Improving group work practices in teaching life sciences: Trialogical learning

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Abstract

Trialogical learning, a collaborative and iterative knowledge creation process using real-life artefacts or problems, familiarizes students with working life environments and aims to teach skills required in the professional world. We target one of the major limitation factors for optimal trialogical learning in university settings, inefficient group work. We propose a course design combining effective group working practices with trialogical learning principles in life sciences. We assess the usability of our design in a) a case study on crop science education and b) a questionnaire for university teachers in life science fields.

Our approach was considered useful and supportive of the learning process by all the participants in the case study: the students, the stakeholders and the facilitator. Correspondingly, a group of university teachers expressed that the trialogical approach and the involvement of stakeholders could promote efficient learning. In our case in life sciences, we identified the key issues in facilitating effective group work to be the design of meaningful tasks and the allowance of sufficient time to take action based on formative feedback. Even though trialogical courses can be time consuming, the experience of applying knowledge in real-life cases justifies using the approach, particularly for students just about to enter their professional careers.

Introduction

Feedback from alumni, employers and the general community about the skills actually needed from university graduates (see e.g. Holtzman & Kraft, 2011; Lindholm, 2011; Tynjälä, Slotte, Nieminen, Lonka, & Olkinuora, 2006) is putting increasing pressure on educational institutions to change their teaching practices from lecturing towards learning activities that better promote competences relevant to tomorrow's work life (Bettger et al., 2014; Lakkala, Toom, Ilomäki, & Muukkonen, 2015, Mills-Dick & Hull, 2011). These practices usually include employing joint efforts to target open-ended problems using internet-based tools and social media, and being able to publicly present the outcomes (Bettger et al., 2014; Holtzman & Kraft, 2011). *Trialogical learning* is one approach emphasizing collaborative knowledge-creation practices aiming to produce new knowledge via developing novel reusable solutions or improvements on real-life artefacts (e.g. operation models, plans, products) in collaboration with other parties (Paavola & Hakkarainen 2005; Paavola, Lakkala, Muukkonen, Kosonen & Karlgren, 2011; Lakkala et al. 2015).

The trialogical approach can be utilized at any level of learning, although the significance of this pedagogical method is probably best evidenced in the academic and corporate worlds. In trialogical learning, conventional monological (individual efforts) and dialogical (community participation) learning models are combined with a 'trialogical' learning layer, whereby the third element is the commitment of students to producing artefact(s), that is, meaningful and concrete outcome(s) (Figure 1), preferably in collaboration with working life professionals. Ideally, the group members use the synergy of collaborative knowledge creation to go beyond their previous individual capabilities, skills and knowledge and to develop and improve real-life artefacts – the production of which combines individual aims with collective ones (Paavola & Hakkarainen, 2005). Trialogical learning thus efficiently familiarizes students with working life environments and facilitates especially those learning and working skills that are eventually required in the professional world, including social skills (in particular, team work), project management skills and presentation skills (Holtzman & Kraft, 2011; Lakkala et al., 2015).

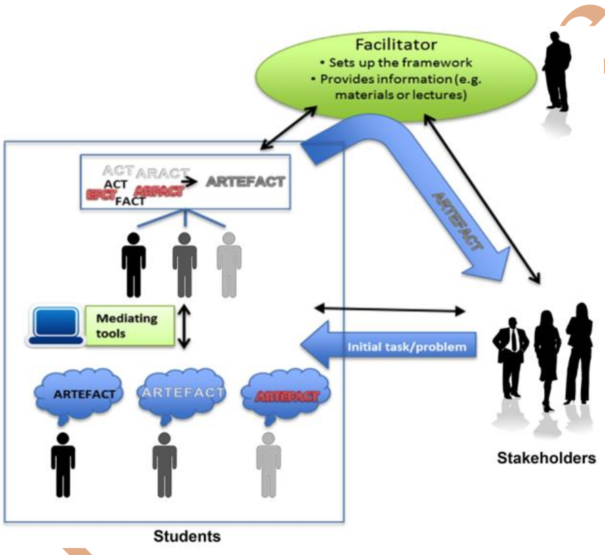

Figure 1. *Graphic representation of the trialogical learning process, where the students, stakeholders and the facilitator (teacher) are the actors with specified responsibilities. Here the students collaboratively develop a new solution for the initial task/problem of the stakeholder, by moving from the scattered individual concepts to joint knowledge using the available information and mediating tools. The black arrows illustrate the movement of information and feedback, and the thick blue arrows the movement of the problem/the artefact as a solution*

The collaborative group in trialogical learning typically (or optimally) consists of people (learners) with diverse backgrounds. At best, this multidisciplinary approach brings innovative thinking to the learning process, enabling not only efficient learning but also novel ideas and innovations. To facilitate this, the selected target problem to solve (and the foreseen solutions thereof) should attract (i.e. motivate) all group members involved in the learning process to take ownership of the common goal (Smarkusky, Dempsey, Ludka, & de Quillettes, 2005). Further, joint efforts should be made to negotiate the objectives of collaboration and the ways in which these objectives will be achieved by iteratively developing the artefact(s). Indeed, trialogical learning should be an active iterative process between the group members, stakeholders and the supervising teacher (Lakkala et al., 2015).

The aim of this study is to combine guidelines of effective group work with principles of trialogical learning in a university course in life sciences and to specifically develop models and guidelines to improve the coaching and evaluation of group work during the learning task for academic students. We introduce a model illustrating key steps for organizing a process of trialogical learning in a life-science course, combined with the principles of effective group work. Further, we test our model in a real-life course and analyse the feedback from the participating teacher, stakeholders and students. Additionally, to explore the potential for such a pedagogical approach to be widely used in life sciences, we surveyed a cohort of experienced life science university teachers about their views on the model and their proneness to use the model to design their courses.

Theoretical framework

Trialogical learning

Trialogical learning is a pedagogical approach focusing on the joint creation of new knowledge and practices while working on real-life artefacts (e.g. products). Paavola et al. (2011) suggested six design principles (DPs) to describe the selection, design and evaluation of knowledge practices in educational settings. These DPs derive from earlier theories, such as the knowledge-building approach (Bereiter, 2002) and technology-enhanced collaborative inquiry (Lakkala, Muukkonen, Paavola, & Hakkarainen, 2008).

In brief, the six principles of trialogical learning are as follows: **DP1**, organising activities around shared objects; **DP2**, supporting interaction between personal and social levels and eliciting individual and collective agency; **DP3**, fostering long-term processes of knowledge advancement; **DP4**, emphasising development through transformation and reflection between various forms of knowledge and practices; **DP5**, cross-fertilization of various knowledge practices across communities and institutions; and **DP6**, providing flexible tools for developing artefacts.

Putting the DPs into practice has been analysed previously through examples from different fields of education (Lakkala, Ilomäki, Paavola, Kosonen, & Muukkonen, 2012; Lakkala et al. 2015; Muukkonen et al., 2013). For example, Muukkonen et al. (2013) have examined DP1, DP5 and DP6 in a case study of two courses. In their study, one of the objectives was to examine how course activities could promote working on shared objects. Another objective was to analyse how well the groups were guided throughout the course projects. In the study, the groups received feedback throughout the process not only from the teachers but also from customers. Real-life customer involvement was shown to promote cross-fertilization of knowledge (Muukkonen et al., 2013). Further, both the customers and students valued their collaboration because of the proximity of this practice to real working life, since the expert's perspectives were heard during iterative sessions and the students learned multidisciplinary problem solving. On the other hand, some of the students would have wanted more instructions, feedback and clearer structure in the courses (Muukkonen et al., 2013).

The trialogical learning approach shares several characteristics with *community-engaged problem-based learning* (Bettger et al., 2014), as in both approaches student groups use their creativity to work on a specific project (usually originating from the community), and the skills learned are relevant to their later careers. Bettger and colleagues reported that the combination of community-engaged and project-based learning facilitated students to meet or exceed their previously self-defined learning objectives, and the project's results (or artefacts) clearly demonstrated 'ethical, creative professionalism', according to their community partners. Further, the group work on the projects developed communication skills both within and outside the academy, but also produced good experience of project management skills – all of which are a good match to the skills the community expects from graduates (Holtzman & Kraft, 2011). Bettger et al. (2014) further stressed the importance of the continuous formative feedback that engaged students in continuous/sustained learning activities (and reduced the teacher's workload). Moreover, the efficient use of modern digital technology was shown to activate students and to increase their efforts in the shared project.

The challenges for the implementation of the trialogical learning approach are often university courses that are too short for the whole synergetic process to be effective and the issue of encouraging students with different backgrounds to take ownership of the common goal (Lakkala et al., 2015; Paavola, 2012; Paavola et al., 2011). The ownership problems can be classified under DP2, as in this principle projects should be designed so that students must take responsibility for their own activity and learning as well as shared tasks (Paavola et al., 2011). DP2 is also the most interesting from the perspective of creating an environment for successful group work. Lakkala et al. (2015) examined how the principles of trialogical learning could be utilized in redesigning three university courses, one of which was a project work course in biosciences. Apart from that particular study, there is little knowledge on how well trialogical learning can be adopted to life sciences.

Effective group work

Trialogical learning is strongly based on efficient group working, because the coaching and monitoring of good group working practices and dynamics is often insufficient, particularly in academic settings (Bolton, 1999). Student groups are commonly taught only the content and not instructed on group work dynamics, which is why students often have negative experiences with group work (Bolton, 1999; Pauli, Mohiyeddini, Bray, Michie & Street, 2008). Prevailing issues often not adequately addressed include the lack of group commitment, the failure to set ground rules and take optimal advantage of the group members' skills, as well as the issue of 'free-riders' (Bolton, 1999; Colbeck et al., 2000; Pauli et al., 2008).

Bolton (1999) suggests targeting optimal group working *via* three modules (contact sessions of coaching): **1**) the initial phase, **2**) the discussion and feedback phase, and **3**) the reflection phase. During the first phase, the facilitator introduces the tasks to the students and forms the teams. Previous experiences with group work – both positive and negative – are also jointly reflected on and discussed. This phase is considered the most important (Bolton, 1999). Indeed, if there is no time to complete all the other phases, this one should be always included.

Smarkusky et al. (2005) elaborated on the useful procedures for the initial phase: efficient team building and discussions on team dynamics and problem solving will facilitate awareness of optimal team work and tools for dealing with potential conflicts. After the teams have agreed on the procedures, all the team members sign concrete agreements containing clear working rules. The team contract and agreed rules increase the self-awareness of individual responsibilities. Like any other contract, the team can refer to it when significant problems arise (e.g. insufficient input from a group member).

According to Smarkusky et al. (2005), project milestones could be used to prioritize tasks and manage the time schedule. Self-awareness of one's own functioning in team work and awareness of the diverse roles in the group (leader, recorder etc.) could be deepened using short interactive pretasks within randomly assigned groups. Finally, effective meeting practices could be scaffolded to facilitate optimal group working (e.g. a meeting agenda, premeeting materials, follow-up) (Smarkusky et al., 2005).

The discussion and feedback phase should be organized after three to four weeks of working on the project (Bolton, 1999). This should allow constructive feedback on the progress and on individual investments and roles. Formative feedback (Boud 2000; Nicol & Marcfarlane-Dick 2006; Nicol, 2010) is crucial in efficient learning during the time that students are working on the tasks and artefacts. Students need to continuously receive understandable and targeted feedback in a timely manner in order to be able to improve the next assignment. In addition, the feedback needs to be contextualized and goal referenced: framed with reference to the learning outcomes and assessment criteria, and balanced in that it points out the positive as well as areas in need of improvement (Boud 2000; Nicol & Marcfarlane-Dick 2006; Nicol, 2010). The feedback should also be concrete enough to allow the students to take action.

The final reflection phase is ideally organized within a week after the students have completed their assignments at the end of the course. This time window allows students to take some distance from the actual project and facilitates reflection on the overall learning experience. All group members will receive feedback and a rating reflecting the overall success based on preagreed group rules. Group members should also reflect on their own input. We have taken these principles of effective group work into account when developing the model of a course design based on trialogical learning in life sciences.

A course design model of facilitating effective group work in trialogical learning settings in life sciences

Based on previous research (Bolton, 1999; Paavola & Hakkarainen, 2005; Paavola et al., 2011; Bettger et al., 2014; Lakkala et al., 2015), we have designed a model flowchart of a trialogical learning course applicable to a range of project-based or inquiry-based life science courses illustrating the roles and key activities of the teacher (facilitator), students and stakeholders at different phases (Table 1). We strove to make the model as concrete as possible so that it is easy to apply in practical course design, but also to be in line with and follow the abstract trialogical design principles.

Table 1. A flowchart of a trialogical learning course and the roles of the teacher (facilitator), the student and the stakeholders at different stages. The text in **bold font** refers to changes made based on the case study feedback.

	Planning and pre-course	First session	Contact sessions	Mid-course	Final session	Post-course
Timing	0–8 weeks before the course	Week 1	Weeks 1–n	After 2/3 of the course**, at least 2 weeks before the final session**	During the last week	After the last week
Facilitator	Identifies stakeholders and problems, and designs the course **(4–8 weeks before the course)**. Sets up, collects and analyses the pretasks; based on the results of the pre-tasks forms even teams.	Introduces the tasks to the students and forms teams. Acts as a discussion moderator concerning previous experiences with group work. Collects and structures the feedback of the groups. Introduces effective group working practices.	Oversees that the group work is running according to the agreement. Answers questions.	Coaches and facilitates the discussions. Arranges feedback from stakeholders and teacher(s).	Coaches and facilitates the discussions. Assesses the presentations. Gives feedback.	Gives feedback and assessment of the student learning. Gives feedback to students and stakeholders about the course. Uses the course outcomes to design the next courses.
Student	Pre-course task	Actively participates in the discussion of group work experiences and suggests effective working methods. Starts drafting the group work ground rules agreement.	Submits the group work agreement within one week and follows it during the learning process. May contact the stakeholders for extra information on the task.	Gives a short presentation on the progress of the group work. Discusses and gives feedback on the progress of the group work, e.g. completes the feedback form about the group members in silence and then discusses. Gives feedback to other groups about their work.	Presents the final version after the formative feedback. Assesses other groups and his or her own group members, gives feedback.	Uses the course outcomes. Gives feedback to the facilitator and stakeholders about the course.
Stakeholders	Contributes to the problem design, communicates to the facilitator the desired outcomes and the time available for the course work (problem design, feedback from the student work etc.)	May participate and explain the tasks/problems. Provides extra information, if needed.	Provides extra information, if needed.	Can participate and give feedback.	Can participate and give feedback.	Uses the course outcomes. Gives feedback to the facilitator for next year’s courses.

Research questions

Our study aimed to assess the usability of our design model of facilitating effective group work in trialogical learning settings (Table 1) and to find ways to improve it. For that purpose, we used feedback from all parties (students, stakeholders and the facilitator) of a case study course in crop science. Further, as the final decision on whether or not the model will actually be used in future teaching settings depends on university teachers, we explored the views of a cohort of life science university teachers on the model. Specifically, the research questions were:

1. How did the participants of a crop science course (students, stakeholders and the facilitator) evaluate the pedagogical approach based on their own experiences in the course?
2. How did a group of university teachers evaluate the benefits and challenges of the pedagogical approach with the course design model? How likely is it that they would themselves design a course based on the proposed model in the near future?
3. Were the group work practices suggested in the course design model perceived differently by the students participating in the course and by experienced university teachers?

Methods

In the current study, we used design-based research (Design-Based Research Collective, 2003) to study the course design model based on the trialogical learning approach, in that the initial model was later modified based on the experience gained from the course, which was designed according to the model. These changes (mostly regarding the timing of different tasks) are marked in the model (Table 1).

Participants

The participants in the current study can be divided into those involved in the case study course (students, stakeholders and the facilitator) and a set of life sciences university teachers at the University of Helsinki evaluating the model. The students of the course were sixteen in total, all Finnish students of 3–5th year plant production majoring students. The stakeholders were two farmers from Southern and one from Central Finland, each of whom contributed one problem field to the course (with the exception of one farmer from Southern Finland who contributed two fields). The first author was the facilitator and responsible teacher in the course.

Additionally, a cohort of university teachers (n = 14) teaching in life sciences at the University of Helsinki was asked to fill in a questionnaire about their views towards the trialogical learning approach and how they suggest it should be developed further. Half of the teachers were participants of the University Pedagogy 5 course in the University of Helsinki (2015–2016), mostly having < 10 years teaching experience and half were departmental colleagues of the three first authors of the current paper; an effort was made to include more teachers with longer teaching experience to ensure representability (mean of teaching experience was 10.9 ± 8.3 years).

All participants who provided their answers in the survey agreed that their answers could be used in the present study.

Case study course

The case study course was an eight-week graduate degree (MSc) course entitled ‘Current issues in crop science: nutrient cycling’. The course consisted of a pretask, facilitating lectures and nine topic lectures on novel methods on how to close nutrient cycles in agriculture (e.g. ‘catch crops’).

The facilitator contacted farmers ('stakeholders') from different regions of Finland and collected the group work topics, problematic fields with poor fertility, a week prior to starting the course. This time window was soon recognized as inadequate since several farmers provided their 'problem fields' only after the course had started.

The pretask included questions about the students' previous experience with nutrient cycling and the methods that students considered most beneficial for making the group work more efficient (Bolton, 1999). Based on the students' responses to the pretask questions, the facilitator formed four four-member student groups, so that each of the groups included students with and without personal experience in farming.

Altogether there were four facilitating lectures. The first of these provided an introduction to the topic and explained the course requirements and the trialogical approach. Furthermore, in the first lecture, anonymous answers to the pretask exercise were reviewed and discussed, groups were formed, and the group members were asked to gather together and discuss their previous experiences with group work. After a short discussion, the results were shared on a Padlet virtual wall (http://padlet.com), followed by discussions on how to avoid the previously experienced problems related to group work. The second introductory lecture introduced the theoretical concept of soil fertility and provided information about available tools (including online tools such as WebWisu for soil fertility management) and resources for completing the group work task.

One week after the first lecture, the students were required to submit signed agreements on group work practices, tools and roles. During weeks 2–6, the students participated in topical lectures as well as independently worked on the artefacts in groups. This group work included, in addition to using the literature and information from the lectures, direct contact with the stakeholders (i.e. farmers) to acquire more details about the farmers' perceptions and the technologies and solutions available in the study region. The students used several flexible tools during the group work: Moodle, Padlet, Google Docs, Google Forms, WhatsApp and Office365.

The students received two rounds of formative feedback on their artefacts. The first of these was in course week 4, when they received peer feedback from other groups on a three-page (mid-course) report via the online platform Moodle. The second round took place in week 6 (the first full draft). The full draft, an eight-page report, was also uploaded to Moodle for their peers to become familiar with, followed by the third facilitating session, in which the groups briefed their peers about their project in a five-minute oral presentation. Next, other groups provided oral feedback in group-to-group discussions, followed by all of the group members giving personal feedback to their own group members regarding their group work performance and habits (in writing). The next day, the students were provided with written feedback from the farmers (stakeholders) and the teachers (two teachers plus the facilitator) via the online platform Moodle. After the feedback session, the students had one week to finalize the artefacts. After that week, the final assignments were submitted, and the student groups presented them orally during the last session, followed by peer assessment. Finally, the students submitted individual learning journals two weeks after the final session.

The students' learning was assessed based on:

1. an individual learning journal about the topical lectures and provided scientific papers (60% of the grade) and

2. the group work task (the artefact) of a 15-year crop rotation plan for a real-life farmer (stakeholder) on a problematic field: the written task (20% of the grade) and an oral presentation (20% of the grade).

Data collection

Experiences about the course approach were collected on paper (from the facilitator) and by e-mail communication (from the stakeholders). The student feedback was collected during the last contact session, after the students had completed the peer assessment. All the students (n=16) returned the questionnaire requesting feedback about the general course approach (working on a real-life problem), the group work practices and assessment.

The surveys were numbered 1–16, and the answers were saved in a spreadsheet program by the first author and cross-verified by the second and third co-author by carefully comparing the scanned questionnaires to the spreadsheet. Further, as the majority of students (n = 13) also provided non-anonymous textual (NAT) feedback as part of their individual learning journals, this data was used as a separate dataset to further illustrate the points made in the anonymous questionnaires (the NAT answers were coded A–M).

The teacher survey was completed within a 15-minute timeframe, after the teachers had been introduced to the trialogical learning approach and the course design based on it (by giving them a hard copy of Figure 1 and Table 1). These surveys were also numbered (1–14) and processed in the same way as the anonymous student surveys. Both the student and teacher questionnaires contained options for giving both numerical feedback (multiple choice scores 1–5, where 5 was the highest) and open comments.

Data analyses

The numerical scores were used to calculate the descriptive statistics (means, standard deviation and standard error of the mean). To answer research question 3, the views of the students and teachers regarding group work practices were compared using the independent samples Mann-Whitney U Test. This non-parametric test was chosen for the majority of the questions because the data was not normally distributed ($p < 0.05$, Shapiro-Wilk test). The numerical data was analysed with statistical package SPSS v. 23.0 (SPSS Corp., Chicago, USA).

The open comments were analysed with a data-driven thematic analysis method (Braun & Clarke 2006) by first dividing them between mutually exclusive *challenging/negative* and *positive* features of the course, followed by dividing those between three main topics (*course approach and setup*, *group work practices* and *assessment*). Next, the most commonly occurring categories were identified in a data-driven manner (altogether there were 10 most common categories), and the answers were coded according to these. The labelling of the categories and the suitability of each individual answer to the categories were reviewed by the first author through several iterative data examination phases, as suggested by Braun and Clarke (2006), followed by data validation by the second and third author according to the principle of investigator triangulation (Creswell & Miller, 2000) to reduce possible biases in the analysis.

Results

Evaluation of the pedagogical approach by the course participants

Facilitator and stakeholders. The participating facilitator (the first author) and the stakeholders were, in general, satisfied with the trialogical learning and teaching approach in the case study. Organizing (the first) trialogical learning course was a new learning experience for the facilitator and required significant input and time. It was also challenging to find enough interested and motivated stakeholders (i.e. farmers), and it became evident that the one-week time allocated for this was not adequate. Furthermore, certain organisational aspects (e.g. e-mail communication with the stakeholders if the student teams did not receive the information directly) caused extra work. All these processes can be improved based on the experience of the facilitator in this case and, in particular, the feedback from the students (see the next section) and stakeholders. Overall, the facilitator witnessed highly motivated student teams working effectively, and the quality of their work clearly met the expectations of the stakeholders and teachers; thus, the facilitator would definitely consider organizing similar courses again in the near future.

The stakeholders (i.e. farmers) agreed that the ideas suggested by the students were useful and well thought through, and they would consider changing their current practices according to these proposals. They also mentioned that they received the initial data request with too short notice, which should be changed. The farmers liked that the students were active and motivated to contact them directly and request additional details and information, and that they acted on the farmer's feedback based on the preliminary version of the cropping plan and made the requested changes (e.g. provide more detailed economic calculation of the proposed practices).

Students. The students assessed the course, in general, rather highly (mean 3.8 out of 5, ± standard deviation (SD) 0.8, n = 16). The open answers support this conclusion, with 16 positive comments about the course approach compared to 4 negative comments (Figure 2). For example, student #9 responded: *'I think that the group work was a great way to activate the students. (...) The course was different than others! More courses based on these ideas should be organized!'*

Students also felt that the trialogical approach (work on a real farmer's case) is useful (mean 3.9 ± 0.7) and facilitates creativity and effective learning compared to traditional group work exercises (mean 3.5 ± 0.7). The higher effectiveness of this approach in deep learning was mentioned by 13% of the respondents. The NAT feedback provided more details:

A: 'I liked that the groups were formed for us [by the facilitator] and the group work was performed professionally via actually usable solutions. This does not always seem to be the approach of choice in the university environment.'

D: 'I found the course to be really useful, and I hope that it will be organized in some form also in future for other students. I feel that I learned more during the course than is usual in five-credit courses. This of course is affected by the fact that I grew interested in soil amendment materials and closing the nutrient cycles in farms in a completely new way.'

G: 'It was a very positive experience to finally have the opportunity to apply the skills acquired from other courses.'

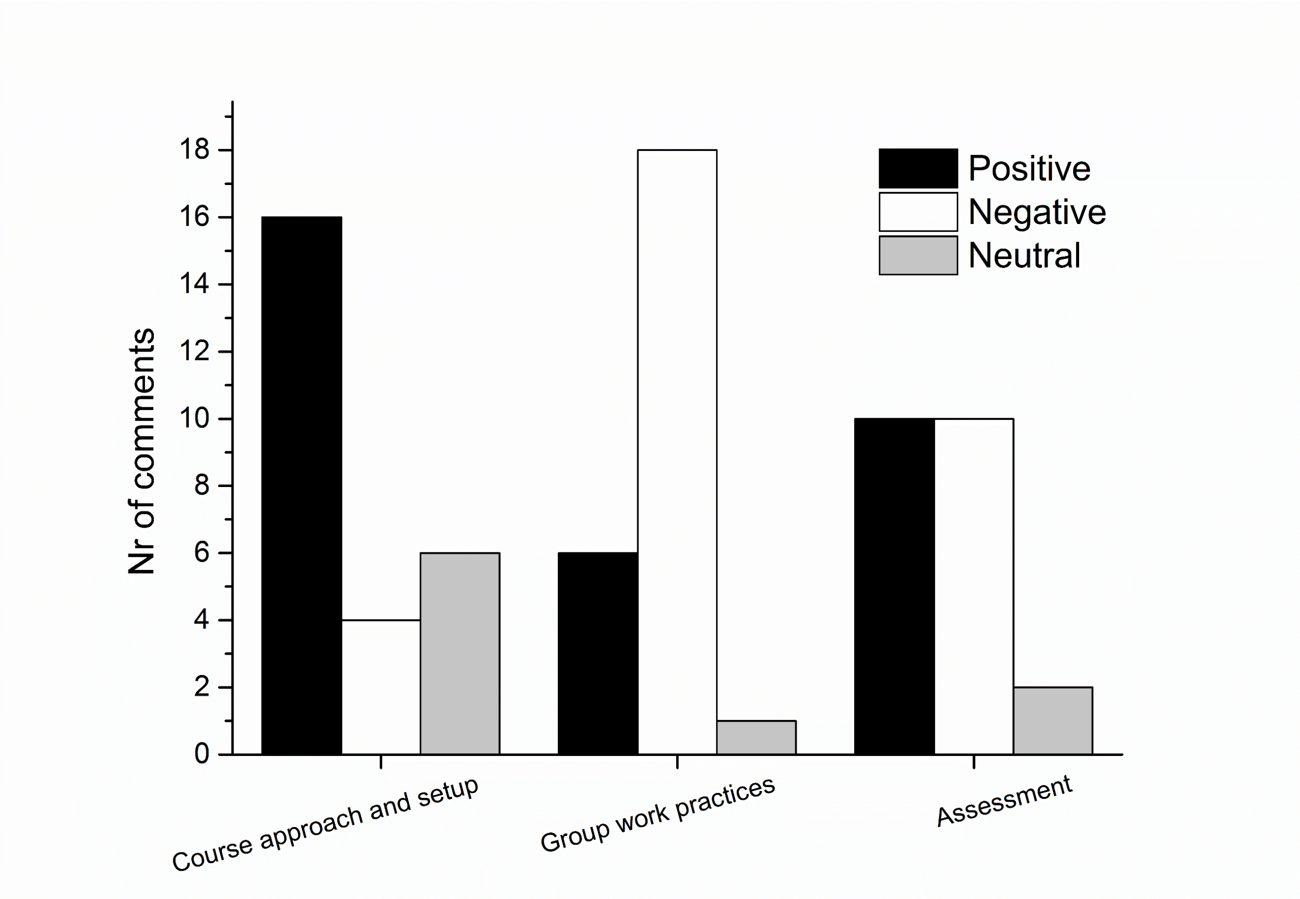

Figure 2. *The student responses as open comments distributed between the main categories and their nature. Altogether we identified 32 positive, 32 negative and 9 neutral responses.*

The most criticism was directed to the group work practices (18 negative comments vs 6 positive comments, Figure 2). The textual analyses revealed that the most concerning issues were the short time (one week) provided for taking the peer and teacher feedback into account (38% of the students), the claim that the '*five-minute preliminary presentations and/or the following feedback was of no use*' (31%), and in general, that the level of feedback asked for was too high (19%).

The students' feedback suggested that the trialogical learning course made a greater time demand compared to standard group exercises, which should be taken into account when setting the study credits. Indeed, the student workload of the course was assessed higher than the earned credits (mean 3.7 ± 0.8, where 4 would have been 'rather high'). The open answers supported this: 38% of the students replied that the workload was too heavy compared to the credits, whereas 19% reported that it was suitable:

#15: 'The group work was too heavy. Especially when doing the calculations, one has to go through so much information (...) that none of the group members has time to get acquainted with the work of the other group members, and learning occurs only from one's own tasks.'

#6: 'Why did the course have two separate tasks when both of them were at least five credits already?'

On the other hand, the different tasks were also seen as supporting the learning of the course content:

#8: 'The group work and learning journals were rather time consuming, compared to if there had been an exam. But this way one learns more.'

Three students (probably from the same group) noted that the stakeholders/cases should have been chosen better as they faced obstacles in obtaining information from the farmer, and in addition, the case field given to them was too small for meaningful maintenance (0.61 ha). This underlines, again, the need to plan the course early. Moreover, the NAT feedback provided some useful hints for finding suitable stakeholders in the future through the course participants' own networks:

K: 'From the exercise fields I would have expected a more reasonable scale than a range from less than a hectare to fields with more than eight hectares, especially when we did not receive the farmers' contact details in the first contact session. I am sure that among the course participants there would have been enough students with access to their own farm data so that there would have been enough interesting problem fields for all the groups. For one's own (or one's friends') needs, one works with much higher motivation than for a farmer who cannot even be called or met ever in person.'

Two students also pointed out the importance of good communication during the course; for instance, student #11 answered in the following way to the question about the main positive features in the course:

'Good communication of the timetables, varying lecturers and topics, deep learning.'

Evaluation of the course design model by university teachers

Overall, the teachers' answers had fewer strong opinions than in the student survey concerning the course design model based on the trialogical learning approach; the majority (9) of the open comments by teachers were neutral, usually just discussing the issues rather than giving an evaluation. Altogether we identified six positive, four negative and nine neutral comments. This difference is understandable because the teachers only evaluated a theoretical model, whereas the students had actual experience of working in the course based on the model.

The teachers saw considerable benefits in the trialogical approach (mean 4.1 ± 0.7) and were of the opinion that this approach supports creativity and effective learning more than traditional group work (mean 4.3 ± 0.5). The latter opinion was higher than that of the students who had actually taken the course (mean 3.5 ± 0.7; $p = 0.006$). They also saw that the involvement of stakeholders in student learning is useful for the learning process (mean 4.1 ± 1.0), yet only 21% of them would organize such a course in the next two years themselves (mean 2.8 ± 0.9, Figure 3).

Figure 3. *The teachers' view on the probability of organizing a trialogical course within the next two years and their opinions on assessment practices*

The open comments explained their views in more detail:

Teacher #1: *'Why not, for an appropriate course where trialogical learning fits.'*

Teacher #10: *'I use problem-based learning in two of my courses, and the involvement of a stakeholder (and his/her practical problem) would bring a novel aspect. I am ready to try. ... I think it is a very good way to learn how to study in a group and to utilize previous learning in a new context.'*

Teacher #12: *'It would be highly motivating for both the student and the teacher, if the problem comes from real life.'*

However, some issues were also raised; 14% of the teachers concluded that organizing a trialogical course is more demanding for the teacher than a regular course.

Teacher #10: *'It might be difficult to find a suitable stakeholder in the beginning. I would definitely use my connections for this.'* Teacher #10 further noted, *'This sort of group work [trialogical learning] requires strong investments in the beginning and also support to establish the setting for optimal role-forming practices. Particularly since the problem-based learning type of group work has not been really used in biology studies. It would be great if one gets help from the teaching personnel to find "appropriate" stakeholders.'*

The involvement of stakeholders stimulated many comments among the teachers.

Teacher #4: *'It [the participation of a stakeholder] depends on the nature of the problem: if research is conducted, could the "outside supervision" pose a problem? A conflict of interest.'* In contrast, teacher #7 said that *'It [the participation of a stakeholder] fits better in polytechnic schools where practical applications are more usual.'*

Teacher #14: *'It is critical to engage the stakeholder and to make sure that the stakeholder understands that the project is primarily a learning task/project. It could be also laborious [for the stakeholder] if the students require lots of supervision.'*

The teachers' opinions conflicted the most regarding assessment: while 36% of the teachers were of the opinion that in a trialogical course, there should also be an additional personal component in the assessment, 21% claimed that effective group work should be enough (Figure 3). They, however, were of the opinion that the written group work report should contribute the most to the final grade of the students (Figure 3).

Teacher #1: *'Personal documents may be valuable for the whole group when carrying out the project.'*

Teacher #2: *'Evaluation of the group work (project) is extremely important, and personal assessments are not really required, assuming that there are no free-riders.'*

However, teacher #6 wrote, *'The grades should be personal.'*

Teacher #10 wrote, *'If this [trialogical learning] group work principle will be used several times, learning diaries or even personal assessment is not necessary. Getting a more responsible role at some point of the group work would ensure that "everyone participates". However, if the model is used only once, this makes the change for somebody "just to be part of the group", or even worse "just to wonder what happened".'*

Teacher #13: *'A part of the written report could be prepared individually.'*

Evaluation of group work practices

Regarding the group work practices, the students felt that the more traditional methods, the teacher feedback (4.3 ± 0.7) and group meetings, were the most effective (mean 4.3 ± 1.0; Figure 4). The less traditional group work methods, such as starting off by discussing the previous group work experiences and compiling the group work plan, were ranked as the least effective (with the mean 2.9 ± 0.7 being still quite high, the grade '3' would mean that the method was seen as 'moderately useful'; see Figure 4). Interestingly, the new method of giving feedback to one's own group members about their group working habits was ranked the lowest (mean 2.7 ± 0.9), whereas receiving feedback from one's own group members was ranked a bit higher (mean 3.3 ± 1.1).

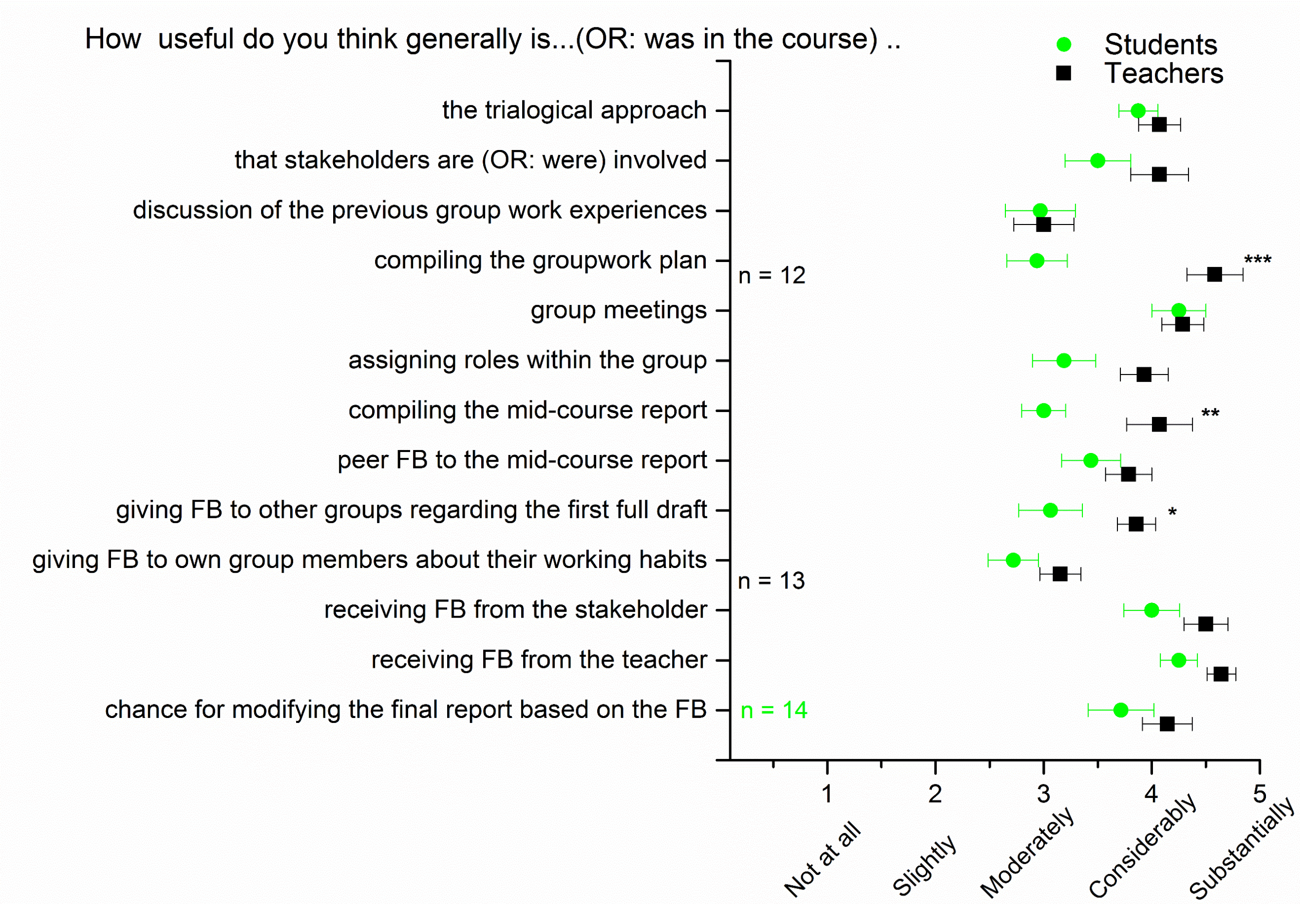

Figure 4. *Results of the students' perceptions (based on the course they just took) and the experienced university teachers' perceptions (after familiarizing themselves with Figures 1 and 2) of the effective group work practices. The data show means and standard errors of the mean, n = 16 for the students and n = 14 for teachers, unless otherwise indicated. Asterisks indicate the statistically significant differences between the student and teacher groups, with* $p < 0.05$ *(*),* $p < 0.01$ *(**), and* $p < 0.001$ *(***). Abbreviations: FB = feedback*

'Too much feedback' was often mentioned (19% of the students), but one of the students (#11) had the opposite opinion: *'Giving feedback at many stages allowed me to familiarize myself with the work of other groups.'*

The NAT feedback shed some light on the group work practices that were seen as least useful:

K: 'The main problem was too much repetition. Continuous submission of preliminary versions took time from actual work, the same problems were continuously noted in different feedback, both oral and written, and this is why it didn't feel good to submit the preliminary versions.'

M: 'Our group contributed perhaps even more time to the group work than would have been needed. In addition, the preliminary submissions caused us extra work that in my mind was almost needless. It would have made more sense to submit a really rough draft which would have been easy to revise and possibly change some soil amendment materials or fertilizers.'

However, there were also opposing views:

J: 'The group work task was too time consuming, and there were perhaps too many submission rounds? On the other hand, the high number of submission rounds ensures that there is a need to do something throughout the course, not just on the last night before the final deadline. In addition, I liked the idea of a precourse task.'

The questioned teachers had a generally more positive opinion on efficient group work practices than the students, even though the differences between these two groups were only seldom statistically significant (Figure 4). Indeed, the teachers were significantly more optimistic about how well the compilation of the group work plan, the mid-course report and the feedback given to other groups regarding the first full draft would assist learning than the students who just had finished the course (Figure 4).

Teacher #10: *'The mid-course report is good – this assures that engagement in the task will not be postponed until very late. The students can get feedback already at this stage.'*

Regarding the optimal group size to support learning, both the students and teachers agreed that four would be best in settings similar to our case course.

Teacher #3*: 'However, it depends a lot on in which grade the students are and how heterogenic the group is (could be either good or bad in the end).'*

Both the students and the teachers agreed that the most useful technological tools facilitating effective group work are Moodle and Google Docs, followed by e-mail (Figure 5). The students reported that the classroom platform Padlet was the least useful tool in terms of group work, while the teachers saw it as significantly more useful (Figure 5). However, six teachers had either no opinion or no experience with the use of Padlet. Indeed, teacher #10 said, *'It must be admitted that I have never used a Padlet/Google Docs. I have watched how it is used, and it really seems to make things easy.'* Other tools that the students reported as being useful in facilitating group work were WhatsApp, MS Office365, cell phones and SMSs. Similarly, teacher (#5) also mentioned WhatsApp as another, potentially useful tool.

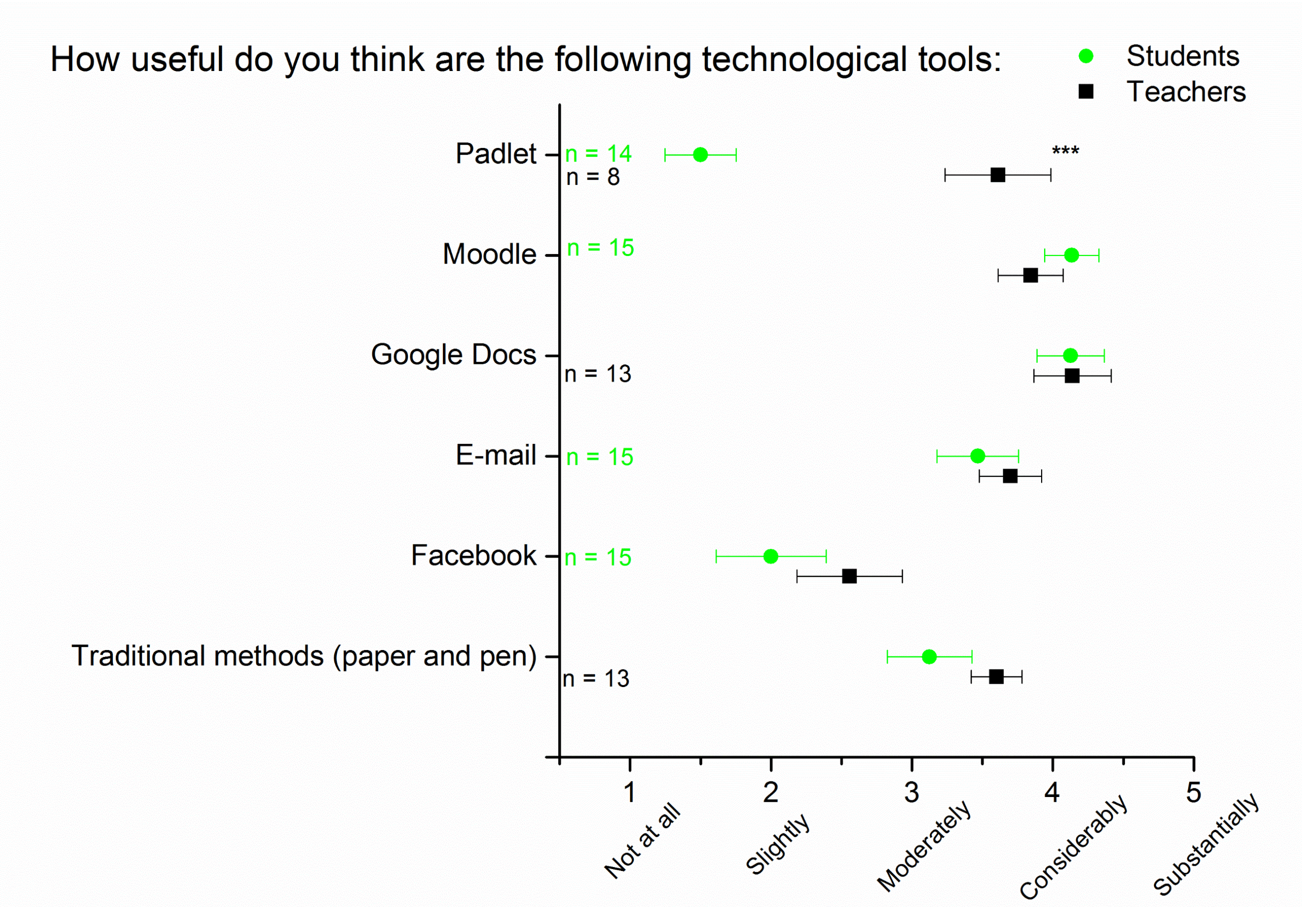

Figure 5. *Results of the students' perceptions (based on the course they just took) and the experienced university teachers' perceptions (after familiarizing themselves with Figures 1 and 2) of the usefulness of the tools facilitating group work. The data show means and standard errors of the mean, n = 16 for the students and n = 14 for teachers, unless otherwise indicated. Asterisks indicate the statistically significant differences between the student and teacher groups with p < 0.001 (***).*

Discussion

Our model, which combined effective group working practices with trialogical learning principles in life sciences, was seen as useful and supportive of the learning process by all the participants in the case study: the students, the stakeholders and the facilitator. However, challenges and areas for improvement also emerged. Correspondingly, other life science teachers of the university, who did not participate in the investigated course, considered the trialogical approach and the involvement of stakeholders as very useful for efficient learning, provided that a particular course is otherwise suitable for this learning method. This corroborates well with previous work from Lakkala et al. (2015), where both students and especially teachers gave very positive feedback regarding the general outcome of a trialogical life science course including a group work assignment for an external client. Similarly, the effective group working and coaching was seen as enhancing student satisfaction and learning from their peers in a study by Bolton (1999).

In our case study, a major issue noted by all the parties was the need for thorough planning (and time) in order for the group work process to be efficient in supporting studying in the course. Specifically, the course planning (i.e. searching for suitable stakeholders and thoroughly planning the group work tasks to be meaningful) should start already months before the first contact session, rather than one week before, as in the current case. The timing should be considered particularly well when the course is designed for the first time. Our study, however, agrees with Bettger et al. (2014) that a considerable amount of effort, time and motivation is needed from the facilitator to arrange such a course for the first time.

A useful idea worth considering was suggested by the students: use the pre-course task to identify possible stakeholders among the students' own networks (e.g. many agricultural students have a family farm), as this would increase the motivation of the students to perform the tasks (Paavola et al., 2011). Naturally, it needs to be ensured that any conflict of interests is avoided and that the same student would not end up with a double role (as both stakeholder and student), but this should be manageable through effective grouping by the facilitator.

The relatively low proportion of the surveyed teachers willing to organize a trialogical course in the close future (21%, Figure 3) can probably be explained by the novelty of the approach, the relatively high time investment needed to arrange the first course, as well as the considerable difference between the suggested approach and classical, more theoretically organized university courses. In many basic courses, it may be difficult to find tasks and stakeholders willing to contribute their time and provide data if the artefacts or solutions would not be very helpful for the stakeholders themselves. The trialogical learning approach also probably works best with students with sufficient knowledge and skills from previous years, perhaps in the final year before graduating and entering professional life.

In our study, most teachers valued the written group report the most highly in their assessment (Figure 3). This is in accordance with the work of Johnson and Johnson (1999), in which they highlight positive interdependence as one of the key elements of effective group learning. Group assessment helps students to commit to the task while realizing that they cannot succeed without the whole group succeeding. However, in their model, individual accountability is a basic element (Johnson & Johnson, 1999), and individual assessment was also seen as necessary by almost all of the teachers in our study.

Both students and teachers considered typical group working practices, such as group meetings and teacher feedback, as the most important for efficient learning. However, the involvement of stakeholders was also considered very valuable. Interestingly, the teachers assessed several less traditional practices as better facilitating learning than did the students (i.e. a group working agreement, the mid-course report and feedback given to other groups regarding the first full draft). The lower assessment of these practices by students can be explained by the timetable issues, which reduced the efficiency of the mid-course report in this particular course. Furthermore, the beneficial effect of the group working agreement and the feedback given based on one's own understanding might be more indirect and thus not directly linked with higher efficacy in learning.

The open comments from the students identified the key issues for further improvement as 'too much feedback' and 'timetable issues', which can be united under 'low efficiency of the received formative feedback due to a poorly planned timetable'. Feedback efficiency could be improved here by avoiding unnecessary repetition and providing more time for acting on the received feedback. Repetition could be reduced, for instance, by organizing the peer feedback session so that the presenting group remains standing and the floor is opened to all for discussion and feedback, instead of doing the session group by group (as in the case study). Moreover, at least two weeks of time should be set between the midtime course and the final session to allow enough time for the students to act upon the formative feedback (we have modified the model accordingly, see Table 1).

A key challenge of facilitating effective group work in trialogical courses is the difficulty in designing problems complex enough to facilitate the learning of all the group members, which requires the problems to be open-ended and require variable skills (as in Complex Instruction; Cohen, 1994), yet simple enough for the group members to be willing to try to perform tasks outside their comfort zone (that they do not perceive to be too challenging to begin with). In the present case study, the latter was not the case according to some students, who stated that the group work was so heavy that none of the group members had time to acquaint themselves with the work of other group members, hence the learning stemmed only from their own tasks.

The technological tools rated the most highly by both the students and the teachers were the commonly used Moodle as well as GoogleDocs. However, it was mentioned that the limited formatting capabilities in GoogleDocs decrease its efficiency, and instead sending the documents as e-mail attachments and physical group meetings were seen as helpful. The low ranking of the Padlet platform by the students (and the notably higher ranking of it by the teachers) may be related to the fact that it is mostly a classroom tool for collecting feedback and, as such, aids the teacher more in a classroom situation than the students during the span of the group work.

Finally, if the trialogical courses on a certain topic are repeated annually or several trialogical courses are held on different topics in a students' curriculum, the growing skills and knowledge of the students requires the complexity of the tasks and tools for learning to be increased to remain motivating (Figure 6). We propose using course feedback to find ways to add layers of complexity to the student projects, develop mediating tools and vary the stakeholders to keep the subsequent trialogical courses interesting and motivating for the students.

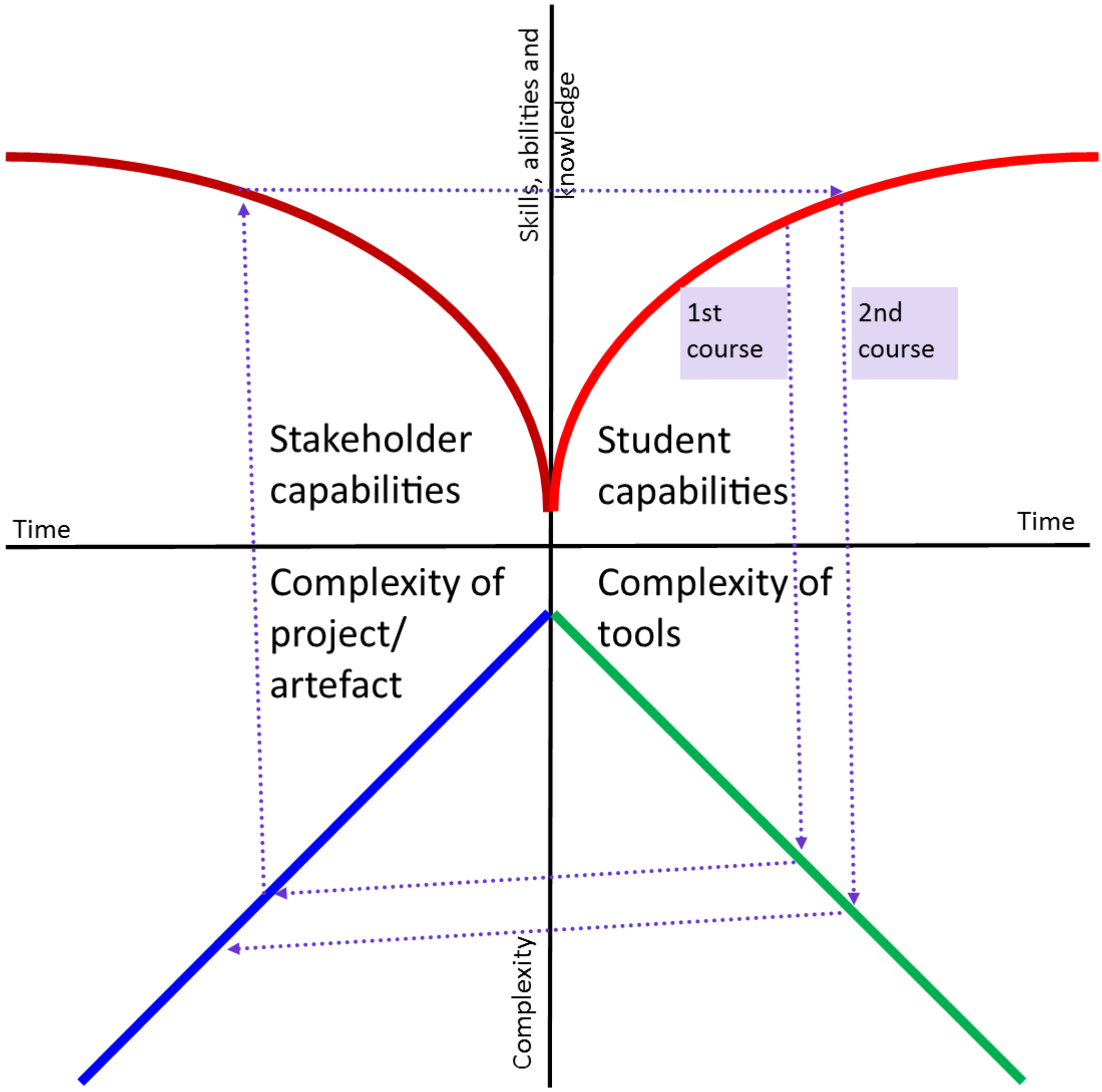

Figure 6. *Four-quadrant representation of the changes in capabilities (skills, abilities and knowledge) of the students and stakeholders and the complexity of the course projects/artefacts and mediating tools (thick lines) after participation in trialogical courses (the expanding spiral of dotted arrows).*

Conclusions

Our model combining effective group working practices with trialogical learning principles in life sciences could be a useful aid for teachers in life sciences, although the small number of respondents limits the generalizability of the present study. Thoroughly designing meaningful tasks and allowing sufficient time to take action based on the formative feedback were identified as the key issues in facilitating effective group work in life sciences. Even though trialogical courses can be time-consuming for the parties, the improved learning of applicable knowledge and practices vindicates using the approach, particularly for students just about to enter a professional career. To extrapolate these findings to other settings, further research is needed with more participants and on courses where the trialogical approach has been used in several rounds of iterations, together with comparisons with the efficiency of other pedagogical approaches.

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