can be found in all years and seem to be marginally influenced only by the learning format, presence, online or hybrid. Still, the workload for the tutors was clearly higher during the coronavirus pandemic due to higher efforts for organizing the activities and the many additional regulations.

The overall rating of the Section B indicators was on average lower and showed more variation than for Section A, with report ratings ranging from low- to high-quality. Students' eagerness to deal intensively with the subject area was clearly noticeable in the vast majority of reports.

One reason why all reports in the point of *practical approach* scored into the high and medium range may be the practical relevance of the module. Due to the close connection, the usability and transferability of the results to the study site are in the foreground for students with regard to the implementation and the results. In any case, this aspect should also retain a central role and be strengthened in the future processing of questions.

Despite the low rating of *interdisciplinarity* in the student reports, it can be stated that to date, 250 students from eight study programs have already worked together in the "Ackerbaum" project study site. The evaluation shows that the aim of interdisciplinary study participation was achieved at the level of the study programs. Within the student working groups, however, interdisciplinarity was more difficult to achieve: it was found that students tended to work together with known people from their degree program and less often with unknown people from other degree programs. Interdisciplinary contacts and exchange therefore took place mainly within the framework of lectures, excursions, and practical fieldwork. Many course participants were at the beginning of their studies (2nd Bachelor's semester), getting to know each other at the time of the module, which is probably why the groups were less diverse. Students in higher semesters or Master's students tended to join interdisciplinary groups. However, they also registered for the module less frequently.

The biggest interest among students is found among Bachelor's students in the degree programs "Forestry" (79) and "Organic Farming and Marketing" (83). Among the Master's students, the interest is just low (24 students in total). This could be due to the fact that the advertising for the module was mainly aimed at Bachelor students and was not sufficiently worked up for Master students. Many of the Master programs are taught in English, so many of the Master's students do not have a good enough command of the German language to participate in a German-language module.

When looking at the report ratings for *Transdisciplinarity* only, indicators were low. This may have been related to time constraint during a single semester; in addition, for certain subject areas, clear instructions for data collection were already available, minimizing students' needs to contact external sources. Based on our results, we therefore conclude that this indicator should be reconsidered. Still, we noticed that besides the external contacts of the students, many external contacts took place: in the course of the ITL, several field trips took place with farmers, media, politicians and other interested parties to visit the agroforestry sites and discuss the experiences on site. This resulted in more than 15 articles in newspapers and social media as well as several features on TV and radio programs, spreading the idea of agroforestry and stimulating discussions in society in general and among farmers in particular.

Furthermore, the team participated in scientific conferences, national and international, on agricultural future concepts and management approaches. In total, 10 final theses with a direct link to the study site were written by Bachelor and Master students, which enabled further contacts with researchers in Germany and Europe. This resulted in joint research proposals and activities with renowned institutions such as the Leibniz Centre for Agricultural Landscape Research (ZALF) and project cooperation such as participation in the DAKIS project: https://agrarsysteme-der-zukunft.de/en/consortia/dakis, accessed on 30 April 2022. These transfer activities stimulate discussions about current challenges but also possible paths and concepts for agriculture of the future.

The examination of the student reports was completed by two student assistants. Since they are still studying, it was decided in discussions with the professors that grading on a 5-point scale would be too time consuming (due to the large number of reports). In addition, it is difficult to make such a differentiated grading/subdivision for specific criteria. This gives the impression of extreme accuracy, which is not always the case. Therefore, the decision was made to use a three-level and thus "coarser classification".

6. Conclusions and Outlook

The analysis of the indicators can be used to reflect the process of transformation in our module as one example of how higher education should look in the future. When comparing the characteristics of higher education today and what separates it from ESD (see Table 1), and when comparing these characteristics to how the module is organized and implemented, we see a high congruence: the inter- and transdisciplinary approaches are clearly visible and the students generate knowledge rather than just reproducing it, with special focus on collaborative synergetic learning. There is a high degree of self-determination of the students, and through the combination of lectures, excursions, group work and practical work, the module is using a holistic approach. As well, enough room for reflection is given.

The ITL's achievement of the *social aspects* of the transformative Real-World Laboratory is progressed. The practicability and benefits of the ITL were put to test by a critical self-assessment. The tool for this investigation was a document analysis, which evaluated 53 student reports in order to identify not just the students' skills and knowledge in scientific work but also the strengths and fields of improvement of the ITL. The tutors organized and supervised 10 successfully completed module runs, which were mastered independently to a larger extent. Some of the former tutors remain loyal to the ITL and the study site, sometimes even from distance. However, the student participants also identify strongly with the experimental area, their research question, and the topic issue of the transformation of agriculture, to which agroforestry would like to bring its contribution. Motivated people emerge from their courses who take on the role of tutor for the following one to two semesters.

The big aim toward more *transdisciplinarity* within the ITL should be emphasized here once again. So far, the degree programs and departments as well as the different levels, Bachelor and Master student, intermix only to a certain point. Since there are no strict rules in this regard and the choice of group members remains open, it will be the task of the professors and coming tutors in the future to promote the advantages of transdisciplinary work. The opportunities for insights into and contacts with other disciplines are usually rare. However, the extended contact to stakeholders outside the ITL and the HNEE should also be more focused. It is pleasing to see the emergence of a handover culture in which module participants from the previous semester voluntarily come to the current course depending on time and interest and contribute their experience and learned skills to work in the experimental area and share them with others.

Finally, the aims of *ecological objectives* are constantly followed, such as the development and testing of methods and techniques for transformation toward a more sustainable agriculture. Furthermore, the advantages of agroforestry cultivation should be shown as options for actions and positive examples for agricultural practitioners. In order to achieve these goals, some components of the agroforestry system will have to continuously grow and be studied; here, we consider a great potential for activity in the following years and good opportunities for students to participate in shaping science themselves. The evaluation of the ecological successes will therefore be given bigger focus in the future.

Finally, the authors do see interesting opportunities to transfer the findings from this ITL, focusing on agroforestry, to other forms of land management and land utilization such as forest management and agroecology, which is also complex and experience-based. At the university, promising approaches are being discussed on how to develop forest stands and different forms of managing these forests in Real-World Laboratories as well, using comparable approaches and making use of our learnings from the ITL and the study site "Ackerbaum".

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