WORKSHEETS AS SCAFFOLDS INFLUENCING THE SELF-DIRECTEDNESS OF LIFE SCIENCES STUDENT-TEACHERS

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ABSTRACT– Literature indicates that people need to possess higher order thinking skills, such as problem solving and creative thinking as well as social skills, in order to take on the many global challenges posed by the 21st century. In this paper, I refer to these skills as self-directed learning skills. Persons possessing high levels of self-directed learning skills are regarded as having a high level of self-directedness. Literature also indicates that most school leavers do not possess these skills because most South African classrooms are dominated by teacher-centred lessons where these skills were not necessarily fostered in learners. Although the benefits of a learner-centred approach to teaching and learning are thoroughly described in the literature, active learning still remains a dream in most South African classrooms. In this paper I argue that if student teachers are confronted with various learner-centred teaching-learning methods, they will be empowered to apply such methods as part of their daily teaching practice. This quantitative study reports on the research done to determine whether the self-directedness of Life Sciences student-teachers can be influenced if worksheets (as scaffolds) are applied in a cooperative teaching-learning environment. During the Life Sciences classes students' pedagogical content knowledge and awareness of the affordances of self-directed learning were scaffolded within the students' zone of proximal development. Depending on the particular Life Sciences content, the researcher designed appropriate worksheets which were used as scaffolds to provide support to students during the teaching-learning process. The data-analysis indicated that the worksheets may have influenced the students-teachers self-directedness. The third-generation cultural-historical activity theory (CHAT) was used as a lens to identify the factors which play a role in influencing the students' self-directedness.

Keywords: Life Sciences; worksheets, self-directed learning; self-directedness; scaffolding.

1. INTRODUCTION AND PROBLEM STATEMENT

Today's global world can be regarded as "one country" as the distances between different countries shrinks daily, as information technology develops exponentially and dictates change. This global society is continually faced with increasing challenges. Jean-Francois Rischard, an economist at the World Bank, lists the world's top 10 problems that must urgently need attention as: global economic collapse; terrorism; proliferation of weapons of mass destruction; climate change; overpopulation; water scarcity; poverty; species extinction; potential meteorite impact and oil and gas depletion (Beforeitsnews.com, 2013). Saavedra and Opfer (2012) add to this list migration of peoples, international competition, changing markets and political challenges. To solve these problems we need citizens who are skilled in Mathematics and Sciences, but the reality is that most South African school learners and university students perform poorly in these subjects (Centre for Development and Enterprise 2011). Adding to this, South Africa only delivers three natural scientists per 1000 people, whereas Japan delivers 71, USA 22 and Brazil 11 (De Beer, 2008). This state of affairs begs for serious interventions.

I argue that we need science school leavers who possess sophisticated knowledge, skills and attitudes such as problem solving, creative thinking skills, being reflective, taking ownership of their own learning, being able to hold social skills (listening, respecting others views, accountability) to tackle the

many global challenges posed by the 21st century. In this paper, I refer to these skills as self-directed learning (SDL) skills. SDL is a process where the student take ownership of his/her own learning (Guglielmino, 1978). I further argue that any education system can only deliver such school leavers if their teachers possess these skills and have the pedagogical content knowledge to design and execute learning experiences where these skills can be fostered. This study aimed to use worksheets as scaffolds to influence the self-directedness of 2nd year Life Sciences student-teachers while covering the prescribed Life Sciences curriculum content. In this regard the Council on Higher Education (CHE) indicates that "South Africa has a pressing need for more graduates of good quality to take forward all forms of social and economic development. It also needs more graduates to build up the education system itself by providing a strong new generation of teachers, college lecturers, academics and education leaders" (CHE, 2013, p. 15).

2. CONCEPTUAL AND THEORETICAL FRAMEWORKS

2.1 Cultural-Historical Activity Theory (CHAT)

The third generation cultural-historical activity theory (CHAT) (Engeström, 1987), as theoretical framework, was used as an analytical lens for this study.

According to Vygotsky (1978), learning is in essence a social interaction where elementary processes are converted to higher cognitive functions by using cultural artifacts. Such learning must be scaffolded within the students Zone of Proximal Development (ZPD) which Vygotsky (1978) defined as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers" (p. 86). Vygotsky (1978) further argued that active and cognitive apprenticeship, with the aid of effective scaffolds, should be facilitated to take the student from their actual developmental level (dependent) to their potential development level (independent) within the ZPD.

The activity system (Engeström. 1987) of the 2nd year Life Sciences student teachers refers to the teaching-learning activities based on the prescribed Life Sciences content. In the discussion part of the paper, figure 2 depicts the tailor-made activity system where the second year Life Sciences student-teachers (**subject**) will engage in cooperative teaching-learning activities (**object**) to influence their self-directedness (**outcome**). **Tools** such as worksheets and group members, the **community** (individual group members and teacher-educator), the spoken and unspoken **rules** in the class (for instance, the principles guiding cooperative learning) and university as well as the **division of labour** (e.g. power issues between group members and the teacher-educator) all play a role in order to achieve a positive outcome. Based on the findings, possible tensions may exists between these elements, and these will be discussed later in the paper.

2.2 SELF-DIRECTED LEARNING (SDL)

A person's self-directedness can be expressed in terms of the SDL skills that they possesses. Knowles (1975) defines SDL as "a process in which individuals take the initiative, with or without the help of others, to diagnose their learning needs, formulate learning goals, identify resources for learning, select and implement learning strategies, and evaluate learning outcomes" (p. 18). Developing these SDL skills in students aids them in their development of becoming more self-directed and can act as lifelong learners in the real world. Although metacognition can be regarded as a SDL skill because it is a way of thinking about one's thinking in order to grow (Morris, n.d.), it can also be used as a vehicle that drives self-directedness.

Students who have high levels of SDL skills can be viewed as having a high level of self-directedness and those who have a low level of SDL skills as having a low level of self-directedness. Self-directedness can therefore be placed on a continuum with two contrasting sides of high self-directedness and low self-directedness (Fisher, King & Tague, 2001). I argue that it is, amongst others, the teacher-educators' job to facilitate the teaching-learning process in such a way that student teachers become more self-directed.

2.3 Cooperative Learning

Johnson and Johnson (1994) define cooperative learning as group work that occurs when students work cooperatively in small groups to accomplish mutual goals. These authors argue that group work can only be regarded as cooperative learning if the following five basic elements are present: positive interdependence, face-to-face promotive interaction, individual accountability, interpersonal and small-group skills and group processing.

Positive interdependence entails that the members of a team are linked to each other in such a way that one cannot succeed if the others do not, the so-called "sink-or-swim-together principle. **Face-to-face promotive interaction** may be defined as individuals encouraging and helping each other's efforts to attain complete tasks and contribute in order to reach the group's goals. **In individual accountability**, each member is held accountable for their share of the work but each group member must be able to perform similar tasks by themselves. During a cooperative learning activity, student-teachers develop **interpersonal and small-group skills** (social skills) such as believing in each other, communicating effectively, accepting and supporting each other are cultivated. And finally during **group processing** the group members need to determine, through self-reflection and group reflection, how well they have achieved their goal(s).

Different cooperative teaching-learning methods, such as jigsaw, learning together, group investigations, peer tutoring in small groups (Lazarowtz & Hertz-Lazarowtz, 2003), cooperative graffiti, GIG, and Note-Taking-Pairs (Lubbe, 2015) can be used depending on the topic to be taught. All the cooperative teaching-learning activities, and the worksheets as support materials (scaffolds), were designed in such a way that the five elements were present during the learning experiences. It needs to be stated, that although the intervention was done in a CL environment, this paper only reports on the data collected regarding the influence of the worksheets.

2.4 Scaffolding

Student-centred classrooms are usually characterized by teaching-learning experiences, designed by the teacher-educator where the student-teachers are actively involved in the learning process. In this regard Means (as cited in Brush & Saye, 2002) claims that student-centred learning activities are used to offer students with opportunities to take a more dynamic role in their own learning process by putting the responsibilities of organizing, analyzing, synthesizing, and evaluating content in the hands of the student. This implies that the teacher-educator needs to design and support the teaching-learning experience in such a way that optimal learning can take place. One type of support that a facilitator can provideare appropriate scaffolds to help the students during the lesson. According to Brush and Saye (2002) the term "scaffolding" was initially introduced by Wood, Bruner and Ross (1974), the aim being to provide support to students in the learning setting to understand what should otherwise be impossible. Hmelo-Silver, Duncan and Chinn's (2007) definition of scaffolding will guide this study: scaffolding helps students to "engage in sense making, managing their learning, encouraging them to articulate their thinking and to reflect on their learning" (p. 101).

Brush and Saye (2002) distinguish between soft scaffolds and hard scaffolds. According to them soft scaffolds are dynamic and refer to the support that the adult/peer provides in a certain specific setting

as the need arises (eg. short lecture, video, etc.). In contrast, Brush and Saye (2002) describe hard scaffolds as static supports that can be planned in advance, based on difficulties the student struggles with during the task. I argue that hard scaffolds can also be described in terms of what Hmelo-Silver *et al.* (2007:102) called "scaffolds that structure complex tasks or reduce the cognitive load", referring to the way the learning experience is structured that will help learner's to process information in a most comfortable way while working through the learning activity. The purpose is to ease the learning process and focus the student on the outcomes to be reached. Worksheets, as a type of hard scaffold, were used in this study to support the student-teachers to master the Life Sciences curriculum content.

2.5 Worksheets

The concept "worksheet" means different things and can be used for different reasons by different educators. It is evident from literature that the definition of the concept "worksheet" inherently implies two facets, namely "what it is" and "what it does". Bakirci, Bilgin and Simsek (2011) describe the "what it is" facet of worksheets as a written document or as a tool; or as study material that can be used during teaching (Celikler & Aksan, 2012).

In terms of the what-it-does facet of a worksheet, the researcher compiled the following working definition based on the work of Atasoy, Kucuk and Akdenis (2011), Choo, Rotgans, Yew and Schmidt (2011), and Töman, Akdeniz, Cimer and Gurbuz (2013): a worksheet is a "written teaching-learning learner activity which provides a step-by-step guide to students while systematically exploring the topic under discussion and in doing so takes responsibility for their own learning".

2.6 Life Sciences

As a sub-discipline of Natural Sciences, Life Sciences are inherently an investigative subject discipline, the studying of living things from molecular level to their interactions with one another and their environments (Department of Basic Education, 2011).

Based on my extensive experience as a school teacher and teacher-educator of Life Sciences, it is my view that both school-learners and student-teachers experience Life Sciences content as overwhelming in terms of the amount of content to be covered as well as in the complexity of the subject. Any teacher-educator of Life Sciences needs to develop teaching-learning experiences which complement the investigative nature of the subject but also to scaffold teaching-learning in such a way that it supports student-teachers in understanding the complex nature of the subject content knowledge. I hold the opinion that one of the main purposes of the Life Sciences teacher-educator is to use the subject content knowledge as a vehicle to foster SDL skills within students and in the process helping them become scientifically literate lifelong learners. With this in mind, it serves as the motivation for the researcher to use worksheets to obtain this goal.

3. METHODOLOGY

The purpose of this empirical study was to determine if the use of worksheets as scaffolds, in a cooperative teaching-learning environment, influences the self-directedness of 2nd year Life Sciences student-teachers. The research was guided by the following research question: What is the influence of using worksheets as scaffolds on the self-directedness of 2nd year Life Sciences student teachers in a cooperative teaching-learning environment?

3.1 Research Approach and Paradigm

To answer the research question a quantitative approach was used within a post-positivist paradigm. According to Denzin and Lincoln (2003) a post-positivist paradigm aims to study the behaviour of people with the goal to understand and describe the person's actions.

3.2 Research Method

3.2.1 Sampling

Second year Life Sciences student-teachers, as the participants in this study, were conveniently chosen because the teacher-educator, as researcher, used them as they constitute part of the researchers' normal lecturing responsibilities. The class of 80 student teachers was heterogeneous, consisting of 15 male, 65 female, mostly Afrikaans-speaking (75) white (72) student teachers. A few English (5) speaking, black (5) and coloured (3) student teachers were also part of the class. The fact that the university requires from all students to attend all classes, implies that all students were exposed to the intervention (N=80), but the researcher used only the data of the students who gave their voluntary informed consent (N=55) to complete the questionnaires. The participants were informed that the data would be treated confidentially and would not be used to their detriment.

3.2.2 Instruments

The data collection instrument was self-constructed by the researcher and consists of two sections. In section one (quantitative) the following question was posed to the participants: "To what extent did the completion of this worksheet help you to develop the following characteristics"? The self-constructed questionnaire contains eighteen Likert scale type questions, where number 1 indicates that the characteristic was not developed at all, 2 slightly developed, 3 considerably developed and number 4 indicates that the characteristic was largely developed. The items on the questionnaire were based on SDL literature and can be regarded as SDL skills. The questionnaire with 18 items, aimed at gathering data on the experiences of student-teachers using worksheets to cover the Life Sciences content and to investigate their perceptions of growth or not in their self-directedness. This was done over three teaching-learning-experiences where worksheets were used. The questionnaire (section one) of the instrument is called an SDL questionnaire [SDLQ] in this study. Section two of the instrument (qualitative) consists of two open-ended questions, namely: "Choose from the table above one characteristic that you believe developed the 1) most and 2) the least during the lesson, and give a reason for your choice in each case". Although the instrument was used to collect both qualitative and quantitative data, this paper only reports on the quantitative data.

3.2.3 Intervention

During the course of the semester the lecturer (as researcher) designed different teaching-learning experiences based on the Life Sciences content of the module. Depending on the specific topic, an appropriate worksheet, as a scaffold, was designed and a suitable cooperative teaching-learning method was chosen. The following steps were taken in the planning and execution of the three teaching-learning experiences from which data was collected:

Firstly, the topic/contents of the lesson were identified, for example: In studying animal diversity one of the outcomes is that students need to evaluate why different phyla can be positioned on different evolutionary levels using certain characteristics, such as levels of organization, symmetry, coelom and cephalization.

Secondly, I decided on an appropriate cooperative teaching-learning method. As this topic contains an enormous amount of content to cover, and students usually perceive it as difficult to be mastered, I used the jigsaw method to facilitate this topic. The jigsaw method was also used for the second lesson where the group outcome was to make a poster presentation of the relationship between structure, adaptation, function and deficiency diseases of the human nutrition system. The third lesson, on the dissection of the lungs, the group worked as a team through the worksheet. In all cases the group

consisted of four student-teachers, as Johnson and Johnson (1994) argues that groups more than four are not effective.
Thirdly, I compiled a lesson plan containing the phases of the lesson, the role of the teacher-educator and students-teachers, but more importantly it also indicates how the five CL elements will be built in during the lesson and what SDL skills could be developed during the lesson.
Fourthly, I developed a worksheet based on the subject content, the five CL elements and the SDL skills envisioned to be developed. The worksheets were designed in such a way that the five cooperative learning elements would be visible as the student-teachers worked through the worksheets, as well as the SDL skills that could have been positively influenced.

Lastly, the teaching-learning experiences, supported by the worksheet as hard scaffold, were executed. During the lesson the teacher-educator continually reflected upon the student-teachers progress and provided soft scaffolding or other forms of support as needed.

3.2.4 Trustworthiness Aspects, including Generalisability

Because this study involved a relative small number of participants (N=85) I did not make any large scale generalisations nor did we argue that the findings could realistically be transferred to other settings. Shenton (2004:70), however, contends that the results of such a study could be of value in other similar settings where the same methods were applied.

4. RESULTS, DATA-ANALYSIS AND FINDINGS

The Statistical Package for the Social Sciences (SPSS- version 23) was used to analysed the data of the self-constructed SDLQ. In the following paragraphs the results and findings of the factor analysis (FA) will be summarized.

The Bartlett's test of sphericity and the Kaiser-Meyer-Olikin Measure (KMO) were done on the items to determine whether one can proceed with the FA. The KMO value is .872, meaning that the factors are compact as the score falls within the 0.8-0.9 range, indicating great value and that the FA is appropriate for the data (Field, 2009).

The Eigenvalues output (according to Kaiser's criterium) of the SPSS analysis of this study indicate that three factors can be extracted, explaining 49.80% of the total variance. Oblique Oblimin Rotation method was used for the factor extraction (table 1) because it was suspected that the factors might correlate and are based on theoretical grounds (Field, 2009). In this study the factors were based on SDL theory.

The three factors resulted from the FA were named, self-motivated (behaviour), metacognition and task-orientedness. Self-motivated behaviour signifies intrinsic characteristics indicating the student-teacher's ability to take ownership of their own learning, metacognition indicates the student-teachers ability to evaluate their own learning process, while task-orientedness indicates external acts that need to be performed.

From the Cronbach's alpha coefficient values (Table 1) it is clear that factors 1 and 2 can be regarded as an acceptable reliable level as the values are larger than .7, while the reliability of factor 3 is questionable. In terms of the questionable (unreliable) factor, Kline (1999) argues that levels below .7 are acceptable in psychological constructs as is the case in this study.

Table 1: Factor analysis

Items on SDL questionnaire	Factors		
	1 Self-motivated	2 Metacognition	3 Task-orientedness

Q1. Need to know more	.760		
Q12. Curiosity	.707		
Q15. Self-efficacy	.571		
Q2. Interest in learning process	.510		
Q5. Willingness to direct own learning	.506		
Q18. Willpower	.424		
Q9. Intrinsic motivation	.352		
Q17. Independent application of subject knowledge	.335		
Q8. Effective implementation of learning strategies		.791	
Q10. Choice of applicable learning strategies		.720	
Q11. Critical self-reflection		.597	
Q14. Self-adjustment based on feedback		.424	
Q3. Evaluating learning outcomes			.649
Q7. Formulating learning goals			.622
Q6. Identifying resources			.590
Q4. Identification of learning needs			.574
Q13. Does not work to receive recognition			.352
Cronbach's alpha coefficient	.817	.706	.677

As a guide, Field (2009) indicates that correlations of 0.3 signifies a noticeable, and 0.5 a practically important relationship. From table 2 it is clear that there is a medium correlation between task-orientedness and self-motivated behaviour (.325) as well as between metacognition and task-orientedness.

Table 2: Correlation matrix

Factors	**1 Self-motivated**	**2 Metacognition**	**3 Task-orientedness**
1 Self-motivated	1.000		
2 Metacognition	.280	1.000	
3 Task-orientedness	.325	.329	1.000

The data gathered in this study can be regarded as hierarchical because the data were repeatedly collected on the same individuals (Osborne, 2000). Hierarchical linear modelling was used to statistically analyse the data gathered on the completion of the three consecutive worksheets and can be seen in table 3.

Table 3: Hierarchical linear modelling results

Factors	**Mean**			**MSE**	**Variance-Student**	**Significance**	
	Worksheet 1	**Worksheet 2**	**Worksheet 3**			**p-value**	**Explanation**
Self-Motivated	2.944	3.277	3.018	0.0939	0.0892	0.00	$p < .05$

							significant
Metacognition	2.898	3.054	2.933	0.1714	0.0595	0.212	p > .05 not significant
Task-orientedness	2.87	3.013	2.964	0.1384	0.0371	0.196	p > .05 not significant

As shown in table 3 a significant difference ($p<0.001$) was found for the self-motivated factor and that the other two factors (metacognition and task-orientedness) show a non-significant difference because the p-values are larger than 0.05.

The mean scores for the three factors on the three worksheets are represented in the graph in figure 1 and table 4 depicts the effect sizes.

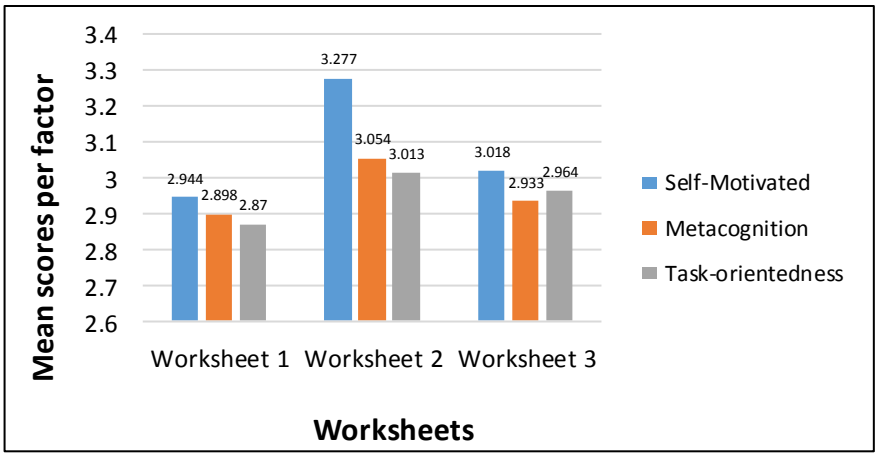

Figure 1: Graph indicating the mean scores per factor

Table 4: Effect sizes for the three factors.

	1 Self-motivated			**2 Metacognition**			**3 Task-orientedness**		
W *	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
W_1	-			-			-		
W_2	.78	-		.33	-		.34	-	
W_3	.17	.60	-	.07	.25	-	.22	.11	-

W= worksheet

The effect sizes (d) for self-motivated behaviour between worksheets 1 and 3 is 0.78, and indicates a large statistical and practical significant difference and between worksheets 2 and 3, d=0.6 indicating a medium statistical and practical significant difference. On the other side, worksheets 1 and 3 indicates no statistical and practical significant difference as d=0.17. The graph (in figure 1) which depicts the mean scores of the worksheets per factor indicates that the participant student-teachers perceive that their self-motivation was developed more in relation to the other two factors. A possible reason that they believed that their self-motivation improved the most when working through worksheet 2, can be that the learning experience was on the dissection of the lungs. Literature indicates that dissections usually motivate students (Cake, 2006).

The effect sizes for metacognition between worksheets 1 and 2 is 0.33, and points to a small to medium statistical and practical significant difference and between worksheets 2 and 3, d=0.25, which

indicates a small statistical and practical significant difference. Worksheets 1 and 3 indicate no statistical and practical significant difference as d=0.07.

The effect sizes for task-orientedness between worksheets 1 and 2 is 0.34, pointing to a small to medium statistical and practical significant difference and between worksheets 1 and 3, d=0.22 which signifies a small statistical and practical significant difference. Worksheets 2 and 3 show no statistical and practical significant difference as d=0.11. The graph (figure 1) depicts that the participant student-teachers perceive that their metacognition and task-orientedness might have been developed when working through all the worksheets as all the mean scores (table 3) are close to 3 out of a maximum of 4 (according to the four point Likert SDLQ).

5. DISCUSSION

The objective of this study was to investigate the influence of using worksheets as scaffolds on the self-directedness of 2nd year Life Sciences student-teachers in a cooperative teaching-learning environment. Based on the results of the FA, three factors were identified, namely self-motivation, metacognition and task-orientedness. The analysis indicated that there are noticeable correlations between the three factors. This outcome is not surprising as all three of these factors form part of SDL theory. According to the Cronbach's alpha coefficients (see table 1) the reliability of the questionnaire is acceptable.

On the graph (figure 1), based on the hierarchical linear modelling analysis, it is clear that the participant student-teachers perceive that all three worksheets improve their self-motivation mostly in relation to the other two factors. The p=0.00 points to a significant difference. This is especially true for worksheet 2 with the highest mean score (3.277). As this worksheet dealt with the dissection of the lungs, this finding supports the claim that interesting content and teaching methodologies will help students' intrinsic motivation (Randler, Wüst-Ackermann, Vollmer & Hummel, 2012). In terms of CHAT, I argue that the participant student-teachers experience a positive tension (see *a* in Figure 2) during the cooperative teaching-learning activity (**object**) using the worksheets (**tools**), the jigsaw method (**tools**), the group members (**tools**) and the lecturer (**tools**) as a type of soft scaffold. It can be argued that the **object** and the **tools** complement each other and subsequently may have a positive influence on their intrinsic motivation. I also infer that the student-teachers (**subject**) experience the group dynamics (**division of labour**) positive and could also have an influence on their self-motivation (see *b* in Figure 2). In this regard Yildirum, Kurt and Ayas (2011) found that worksheets proved to be more effective than traditional teaching methods where students actively participate to understand abstract concepts and that the application of concepts are more affective and permanent. According to these authors the worksheets also motivated students to ask questions in their groups. In terms of motivation, Celikler and Aksan (2012) found in their study that worksheets can be useful to motivate demotivated students to become interesting and to participate meaningfully in class.

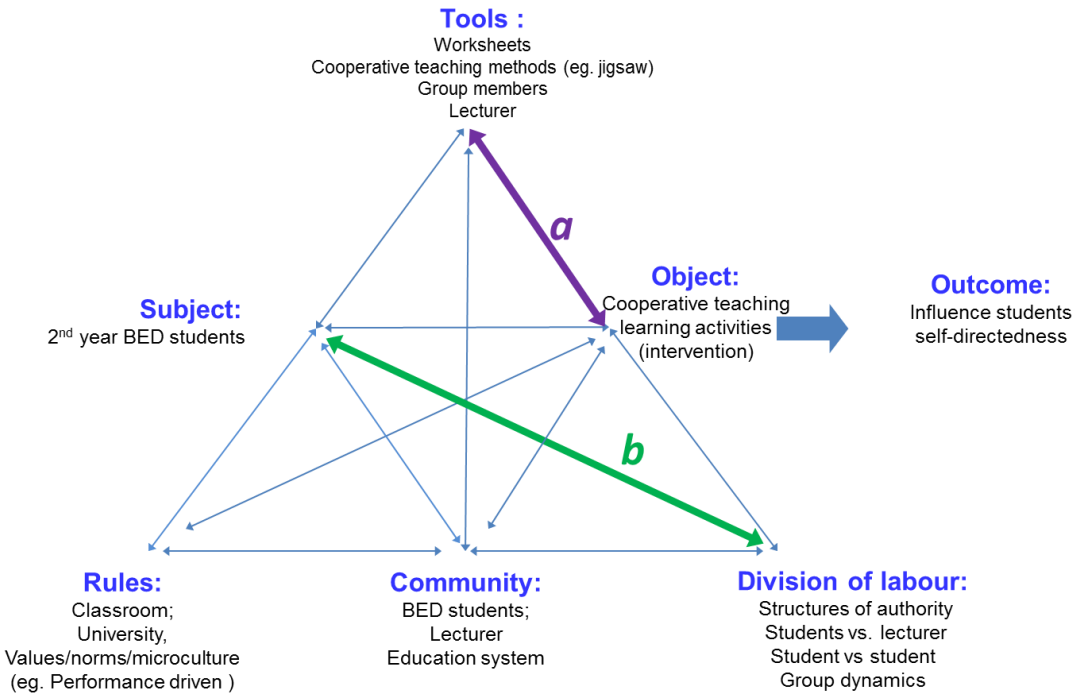

Figure 2: Activity system of 2nd year Life Sciences student-teachers

The mean scores for metacognition for the three worksheets (2.898, 3.054 and 2.933) are also an indication that the participant student-teachers perceive that the worksheets (tools) influence their metacognitive skills, thus also indicating an influence on student-teachers self-directedness. This finding is in line with a study done by Bakirci *et al.* (2001) who found that worksheets and simulations motivate students to take on responsibility to assess what they learn.

The maximum score per item on the self-constructed SDLQ is four, according to the four-point Likert scale used for the SDLQ. The average mean score for worksheet one is 2.904, worksheet two is 3.115, and worksheet three is 2.972 which give an average score close to three out of four. I can therefore argue that the worksheets may have influenced the students-teachers self-directed learning skills and therefore also may have an influence on their self-directedness.

6. RECOMMENDATION

The findings of this study indicated that using worksheets as a learner-centred teaching-learning method may have influenced student-teachers self-directedness. As a result of this study, teacher-educators might be encouraged to use worksheets to scaffold their teaching. Regarding the the self-constructed SDLQ, with a low to moderate internal reliability (average Cronbach's alpha coefficient of 0.733), it is suggested that the questionnaire can be further tested for reliability with more participants. Such further studies can be done to test whether similar tendencies, as was found in this study, could be found. It is also suggested that future studies may also use standardised questionnaires, like the Williamson's (2007) self-rating scale of self-directed learning, which measure students' perception of their own self-directedness, to see if similar trends can be find.

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