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Fostering Students' Competencies in Sustainability in Vocational Agriculture Education in Burundi: Effects of a Participatory Integrated Planning (PIP) Module

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ABSTRACT

Developing students' sustainable agriculture competencies requires the alignment of curriculum content to encompass the full complexity of the dynamics of agriculture. However, empirical evidence from sustainable agriculture research indicates that actions oriented towards fostering students' competencies are scarce. To advance understanding, this study monitored and evaluated the development of students' sustainability competencies for smallholder farming during the implementation of a Participatory Integrated Planning (PIP) module—A sustainability learning programme that elaborates on cross-cutting issues of long-term integrated planning, which is normally not taught. A total number of 104 students from two vocational agricultural schools ($N_1 = 63$; $N_2 = 41$) were involved in the PIP learning module that was implemented from April 2022 to June 2023. Survey data on the development of the students' competencies were collected at the beginning (April 2022), in-between (December 2022) and end (June 2023) of the implementation of the PIP module. A one-way repeated measures MANOVA test was used to evaluate the effect of the PIP module on the development of students' competencies. Findings revealed that the PIP module significantly contributed to fostering all intended competencies, including facilitator of change, leadership, innovation and creativity, planning, system thinking, stewardship, auto-determination and interdisciplinarity. Improvement of these competencies was much higher in the earlier stage of the learning process compared to the later stage, implying that sustainability learning requires going beyond 'business-as-usual' to retain the interest of students and competencies development. Findings also revealed that competencies development levels differ depending on schools' context, implying that sustainability learning programmes should be flexible and adaptive for learning to occur in a real-context environment. These findings have practical implications for policies related to designing and upscaling sustainability learning programmes in vocational agriculture schools.

1 | Introduction

Increasing importance is placed upon sustainability education as an effective way of building sustainability competencies within sustainability change agents (Brundiers et al. 2021; Lozano et al. 2022; Zguir, Dubis, and Koç 2022). However, integration of sustainability within educational curricula is still a challenge given that it should be a transdisciplinary and transformative educational approach beyond transmitting operational knowledge and skills of graduates, with an

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emphasis on sustainability aspects to deal with societal problems (Sandri 2022; Tasdemir and Gazo 2020). For some authors including Güler Yıldız et al. (2021) or Kahriman-Pamuk et al. (2019), sustainability education should be integrated at all levels of the educational streams, i.e. from early childhood to tertiary education levels, with the expectation that students develop sustainability competencies gradually along their educational programmes.

In agriculture, increasing concerns about the unsustainability of agriculture have led to the development of sustainable agriculture (SA) education programmes (LaCharite 2016; Parr et al. 2007; Parr and Trexler 2011; Zamani, Ataei, and Bates 2016), that is, vocational agriculture education. The most crucial aspect of SA education is that students get engaged with real-context sustainable agriculture problems (Parr et al. 2007).

The present study on promoting students' sustainability competencies in vocational agriculture education was carried out in Burundi, which is in recovery from a two-decade civil conflict that has devasted its economy. In addition to the post-conflict situation, 90% of the population of Burundi are dependent on smallholder agriculture farming within a context of land shortage, high rates of land degradation and soil erosion and unsustainable agriculture practices (Kessler et al. 2021). Diverse community development interventions have been implemented, mainly development aid and poverty reduction programmes, mostly defined by donors, incentive-based, top-down interventions, post-conflict emergency programmes, which do not necessarily focus on long-term sustainability challenges (Kessler et al. 2021).

Given that these interventions do not address the root causes of problems, the result is that such interventions 'fade away' after projects end and make the grassroots communities (basically smallholder farmers) increasingly dependent. In such a context, the introduction of sustainability education is more critical than any other sector. It is crucial to rethink development approaches to tackle the root causes, instead of fighting the symptoms. Sustainability education can play a central role in that perspective by building competencies that enable graduates to confront complex sustainability challenges (Brundiers et al. 2021; Nyamweru et al. 2023; Tassone et al. 2022; Weijzen et al. 2024) and, thus, serve as change agents in their communities.

For the specific context of Burundi, change agents are agricultural extensionists, i.e. skilled workers who can support sustainability transformations by means of knowledge exchange, technical advice, empowerment, coaching and collaboration with grassroot communities. These are individuals who graduate from secondary vocational agriculture education (*Instituts Techniques Agricole du Burundi—ITAB*, in French), a network of 29 vocational agricultural schools established for that purpose (Nyamweru et al. 2023). The extent to which context-relevant sustainability aspects were already included in the ITAB education system has been assessed by Nyamweru et al. (2024—under review). Their work showed that the vocational agriculture education system in Burundi does not apprehend the changing dynamics of sustainable agriculture to truly promote students' sustainability competencies with much focus on attitudinal aspects of competencies that would enable behavioural changes in students with regards to their preparedness to handle sustainability challenges.

Efforts in the perspective of overcoming this limitation include the work by Nyamweru et al. (2023), on identifying context-relevant sustainable agriculture competencies that should be prioritized for the ITAB education system to effectively promote competent change agents. This study elaborates on this theoretical background to examine the effects of a sustainable agriculture learning programme that is oriented towards fostering students' competencies. The study monitored and evaluated the development of students' sustainability competencies following the implementation of the Participatory Integrated Planning (PIP) module as a sustainability learning programme.

The aim of the study was to examine the extent to which the PIP module has contributed to students' competencies development. Two research questions are answered:

1. To what extent have sustainable agriculture competencies been improved following the implementation of the PIP module as a sustainability learning programme? (RQ1)
2. What are the differences between the two PIP schools in terms of the development of students' competencies and why do they differ? (RQ2)

The rest of this paper presents the theoretical background of the study, the methodology used, the findings and resultant discussions with related theoretical and practical implications. Limitations of this study and suggestions for future studies are also discussed.

2 | Theoretical Background

2.1 | The Nature of Sustainability Competencies Addressed in the PIP Module

Fostering competencies in vocational agriculture education requires alignment between the world of education and the world of work for this specific domain of agriculture (Mulder and Winterton 2017). Complexity arises from the requirement to reflect real-life sustainability challenges in the curriculum of vocational education to educate for a sustainable future (Weijzen et al. 2024). In other words, the intended educational outcome for a sustainability-oriented education system should be a clearly articulated set of sustainability competencies (Bergsmann et al. 2015; Nyamweru et al. 2023; Wesselink et al. 2017), that is, knowledge, skills and attitudes that enable students to become effective sustainability professionals for agricultural development. This should be the starting point for a training programme characterized by real situation learning (Biemans et al. 2004, 2009; Tassone et al. 2022; Wesselink et al. 2017).

From this perspective, the nature of the intended competencies and what they entail elaborate on previous research by Nyamweru et al. (2023, 2024) in which a set of context-relevant sustainability competencies for prioritization by ITAB

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education was identified. Nyamweru et al. (2023) identified a list of 11 sustainable agriculture competencies, including facilitator of change, innovation and creativity, planning, system thinking, domain expertise, continuous learning, interdisciplinarity, leadership, stewardship, self-determination and engagement.

Overall, these competencies reflect cross-cutting domains of knowledge, skills and attitudes for competent sustainability professionals. Most crucial for intended competencies in the PIP module, the focus is on attitudinal aspects of competencies that are not taught in ITAB education, or only to some extent (Nyamweru et al. 2024—under review). These aspects relate to participatory skills that are relevant for sustainability problem-solving from the understanding that sustainability cannot be a prerogative of only government agencies or any other third-party organizations (De Haan 2006). In connection to the context of Burundi, agriculture sustainability professionals need to be facilitators of change, innovative, creative, committed and intrinsically motivated, with a sense of responsibility to become leaders and planners for sustainability pathways by working together with grassroot farmers to identify problems, opportunities and risks that they face, and jointly determine the right course of action (Nyamweru et al. 2023).

This framework on context-relevant sustainability competencies provides an indication of what competencies should entail and what areas of the curriculum need improvements as far as sustainability is concerned. The remaining question is "how" this sustainability learning can be achieved (Probst 2022) and this is where this study seeks to advance the understanding by introducing the PIP module in vocational agriculture education and evaluating how students develop competencies.

2.2 | PIP Module as a Sustainability Learning Programme: Rationale, Content and Participatory Learning Process

The PIP module was developed as a sustainability learning programme for students of ITAB. The rationale for introducing such a programme was that current ITAB teaching does not address underlying sustainability challenges, including land degradation, soil erosion, depletion of rural ecosystems, misuse of natural resources, food insecurity, extreme poverty and lack of vision at the household level towards envisioning a better future.

The PIP module builds upon the principles of the PIP approach, as originally developed by Wageningen University, in The Netherlands, with the aim of building a foundation for sustainable change at the grassroots level. Its objective is to build capacities for motivated farmers, who are good stewards of their land (Kessler et al. 2021). The sustainable changes envisioned by the PIP approach start at the grassroots level within people, households, farms and communities, with motivation, stewardship and resilience as key principles (Kessler et al. 2016). Based on these foundational principles, the PIP approach is increasingly embraced by farmers and local governments as a means for household livelihood improvement and agricultural sustainability problem-solving (Kessler et al. 2021; Kessler and van Reemst 2018; Kessler et al. 2016; Misanya et al. 2023; Ndagijimana, Kessler, and Asseldonk 2019).

Although the PIP approach was initially developed for farm households (originally named the Integrated Farm Planning approach), it was modified and adapted to be taught at ITAB to help students realize the interconnectedness of the social, economic and environmental aspects in real life, that is, all domains pertaining to human development (McGrath et al. 2022). It was anticipated that the key elements and principles of the PIP approach would increase the intrinsic motivation and engagement of ITAB graduates in sustainable agriculture and enable them to become better agricultural development professionals and environmental stewards in their future careers.

The experience with the PIP approach in Burundi has shown that bottom-up changes in handling sustainability issues can happen if mindset change is rooted in the PIP foundation principles of motivation, resilience and stewardship (Kessler et al. 2021). These are primarily attitudinal elements of competencies, which are, in most cases, the missing part of competencies in the ITAB curriculum (Nyamweru et al. 2024—under review). These attitudinal aspects are central in the competence framework proposed by Nyamweru et al. (2023)—the basic framework of this study. Therefore, helping students uncover the rationale of these PIP principles would help them to think, exercise imagination, create and act differently.

In fact, empirical works on fostering students' competencies in sustainability support that, similar to PIP learning, students' self-steered projects with group collaboration, independent works and connection to real-world context problems significantly help to foster students' sustainability competencies via a participatory learning process (Birdman, Wiek, and Lang 2022; Brundiers, Wiek, and Redman 2010).

The PIP module was designed following the principles of competence-based education design. Specifically, the outcome of the training (i.e. the intended competencies) was the starting point for module content development (Smith 2010). Building on the works by Nyamweru et al. (2023), the 11 competencies that needed to be prioritized were identified in a participatory process using the Delphi Technique, which involves collecting opinions from a group of diverse experts (normally educational stakeholders), who are knowledgeable about sustainability challenges.

This is a kind of participatory process that is central to sustainability competencies identification (Demssie et al. 2019). The participatory process, as a means for increased efficiency and involvement of educational stakeholders (Cebrián, Segalàs, and Hernández 2019) (in this case, students and teachers), was also ensured during the implementation of the PIP module. Teachers involved in the PIP module teaching were asked to consensually prioritize a list of eight competencies, around which the PIP module was articulated, with the purpose of developing teaching content that is more focused, coherent and consistent (Long, Bernoteit, and Davidson 2020; Johnstone and Soares 2014) with the concept of sustainability referred to in the context of this study.

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These eight competencies included: (i) facilitator of change, (ii) leadership, (iii) innovation and creativity, (iv) planning, (v) system thinking, (vi) stewardship, (vii) auto-determination and (viii) interdisciplinarity (or integration). A detailed description of the eight competencies and related assessable rubrics was included with the module to serve as clear guidance for teachers during the teaching process (Table 1).

The module was articulated around four themes, which were divided into 14 teaching units (TU), with intended competencies clearly defined for each theme and TU. The scope of the TU, the learning activities (for teachers and students) and related didactic approaches and materials were also defined in the module.

3 | Methodology

This section presents the methodology that has been used to systematically answer the research questions. We explain the study context and PIP module implementation, process of participants recruitment, study design and data collection tools, as well as the approaches used to analyse data.

3.1 | Study Context and the PIP Module Implementation

Two ITABs were selected to pilot the PIP module from a network of 29 ITABs that constitute the vocational agriculture education in Burundi. The two ITABs were selected because they were the oldest vocational agriculture schools. The two ITABs selected also had enough resources (farms, machinery, laboratories, animals, etc.) for the PIP teaching to be carried out within a meaningful context. There were no differences between the two ITABs in terms of PIP module implementation. There were differences, however, in the learning environment of the two ITABs in terms of size of classes (number of students), diversity of areas of specialization, school location (urban vs. rural centres) and the size (or amount) of school infrastructure (e.g., availability of farms, equipment, laboratories, etc.).

More precisely on differences between learning environments, ITAB Karusi is located in the proximity of an urban centre with more students, more areas of specialization (Agriculture, Water & Forestry, Food Technology and Veterinary) and more farms and equipment compared to ITAB Mahwa, which is located in a rural area with relatively fewer students, two areas of specialization only (Agriculture and Veterinary) and few farms and equipment.

The content of the module was implemented from April 2022 to June 2023. Beneficiaries of the teaching were students in 2nd year of ITAB. The reason to target 2nd year students was to enable them to still finish the module during their last year of ITAB (the 3rd year), given that the teaching of the module was extended on two school years (2021/2022 and 2022/2023). A total of 22 teachers, including 12 teachers from ITAB Karusi and 10 teachers from ITAB Mahwa were involved in the PIP module teaching. The implementation of the PIP module has been similar in both ITABs.

Although teachers were aware of sustainability concepts, it was assumed that they may not have been familiar with teaching sustainability (Leal Filho et al. 2021; Zguir, Dubis, and Koç 2022). Capacity building with all 22 teachers was completed, involving them in the PIP module content development from the start. This is in line with the idea of co-creation or participatory process, which is key for sustainability teaching (Perello-Marín, Ribes-Giner, and Pantoja Díaz 2018; UNESCO 2021). Before they started to teach, all the teachers attended a 5-day intensive capacity building workshop on how to teach the PIP module. The teachers were trained by two PIP experts who developed the module and all teachers from both ITABs were trained together to ensure that they acquired the same capabilities. During the workshop with teachers, each theme and related teaching units with corresponding didactic activities, approaches and materials, as well as intended competencies, were explained and discussed. The expectation was to enable teachers to realize what differed from 'business-as-usual'.

3.2 | Study Participants

The participants in this study were students from the two ITABs who have been involved in the PIP module learning. Before starting the teaching, 148 students (98 students from ITAB Karusi and 50 students from ITAB Mahwa) registered for the PIP module on a voluntary basis. The reason for voluntary registration for the module was to maximize the chances of recruiting students who were committed to sustainability learning. During teaching, 44 students (35 students from ITAB Karusi and 9 students from ITAB Mahwa) dropped out, due to time constraints imposed by other school activities that they were required to perform. A total number of 104 students completed the learning process and participated in all three repeated assessments. These included 63 (60.58%) students from ITAB Karusi and 41 (39.42%) students from ITAB Mahwa. The summary statistics on individual characteristics of study participants are presented in Table 2.

3.3 | Study Design and Operationalization of the Self-Perception-Based Assessment

This study is observational research with a self-perception-based assessment process (Dreyfus and Dreyfus 1980; Galt, Parr, and Jagannath 2013; Redman, Wiek, and Barth 2021). Self-assessment was considered the only valid source of measurement. Teachers could assess their students' competencies only to some extent because each was only involved in part of the training of the students. As a consequence, they had a fragmented view of students' competence development.

Other arguments for self-assessment include the fact that self-reporting makes students aware of the meaning of the competencies and, therefore, contributes to increased consistency of answers by reflecting on how well they are able to apply them

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TABLE 1 | Overview of the PIP module themes, rationale, didactic activities, approaches/materials and implementation periods.

Date/phase	Themes	Rationale/scope	Didactic activities	Didactic approaches	Intended competencies
Phase 1 (April–May 2022)	Understanding the PIP approach	Helping students uncover the rationale of PIP principles would help them to think, exercise imagination, create and act differently, by extending beyond what they are familiar with. It is key that students discuss and understand the rural reality, what sustainability means in the context, what is needed, etc. This is expected to increase the intrinsic motivation to become good stewards of the environment, with changed mindsets, and ultimately, serve as change agents in the community.	Brainstorming indicators of rural development, identification of the challenges of rural development, visiting farmers and hearing their testimonies about successes and failures of interventions; diagnosing causes of any failure of public interventions, and the role of the Government; critical reflection on context.	Group discussions in class, videos, image boxes, household photo tree and testimonies, examples of farmers' planning, field visits, etc.	System thinking. Stewardship. Auto-determination.
Phase 2 (June 2022; September 2022; December 2022; January 2023; April–June 2023)	PIP at school	The rationale of this theme was to enable students to practice PIP principles through existing opportunities and resources available at their schools. Similar to PIP in the family, students were mentored to form PIP entrepreneurial groups (groups of 5–10 people—PIAT[a]) and work together on chosen entrepreneurial activities. This was anticipated to stimulate students to exercise their imagination, use curiosity, reflect on their actions and practice solving sustainability issues in a self-steered learning process.	Setting rules for the governing group, group learning, group discussion, sharing experiences and consensus on relevant activities. Mobilize and organize resources, plan and execute tasks. The teacher plays the role of facilitator, coach and mentor, of PIAT groups.	PIP plans, students' self-steered practical activities and projects.	Facilitator of change. Leadership. Innovation and creativity. Planning. System thinking. Stewardship. Auto-determination. Interdisciplinarity.

(Continues)

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TABLE 1 | (Continued)

Date/phase	Themes	Rationale/scope	Didactic activities	Didactic approaches	Intended competencies
Phase 3 (March 2023)	PIP during internship	The rationale of this theme was to enable students to realize how PIP works at the farm household level.	Students visit household farms and realize farming practices for PIP adopters and non-adopters. Students interact with farmers and collect testimonies, identify constraints in the implementation of PIP action plans and discuss with farmers to get to know what goes on. Students establish a comparison between PIP farmers and non-PIP farmers. The teachers organize feedback sessions after the internship.	Field visits, face-to-face discussions with farmers, feedback sessions, and report write-ups.	Facilitator of change. Leadership. Innovation and creativity. Planning. System thinking Stewardship. Auto-determination. Interdisciplinarity.
Phase 4 (June–September 2022; December 2022; April 2023)	PIP in the family	The rationale of this theme was to enable students to become real change agents in their families, neighbouring households and the community at large.	Before students go home for Summer, Christmas and Easter breaks, the teachers do a recap on how PIP works in the family with instructions on how they are supposed to be coaches and facilitators of changes with a focus on how they should teach by example in their families. During a 2-month (Summer) or 2-week (Christmas and Easter) stay at home, students exercise and put into practice different competencies in their family and the neighbourhood. When students are back to school after the holidays, the teachers organized restitution sessions for students to share experiences learned from their homes.	Interaction and experience sharing.	Facilitator of change. Leadership. Innovation and creativity. Planning. System thinking. Stewardship. Auto-determination. Interdisciplinarity.

Note: PIP module content summary.
[a]PIAT = Integrated Entrepreneurial Student' Planning (In French: Plan Intégré de l'Apprenant Technicien Agronome).

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TABLE 2 | Individual characteristics of study participants.

Variable/characteristic	ITAB Karusi			ITAB Mahwa			Sample		
	Mean	Freq	Percent	Mean	Freq	Percent	Mean	Freq	Percent
Age	19			18			19		
Gender									
Male		30	48		17	41		47	45
Female		33	52		24	59		57	55
Area of specialization									
Agriculture		29	46		22	54		51	49
Water and forest		15	24		0	0		15	14
Food technology		9	14		0	0		9	9
Veterinary		10	16		19	46		29	28
Sample		63	61		41	39		104	100

Note: Authors' calculation from the survey data.

(Galt, Parr, and Jagannath 2013). Self-assessment also has the advantage of fitting for formative assessment (Andrade 2019), ease of data collection administration (Cebrián, Segalàs, and Hernández 2019) and quantitative data analysis within which statistical tests can be applied (Faham et al. 2017) to examine changes in competencies development.

To avoid flaws that could be produced by self-assessment, we discussed with students the meaning of targeted competencies and what is expected from them during the learning process. There were extensive discussions and reflections on the use of the competencies of sustainability professionals in authentic task situations. This was anticipated to increase the consistency of answers during self-reporting of students (Migliorini and Lieblein 2016). We also ensured voluntary registration for the course (self-commitment to performance) so that we could expect students to be sincere by focusing on elements that they effectively learned (Khaled et al. 2014).

The repeated-measurement design with 'time' as the within-subjects factor, and 'school' as a between-subject factor (Crowder and Hand 2017), was used. The appropriateness of this design was justified by the fact that we wanted to assess how competencies levels evolved at different points in time and within different school contexts. During the teaching process, competencies were assessed three times, i.e. at the beginning before teaching the module (April 2022), in-between (December 2022) and at the end (June 2023).

To operationalize the self-perception-based assessment, an individual questionnaire was used. Questionnaire elements included eight competencies, as described in the Theoretical Framework Section. In each assessment, competencies were devised in assessable rubrics, within which students were asked to reflect on each competence rubric and assess their own level of competence. For example, the two first competencies ('Facilitator of Change' and 'Leadership') competencies were self-evaluated by asking them to reflect on how well they can communicate, collaborate, interact, mobilize others, positively influence or coordinate a group of fellow community members towards actions for sustainability problem-solving. Details on the operationalization of the self-assessment for each competence rubric are described in Table 3.

These competencies rubrics constituted questionnaire elements. Students were asked to rate their perceived competence level on a 5-point Likert scale, defined in reference to the Dreyfus model of skills acquisition (Dreyfus and Dreyfus 1980) as (1) 'the student needs close supervision or instructions for performing the particular task', (2) 'the student is able to achieve some steps using own judgement, but supervision is needed for performing the overall task', (3) 'the student is able to achieve most of the task using own judgement though he/she may lack refinement', (4) 'the student can see what is important and take responsibility for performing the task' and (5) 'the student no longer relies on rules and guidelines for performing the task, but can make independent decisions on what is possible with relative ease'. In the last column of the questionnaire, students were asked to provide a short argumentation about the chosen rating level. Argumentations provided helped to deepen the discussions on respondents' perception of competencies development.

3.4 | Data Analysis

The analytical data set was constituted by removing students who did not complete all three successive rounds of assessment. We also verified incomplete questionnaires. The data from 104 participants qualified for analysis. One-way repeated measures analysis of variance was used to determine if there were any significant changes in mean scores over time (i.e. from assessments 1-2-3) for each of the eight competencies (the dependent variables in our case) from the PIP module.

Competencies levels over time were recorded as $Comp_{it}$, meaning the i^{th} ($i = 1, 2, 3, ..., 8$) competence level at time t ($t = 1, 2, 3$). Thus, scores $Comp_{i1}$, $Comp_{i2}$ and $Comp_{i3}$ for each competence were recorded separately for $t = 1$, $t = 2$ and $t = 3$ (the within-subjects factor's levels) at ITAB = 1 (Karusi) and ITAB = 2 (Mahwa) (the between-subjects factor's levels). Data analysis was carried out using a general linear model in SPSS software. Before the interpretation of results, various required

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TABLE 3 | Operationalization of the self-assessment for each competence rubric.

Given your participation in the PIP module learning, how well do you think you can ...	
Facilitator of change	... communicate, conduct dialogue around sustainable agriculture challenges.
	... collaborate with others and inspire them to change.
	... interact with people and understand their situation.
Leadership	... mobilize a team.
	... positively influence others.
	... coordinate/direct a group towards a common vision.
Innovation and creativity	... have a sense of curiosity to discover new ways and opportunities.
	... use knowledge in a different way, being creative with the knowledge gained.
	... always find solutions and innovative ways forward for any type of problem.
Planification	... set goals in your daily life, personal organization to achieve your vision.
	... implement your plans by going step-by-step to get to the end-result or goal.
	... self-reflection/assessment to ensure successful achievement of objectives.
System thinking	... understand and explain the interconnectedness of environmental challenges.
	... understand changes induced by your actions and predict/anticipate your future.
	... identify/distinguish factors likely to influence the success/failure.
Stewardship	... understand and value natural resources (land, soil, ecosystems, water, forest).
	... actively take care of natural resources, fostering nature conservation, in own actions and attitude.
	... commit yourself (with intrinsic motivation) to invest in environmental protection with concrete actions and efforts.
Auto-determination	... self-empower and engagement to realize new opportunities.
	... invest in new opportunities for a better future.
	... independently find and organize means to achieve your vision.
Interdisciplinarity	... identify and integrate complementary activities for resilience purposes.
	... link your expertise with other potentials in real life.
	... integrate others' ideas.

Note: Authors, from the summary of study design.

tests for repeated measures ANOVA, including independence of observations, normality and sphericity tests (Bathke et al. 2018) were carried out.

4 | Findings

Results and related interpretation and discussion are presented in a two-fold logic of argumentation. Firstly, in line with RQ1 about the extent to which students' competencies have been developed following their participation in the PIP module learning as a sustainability learning programme. The first part of the results and related interpretation attempt to evidence what changes in competencies levels through rounds of assessment. We first analyse the significance of changes in competencies levels before interpretation and discussion. Secondly, in line with RQ2 about 'the what and why' of possible differences in students' competencies development between the two PIP schools, we also evaluated the significance of differences in competencies levels before interpretation and discussion. The rationale for adding this second research question is that one could assume that the effects of the PIP module on students' competencies development are dependent on the specific context and circumstances of the particular school.

4.1 | RQ1: Trends and Magnitudes of Competencies Development

Before analyzing the trends and magnitudes of competencies development, the significance of changes (i.e., the effects of the PIP module) was analysed based on multivariate tests (overall effect tests) and univariate tests (disentangled effect tests). Results are presented in Table 4.

Overall, the results of the tests of within-subject effects (Upper Part Table 4) for one-way repeated measures ANOVA revealed that the PIP module had a highly significant positive effect ($p < 0.000$) on students' competencies development for all testing approaches. When interacted with the school's context, the results show that the effect of the PIP module is marginally significant ($p \geq 0.10$).

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TABLE 4 | Results for one-way repeated measures ANOVA.

Design	Source	Measure/approach for testing	*F*-test stat.	*p*-value
Multivariate Tests – overall effect				
Tests of within-subjects effects	Time	Pillai's Trace	30.432	0.000***
		Wilks' Lambda	105.707	0.000***
		Hotelling's Trace	283.320	0.000***
		Roy's Largest Root	568.235	0.000***
Tests of between-subjects effects	Time × School	Pillai's Trace	1.513	0.092*
		Wilks' Lambda	1.516	0.091*
		Hotelling's Trace	1.519	0.090*
		Roy's Largest Root	2.289	0.023**
Univariate Tests - disentangled effect				
Tests of within-subjects effects	Time	Facilitator of change	1106.704	0.000***
		Leadership	768.421	0.000***
		Innovation and creativity	1036.510	0.000***
		Planification	1033.439	0.000***
		System thinking	1090.917	0.000***
		Stewardship	751.689	0.000***
		Self-determination	751.689	0.000***
		Interdisciplinarity	851.933	0.000***
Tests of between-subjects effects	Time × School	Facilitator of change	0.982	0.375
		Leadership	0.125	0.869
		Innovation and creativity	1.007	0.363
		Planification	3.779	0.025**
		System thinking	0.939	0.383
		Stewardship	2.717	0.078*
		Self-determination	1.854	0.160
		Interdisciplinarity	1.400	0.249

*Significant at 10% ($p < 0.1$).
**Significant at 5% ($p < 0.05$).
***Significant at 1% ($p < 0.01$).

At desegregated level (i.e., individual competence level), the tests of within-subjects effects revealed that the PIP module had a highly significant effect ($p < 0.000$) on all competencies. However, within school contexts, the PIP module effects significantly depend on school contexts for only 'planification' ($p < 0.05$) and 'stewardship' ($p < 0.10$) competencies (See more details on differences between schools in Section 4.2 (RQ2).

These test results confirmed the significance of changes that were observed from Assessment 1 (T1) to Assessment 2 (T2) and to Assessment 3 (T3). Overall, the mean competencies level evolved from 1.48 to 3.21 and to 4.01. This implies an overall upward trend of competencies development (Figure 1) during the PIP module implementation. From the meaning attached to these scores, the key message from these results in relation to RQ1 is that students evolved from 'the need of close supervision or instructions', to the point where 'students can see what is important and take responsibility' for sustainability problem-solving (Dreyfus and Dreyfus 1980).

The increase in mean competencies level consistently increased from T1 to T3. The less sharp slope of the trend from T2 to T3 as compared to T1 to T2 (see Figure 1), similar to observed magnitudes of changes in Table 5 ($T2 - T1 = 1.73 > 0.80 = T3 - T2$), is evidence that the PIP module has a more significant impact in the earlier stage (T1 to T2) as compared later phase of the PIP module implementation (T2 to T3). Similarly, at the individual competence level, all competencies displayed an upward trend, with a sharper increase during the earlier stage as compared to the later stage of the PIP module implementation.

4.2 | RQ2: Differences Between Schools

Differences in students' competencies levels between the two ITABs were analysed by comparing the competencies development levels for the two schools at T1, T2 and T3 (Table 5). Students from ITAB Karusi consistently scored higher competencies development levels throughout all assessment points as

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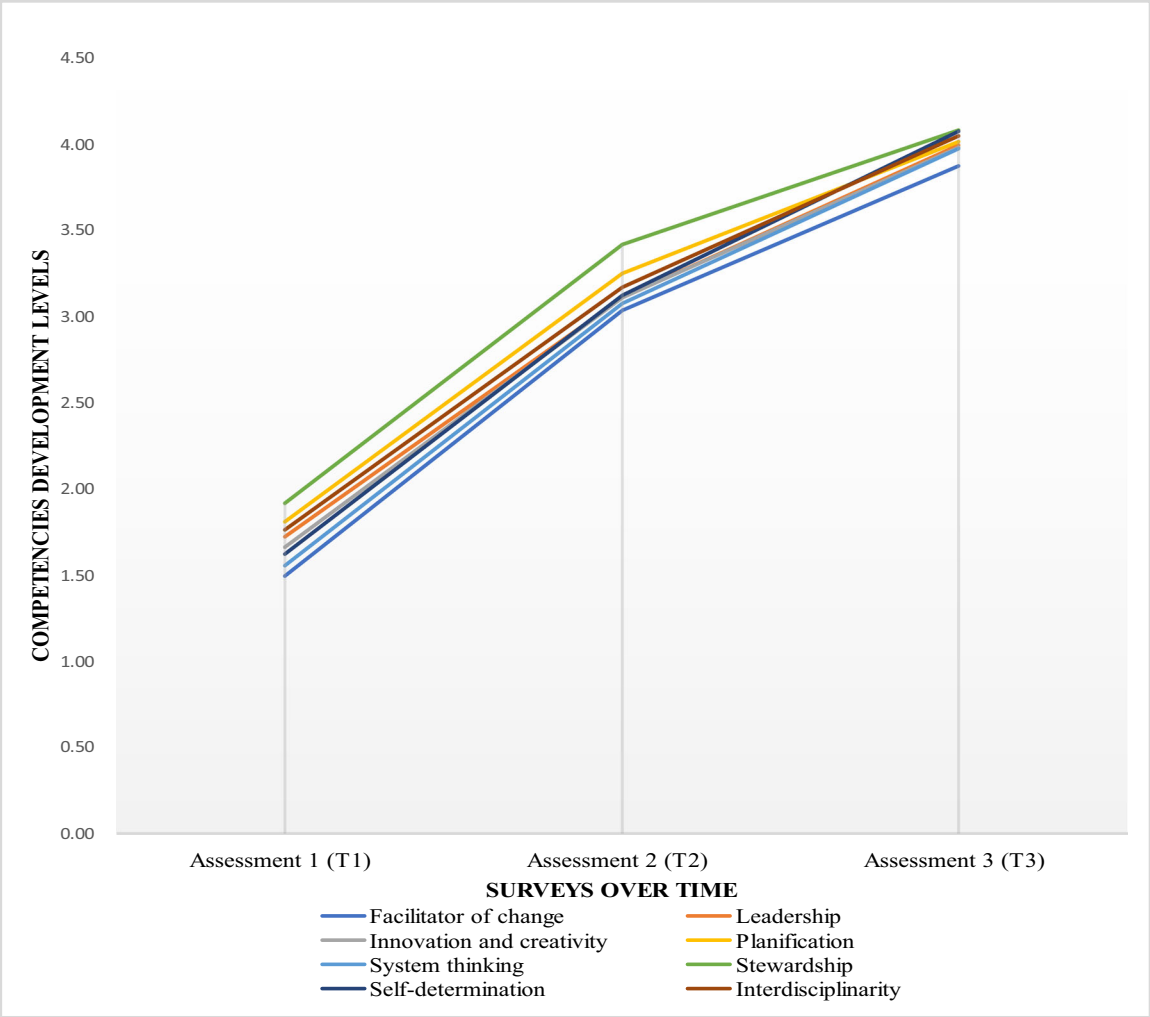

FIGURE 1 | Trends of individual competencies development over time (two ITABs combined).

compared to students from ITAB Mahwa. The differences in competencies development between the two schools were more significant in the earlier stage (T1 to T2) of the PIP module implementation, but less pronounced in the later stage (T2 to T3). Specifically, after the final round of assessment (T3), a significant difference between the two ITABs was found only in Stewardship competence.

The magnitudes of changes in competencies development over time (Figure 2a) were consistently higher at ITAB Mahwa as compared to ITAB Karusi. This indicated that students from ITAB Mahwa developed competencies more sharply as compared to ITAB Karusi. Trends of development over time show that differences were pronounced for two specific competencies, namely Leadership (Figure 2b) and Planification (Figure 2c), similar to results presented in Table 3 in which the differences were found to be significant.

For Leadership competence, the trend displayed in Figure 2 shows that students from ITAB Karusi recorded a higher performance throughout as compared to students from ITAB Mahwa. This difference consistently increased throughout the PIP module implementation. However, students from ITAB Karusi demonstrated higher performance for Planification (Figure 2c), but students from ITAB Mahwa sharply increased Planification, and at the end of the implementation of the PIP module, students' performance converged to the same level of development.

From these results on differences on competencies development between the two schools, the key empirical insight is that the effects of the PIP module on students' competencies development are dependent on the specific context and circumstances of the particular school.

5 | Discussion and Conclusions

In this discussion section, the logic of argumentation is to try to discuss what sustainability teaching elements are to be attached to changes observed and also relate findings to the context (and theoretical framework) of the study. Practical implications, limitations and suggestions for further studies are also discussed with the expectation of bringing theoretical and practical insights for policy orientation for sustainable agriculture education.

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TABLE 5 | Magnitudes of competencies development over time in the two ITABs.

Competence	T1			T2			T3		
	ITAB Karusi	ITAB Mahwa	p-value	ITAB Karusi	ITAB Mahwa	p-value	ITAB Karusi	ITAB Mahwa	p-value
Facilitator of change	1.49	1.33	0.02*	3.04	3.02	0.38	3.89	3.85	0.34
Leadership	1.58	1.48	0.17	3.24	3.07	0.09	4.05	3.91	0.08
Innovation and creativity	1.59	1.33	0.00*	3.26	3.04	0.01*	4.03	3.92	0.10
Planification	1.61	1.39	0.01*	3.51	3.14	0.00*	4.04	3.98	0.24
System thinking	1.43	1.31	0.08	3.05	3.08	0.63	3.98	3.96	0.38
Stewardship	1.78	1.49	0.01*	3.77	3.28	0.00*	4.15	3.97	0.02*
Self-determination	1.52	1.37	0.04*	3.26	3.06	0.03*	3.91	4.33	0.88
Interdisciplinarity	1.63	1.38	0.02*	3.23	3.19	0.32	4.10	3.98	0.09
Mean score per ITAB and per assessment	1.58	1.38		3.30	3.11		4.02	3.99	
Overall mean score per Assessment	1.48			3.21			4.01		

Abbreviations: T1, Assessment 1; T2, Assessment 2; T3, Assessment 3.
*Significant at 10% ($p < 0.1$).

5.1 | RQ1: To What Extent Were Sustainable Agriculture Competencies Improved Following the Implementation of the PIP Module as a Sustainability Learning Programme?

Findings of this study revealed that the PIP module had a positive and significant effect on all intended competencies. In reference to the framework by Dreyfus and Dreyfus (1980), these findings imply that the intended sustainability competencies of students were fostered, and students moved from dependence on close supervision and instructions to a stage in which they could see what was important and take responsibility for handling sustainability issues.

The results indicated that the impact on competency development in the early stage of the training period was not observed as it was in the later stage of PIP implementation. A possible explanation for the decrease in the impact of PIP in the second phase of the training could be the consistency with the principle of diminishing marginal return, a possible ceiling effect. Students were approaching higher competence levels, and the possibilities for further competence development were limited. This is probably more likely than students losing interest or insufficient testing of instruments.

These changes in competencies development can be attributed to PIP module teaching activities in the sense that the focus was on the creation of concrete and meaningful learning situations with an emphasis on attitudinal elements as an important aspect of sustainability learning (Nyamweru et al. 2024—under review). Attitudinal elements of competence were fostered via the use of effective didactic approaches, which were not used in 'business-as-usual' within ITAB teaching. These included group discussions, interactions and experience sharing, videos of testimonies and PIP success stories, images boxes, household photo trees, examples of farmers' planning, field visits and face-to-face discussions with farmers and students' self-steered practical activities and projects.

Practical activities included the practicing of PIP principles by means of Integrated Entrepreneurial Student's Planning (in French: *Plan Intégré de l'Apprenant Technicien Agronome—PIAT*). Field visits included documentation on successes and failures of previous interventions, experience sharing with family members and community development agents at home and in the neighbourhood, etc. Some other reasons for competencies development may be related to the fact that the self-reporting made students aware of what expertise was expected from them and, therefore, permanently reflected on how well they are developing competencies within a formative process (Andrade 2019; Galt, Parr, and Jagannath 2013).

Students were able to think, exercise imagination and act differently beyond what they were familiar with. All these activities ensured an enabling environment, that is, a 'collaborative learning arrangement' or a kind of 'participatory learning process', within which students explored sustainability-related challenges (Weijzen et al. 2024). These initiatives highlighted the effectiveness of the PIP module training. They are also in line with the idea of creating a complex process that enables students to analyse, anticipate, predict and foresee sustainability issues in their complexity (Nyamweru et al. 2023; Wesselink et al. 2017).

The PIP module was introduced within an existing teaching setting in ITABs that is mainly theoretical with teachers as knowledge transmitters. The current teaching contents do not address sustainability problems (Nyamweru et al. 2024—

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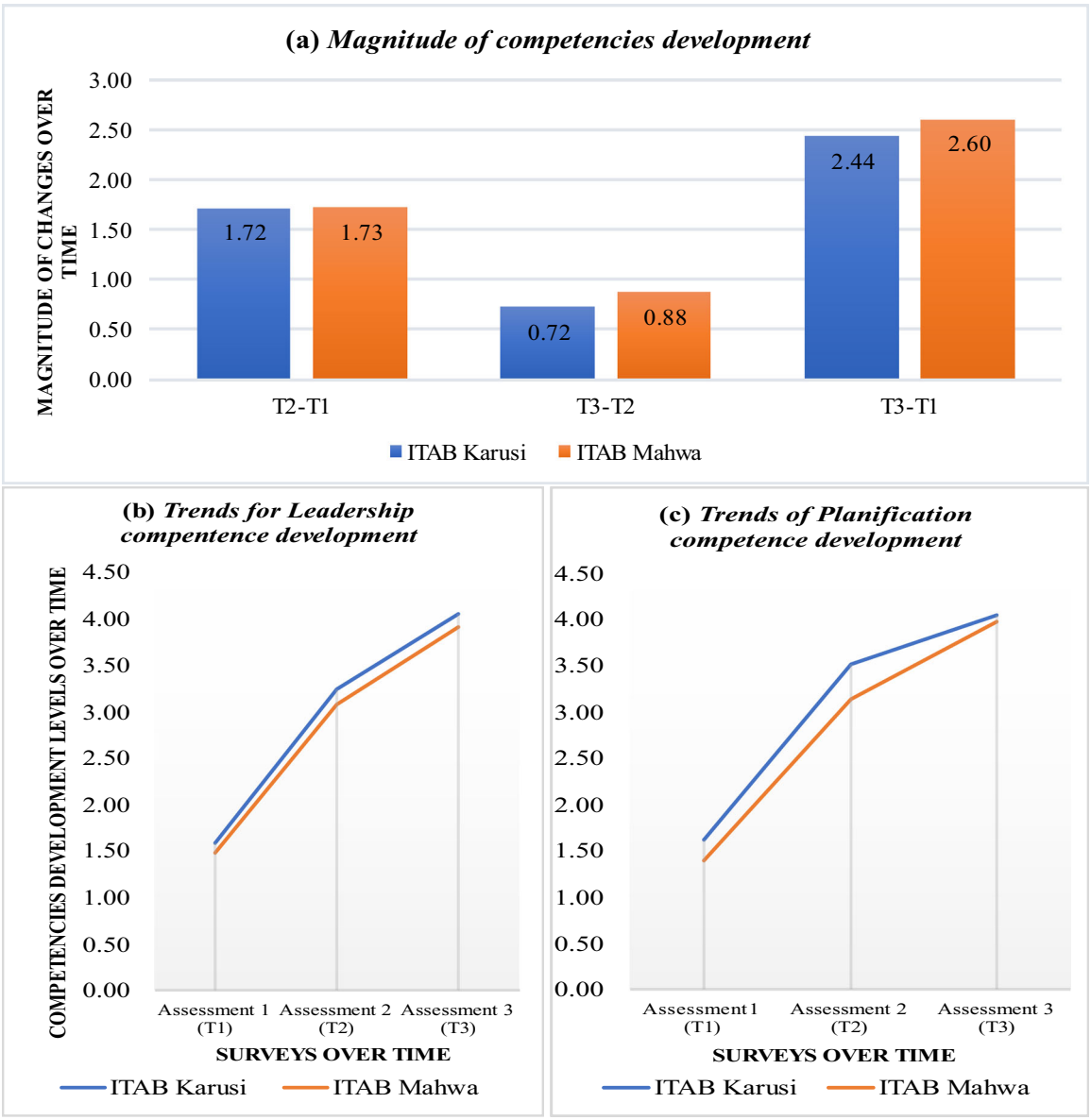

FIGURE 2 | Differences in magnitudes and trends of competencies development between the two ITABs.

under review), such as land degradation, erosion, depletion of rural ecosystems, misuse of natural resources, food insecurity and extreme poverty, and inability at the household level to envision a better future. Although the taught content may have some elements evoking sustainability issues (Nyamweru et al. 2023), students learn from notes and lack connection to real context sustainability challenges. The PIP module added value to the existing vocational curriculum by enabling students to realize things in context, and to understand what sustainability means and what is needed. This is expected to increase intrinsic motivation with changed mindsets. With a recognition that PIP is being now increasingly embraced by local governments and farmers (Kessler et al. 2021; Kessler and van Reemst 2018; Kessler et al. 2016; Ndagijimana, Kessler, and Asseldonk 2019; Nyamweru et al. 2023), it is crucial that these students learn how PIP works, why it is successful and how to apply the key elements and competencies themselves.

5.2 | RQ2: To What Extent Are There Differences Between the Two PIP Schools in Students' Competencies Development?

Findings of this study revealed that students from ITAB Karusi scored higher levels of competencies at the beginning as compared to students from ITAB Mahwa. These differences were almost erased after the implementation of the PIP module. This implies that students from ITAB Mahwa did much to catch up, that is, the trend of competencies development sharply increased at ITAB Mahwa throughout assessment points as compared to ITAB Karusi. This can be qualified as a self-determination of students from ITAB Mahwa and a demonstration of self-inspiration and voluntary commitment to act with motivation for sustainability concerns, which is key for an effective change agent (Nyamweru et al. 2023) and for personal social responsibility (De Haan 2006). Another reason for this result could be the lower competencies level at the beginning of

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the training for students from Mahwa; hence, there was more room for improvement in competence development before a possible ceiling effect was reached than for students from Karusi.

Further arguments on the differences between the two schools may include the fact that ITAB Karusi is located close to an urban centre with more or less sustainability concerns as compared to a rural place where ITAB Mahwa is located. These spatial disparities between urban and rural areas might have led to a preliminary broader view of sustainability challenges for students from urban areas even before the launch of the PIP module, hence a reason to score higher when students were asked to rate their competencies levels at the beginning.

The closeness of ITAB Karusi to an urban centre with a high-density population might also have an impact on the sizes of classes, which might be much bigger. Furthermore, the school being located in an urban place might offer opportunities in terms of the range of students' self-steered sustainability projects during the practical part of the teaching. As a consequence, students from ITAB Mahwa might have received more attention from their teachers (as compared to students from ITAB Karusi) in terms of demonstrations, supervision and monitoring of students' individual activities, which could have reduced the original differences in competence levels, hence a sharp trend of competencies development for students from ITAB Mahwa.

At the individual competence level, significant differences were observed in Planification and Stewardship. This finding can be understood by reflecting on the meaning of these competencies. As seen by Nyamweru et al. (2023) and Evans (2019), in the context of interconnected social challenges, planification competence involves envisioning actions to solve sustainability challenges with clearly defined goals.

To this, stewardship is essential as it refers to the moral responsibility and personal commitment to strive for solving sustainability challenges. From this meaning, three aspects of stewardship competence were assessed: (i) how the student understands and values natural resources (land, soil, ecosystems, water, forest), (ii) how the student actively takes care of natural resources, fosters nature conservation in own actions and attitude, and (iii) how the student commits himself (with intrinsic motivation) to invest in environmental protection with concrete actions and efforts.

In connection to the context of this study, stewardship is crucial. One of the changes in mindsets resulting from the PIP approach is that farmers feel more responsible for the environment and more often make decisions in support of sustainability on their farms and in the local community. This is often lacking as people are sometimes passive spectators (of e.g., environmental degradation) waiting for someone else to solve the problems. Stewardship includes own initiative to restore and protect the environment, community and civic actions, and everyday choices that preserve the ecosystem.

The existence of more diverse specialization, including agriculture, water and forestry, food technology, veterinary and school infrastructure (e.g., availability of farms, equipment, laboratories, etc.), the bigger size of classes at ITAB Karusi as compared to ITAB Mahwa, can be seen as a comparative advantage in terms of diversity of ideas during class discussions/interactions and an active competition of entrepreneurial groups (PIATs), similar to what Jjuuko, Tukundane and Zeelen (2021) considered as 'educative power'. This may lead to more skill development for leadership and organizational skills, as well as planification, which may explain the significant differences between the two schools for these specific competence domains.

However, the bigger sizes of classes had implications in terms of demonstrations, supervision and monitoring of individual students' activities, which was an impediment to the development of competencies. This may be the reason why students from ITAB Mahwa developed competencies more sharply as compared to students from ITAB Karusi. These differences brought out insights relating to the implementation of a sustainability learning programme in a diverse context, similar to what Tarekegne et al. (2023) refer to as the level of competitiveness in a sustainability learning programme. This requires a forward-looking from the design to the implementation of the sustainability learning programme by reflecting on the usefulness of training strategies and the expected learners' performance (Bhat 2023) given the real contexts. This emphasizes the need to observe some competence-based education principles, including the flexibility and adaptation of study programmes to the changing context (Lewis 2023; Nyamweru et al. 2024—under review).

5.3 | Practical Implications, Limitations and Suggestions for Further Studies

In line with the framework by Dreyfus and Dreyfus (1980), the endpoint of development of students' competence is supposed to be a stage where the student no longer relies on rules and guidelines for solving sustainability challenges and makes independent effective decisions. This was not fully achieved. For students who are still at the learning stage, the behavioural changes such as 'no reliance on rules and guidelines' seems to be too ambitious as they might be applicable to change agents who had been already employed or farmers who do not need any close supervision and committed to handle sustainability issues. Given the short time of PIP module learning, effects may have been limited to enabling students to add more value to the learning process with changed attitudes on sustainable agriculture.

Therefore, there is still room to foster competencies for students to ensure they are effective change agents. This is in line with the recognition that integration of sustainability aspects in the education curricula is still a challenge and yet the debate on effective pedagogies is inconclusive (Güler Yıldız et al. 2021; Kahriman-Pamuk et al. 2019; Tasdemir and Gazo 2020).

For optimal sustainability competencies development of effective change agents, sustainability education requires a real situational learning and teaching innovation that is more suited to spatial diversity (inequalities) and schools' individual

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characteristics (the 'educative power' as seen by Jjuuko, Tukundane and Zeelen (2021)) by reflecting on underlying societal challenges in the intended competencies of the curriculum. This requires engaging students in dealing with real-life problems in their respective local communities. Sustainability curriculum designers may consider developing teaching contents that are not generic or static but adapted to each vocational school's context and the nature and spatial disparities of sustainability concerns for sustainability transformations to happen from grassroots-level communities. More crucial, sustainability learning content should consider the duality of urban/rural as sustainability concerns are sometimes different for these two contexts. This requires thorough identification of practical learning contexts and relevant specific learning questions and activities, as well as didactic materials, altogether creating a meaningful learning environment for a typical sustainability competence-based programme (Wesselink et al. 2017; Biemans et al. 2009).

In terms of limitations of this study, although explained throughout that the self-perceived assessment process suited the study, it should be recognized that there is little consensus on effective approaches to assess students' competencies development (Redman, Wiek, and Barth 2021). Critiques exist on the self-perception-based assessment approach, including that students may inconsistently rate their level of competence development, as there are no means provided to assess their declaration (Cebrián, Segalàs, and Hernández 2019; Holdsworth, Thomas, and Sandri 2018).

Further studies could focus on exploring the effect of action-research sustainability-oriented programmes using other effective approaches to assess students' competencies development. These may be concerned with designing experimental research with complete randomization in which treatment and control groups (those involved and those not involved in the sustainability learning programme) are compared from baseline and endline indicators that are more objectively measured, hence enabling argumentations on competence development level to be solely based on statistical evidence (Lans, Blok, and Wesselink 2014). This would yield robust results to qualify changes as impacts of the sustainability learning programme.

Another limitation is related to the possibility of upscaling the implementation of the PIP module to other ITABs. There exists a policy issue related to the process of curriculum revision that is rigid and too hierarchical for it to consider lessons learned from the PIP module experience. It should also be noted that designing a sustainability programme that reflects on real-context dynamic sustainability challenges requires a demanding participatory process involving a lot of investment in terms of time and money. This is very crucial within the context of a poor economy with competing priorities and with a limited governmental budget. Therefore, sustainability curriculum innovations may not be easy to achieve for the short- or mid-term views.

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Conflicts of Interest

The authors declare no conflicts of interest.

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