

# Scaffolding Collaborative Learning in Pairs within a Technology-Enhanced Learning Environment

Per B. Bergamin, Egon Werlen, and Yves E. Bochud

**Abstract**—Previous research shows that scaffolding is an effective method to foster learning in technology-enhanced learning environments demanding self-regulation. This study considers the option of using a scaffold in an online learning environment working with a partner to solve a multiple-choice assessment. A scaffolding sequence was designed in which subjects worked in pairs. Then the collaborative and individual learning performances were measured and compared. Using the cognitive load theory (CLT), variables were defined to explain effects on performance. Participants in the experiment included 41 university students. Findings reveal that learners learning in the collaborative learning scenario performed better than within the individual learning scenario. Results show that three interrelated variables, mental effort, task difficulty and motivation affected performance.

**Index Terms**—Technology enhanced learning, collaborative learning, scaffolding, cognitive load.

## I. INTRODUCTION

Learning complex science topics within technology-enhanced environments requires students to regulate their own learning process [1]. In self-regulated learning, students must make decisions about what and how to learn, how much time to spend, and how to access other instructional material and to control understanding of the learning content. According to cognitive Load Theory (CLT), collaborative learning opposed to individual learning creates additional learning tasks that increase the load in the working memory (WM), thus affecting learning efficiency. Research in the last decade shows inconsistent data with positive as well as negative effects [2]. However, the use of scaffolds within technology-enhanced environments improves self-regulation in learning [3]. In our study, we investigate the relationship between cognitive load and learning performance, using Multiple-Choice-Assessments in technology-enhanced environments with students working in pairs or alone.

## II. LITERATURE REVIEW

### A. Collaborative Learning Research

Dillenbourg defines collaborative learning as a situation in which two or more persons learn together [4]. It is therefore necessary to take the learner, task and group characteristics

into consideration. It is often assumed in collaborative learning concepts that the construction of knowledge is triggered by dialogue. It has been found that learning processes are positively affected by collaborative learning activities such as developing, proposing and extending arguments, negotiating meaning, verbalizing explanations, and justifying reflections [2]. But not all studies have shown positive effects [5]. However, positive results were often found in learning environments that were technology enhanced and closely linked to structured learning processes (e.g. scaffolding). In such environments learners receive clarification about the required knowledge, as well as how and with whom they should collaborate.

### B. Scaffolding in Online Learning Environments

The term of scaffolding was introduced by Wood [6] and corresponds conceptually to Vygotskys' Zone of Proximal Development and is a structured pedagogical tool that aims to support a student's learning of difficult material. In reviewing the last decade of research, Van de Pol, Volman and Beishuizen suggest six instructional practices that are typically used in scaffolding: giving feed-back, hinting, instructing, explaining, modeling and questioning [7].

When conceptualizing scaffolds within these practices by using technology-enhanced learning environments, some specific characteristics need consideration. In this context Azevedo, Cromley, and Seibert define scaffolds as "tools, strategies, and guides that can support students in regulating their understanding of complex topics when using hypermedia" [8]. Van der Pol *et al.* reviewed several different studies on the effectiveness of scaffolding, and concluded that scaffolding is effective [7]. Some authors also distinguish between fixed and adaptive scaffolding. Fixed scaffolding is static, without changing the components while adaptive is dynamic, implying an adaptation of the components to meet students' needs while learning. In a meta-analysis of the effectiveness of procedures influencing learning performance with dynamic assessment scaffolding, Swanson and Lussier found a medium effect size  $d = 0.48$  (coaching  $d = 0.21$ ; general strategies  $d = 0.65$ ) [9]. But there are also studies showing positive effects for the fixed scaffolds [10].

## III. DESIGNING COLLABORATIVE SCAFFOLDS

### A. Dimensions of the Design

In our viewpoint, based on the research mentioned above, there are three dimensions suitable for the conceptualization of scaffolds within online environments: interactions, purposes and sources [11]. The interactions within scaffolds can be regarded as static or dynamic related to the students'

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learning activities. Static scaffolding consists typically of a set of stable instructions being given without any negotiation between students [11] or teachers, or any human-computer interaction. In contrast, dynamic scaffolds rely on an analysis of the learners' behavior [12] to assess progress and provide feedback within the learning process. Hannafin *et al.* present a classification of four scaffolding types: 1) procedural scaffolding providing operational steps, 2) conceptual scaffolding which guides learners, 3) strategic scaffolding that suggests alternative routes, and 4) metacognitive scaffolding [1]. The latter supports reflections on learning goals, monitoring learning processes and assessing actual progress. In several studies procedural scaffolding was shown to be efficient [13]. In the context of learning collaboratively these scaffolds are designed to guide thinking and to answer given questions before discussing with others [14]. The purpose of procedural scaffold is to engage students in two specific learning activities. The first of these is task-management (e.g. organizing the collaboration and time planning of activities etc.) which aims to reduce the task-complexity related to the learning process. The second activity concerns reconstruction of knowledge, by students engaging with each other to negotiate different perspectives.

Also three sources as third scaffolding dimension are often deployed [11]. These are teachers, peers, and the technology. In this context the combination of peers and technology-enhanced environments seems to be a promising way to improve collaboration. When students work collaboratively they can benefit from each other by explaining their ideas to each other, by verbalizing their individual understanding and realizing that there are other ideas and concepts. Such interaction helps to develop perspectives of the learning topic or concepts. Peer-feedback plays a crucial part and can be regarded as a collaborative learning form, leading to benefits for both the addressee and the assessor [15]. However, peer feedback can vary, and can be correct, incorrect or misleading.

#### *B. Design for Scaffolding Multiple-Choice Exercises*

A crucial element for collaborative learning is the task and its implementation in the learning environment. Metacognitive aspects of scaffolding assist students on how to manage the learning process and procedural scaffolding on how to use tools or functions of the learning environment. In this study, we investigated Multiple-Choice Questions (MCQ) on a complex learning topic, assuming that assessing procedures with MCQ is an option to learn more in depth about peer scenarios [16]. If we look to types of the collaborative communication sequences, the justification is an efficient possibility. For instance Wang [17] tested a MCQ-system that included comments on the questions, and it was possible for other students to read these comments and give recommendations. He found that students commenting and recommending questions enhanced their self-regulated learning abilities and performance.

Based on the above-mentioned findings, and based on learning platform (Moodle, Version 1.9) we developed a scaffold for learning in pairs with eight process steps:

1) Instruction with an exercise on learning and knowing the collaborative working process

- 2) Creating learning dyads
- 3) Planning time-management of common learning activities
- 4) Choosing one of two learning topics (one for each student)
- 5) Proposing answers (MCQ) and argumentation
- 6) Reviewing answers and arguments of the peer
- 7) Solving the multiple-choice quiz
- 8) Monitoring time and result(s).

For programming, we used the Moodle-Plugin 'conditional activities' from the Centre of Innovation for the Information Society (CICEI) at the University of Las Palmas de Gran Canaria (ULPGC, Spain) and added some additional functions with in-house programming. Fig. 1 (see next page) exemplifies some of the main screens that appear when student dyads learning together (step 3 to 8).

#### IV. COGNITIVE LOAD, MOTIVATION AND COLLABORATIVE LEARNING

Studying learning collaboration means not only observing the characteristics of the collaboration, but also paying attention to the structures constituting the cognitive architecture of the individuals working together. Cognitive Load Theory (CLT) situates this architecture in the context of the effectiveness of instruction, assuming that the human cognitive architecture consists of an unlimited long-term memory (LTM) which interacts with the working memory (WM) that is limited in capacity and duration [18]. Several researchers have argued that one way to positively affect this limitation of individual learners is by forming groups and initiating collaboration. In this view, learners are imagined to be an information processing system in which group building leads to more available cognitive processing capacity than in individual learning situations [5]. Current theories assume a complex relationship between different factors of cognitive load. Sweller proposes the element of interactivity in the form of task difficulty causes either a cognitive load that is intrinsic (imposed by the task) or an extraneous load (imposed by activities that do not contribute directly to learning, e.g. organization of learning resources etc.) [19]. However, collaborative learning has different characteristics than individual learning. On the one hand, it can be argued that in collaborative learning between individuals, a larger reservoir of cognitive capacity is created and if task difficulty is stable, there is more WM capacity available compared to individual learning. On the other hand, it requires inter-individual communication and information coordination between the individuals, which leads to so-called transaction costs producing extraneous load affecting learning performance [20]. Furthermore, there is also a relationship between extraneous and intrinsic load because of enhanced learning goals, such as collaboration, that can also be allocated in a growth of task difficulty, which leads to an increase of intrinsic load. This means that extraneous and intrinsic load should be managed properly by reducing the elements that impose task. Following this, our study actually poses two research questions: First, does collaborative learning within the developed scaffold lead to better learning performance than the individual learning scenario? Second, how do the

factors of additional mental effort and task difficulty affect learning performance in collaborative scaffolding condition?

Another important factor in learning is the relationship between cognition and motivation. It is often assumed that motivational factors mediate learning by increasing or decreasing cognitive engagement. Thus, motivation can be supposed as a mediating variable of cognitive load that can have constraints or stimulating functions on performance by

improving learning. Another assumption is, the negative affection of collaboration by motivational features distracting learning activities by creating extraneous processing [21]. Given the relationship between extraneous load and learner engagement in the context of instructional design, it becomes necessary to look closer with a third research question: How does motivation conceptualised as learners' engagement affect extraneous load and performance?

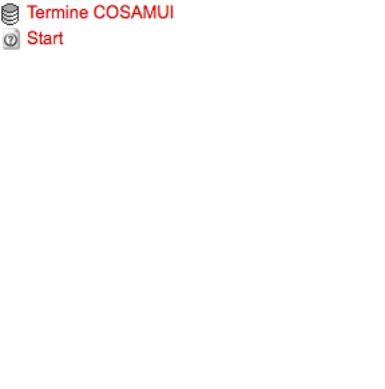

	Activities visible on course site, only after previous steps are completed	Activities in detail (extracts of screens)								
Step 2&3		<p><b>New entry</b></p> <p>Tandemname: <input type="text" value="Andigone"/></p> <p>Name Tandempartner 1: <input type="text" value="Andy Pandj"/></p> <p>Name Tandempartner 2: <input type="text" value="Peter Pan"/></p> <p>Startdatum Aufgabe: <input type="text" value="11"/> <input type="text" value="August"/> <input type="text" value="2011"/></p> <p>Enddatum Aufgabe: <input type="text" value="15"/> <input type="text" value="August"/> <input type="text" value="2011"/></p> <p>Welcher Tandempartner beantwortet die Fragen zum Thema Methodik? <input type="text" value="Peter Pan"/></p> <p>Welcher Tandempartner beantwortet die Fragen zum Thema Forschungstheorie? <input type="text" value="Andy Pandj"/></p>								
Step 4		<p>Wählen Sie unten die Fragen, welche auf ihrem Instruktionsblatt vermerkt sind. Anschliessend wird für Sie ein Forum mit den Fragen angezeigt, welche Sie beantworten müssen.</p> <p>Nachdem Sie die Fragen beantwortet haben, werden Sie die nächsten Instruktionen sehen.</p> <p><input type="radio"/> Fragen 1-3</p> <p><input type="radio"/> Fragen 4-6</p> <p><input type="button" value="Meine Auswahl speichern"/></p>								
Step 5&6		<p><b>Student 47</b> • 29. Mai 2012, 08:29</p> <p><b>antwort a</b></p> <p>könnte antwort a sein, die nicht richtig ist. denn die lunge senkt die H-Konzentration, also sorgt dafür, dass diese nicht irgendwie zu sauer oder basisch wird.. Und auch wenn man übermässig atmet, wird diese senkende funktion ja durch einen sauren ph-wert animiert, und nicht einfach ungebremst vordannnen gehen. .. zudem beeinflussen ja respiratorische störungen den co2 gehalt, es wird kein weiterer zusammenhang zwischen lunge und basenkonzentration erwähnt. und die anderen antworten leuchten mir irgendwie ein wenig schneller ein.</p> <p>Gehe zu: <a href="#">Parent</a> <a href="#">Teile</a> <a href="#">Löschen</a> <a href="#">Bearbeiten</a> <a href="#">Antworten</a></p> <p><b>Student 48</b> • 29. Mai 2012, 08:48</p> <p>"Überschreitet die H+ - Konzentration eine bestimmte Grenze, so spricht man von einer Azidose (pH 7,43)" Heisst dass, das eine hohe H+-Konzentration = Azidose und eine tiefe H+-Konzentration = Alkalose?</p> <p>Gehe zu: <a href="#">Parent</a> <a href="#">Teile</a> <a href="#">Löschen</a> <a href="#">Bearbeiten</a> <a href="#">Antworten</a></p> <p><b>Student 47</b> • 29. Mai 2012, 09:01</p> <p>ja, würde sagen. aber glaube nicht, dass das einfach passiert, wenn die lunge viel benutzt wird.</p> <p>Gehe zu: <a href="#">Parent</a> <a href="#">Teile</a> <a href="#">Löschen</a> <a href="#">Bearbeiten</a> <a href="#">Antworten</a></p> <p><b>Student 48</b> • 29. Mai 2012, 09:05</p> <p>muss a oder e sein, denn bei A wird übermässig geatmet und es kommt zur alkalose, bei e wird weniger geatmet und es kommt zur alkalose... bin auch für a.</p> <p>Gehe zu: <a href="#">Parent</a> <a href="#">Teile</a> <a href="#">Löschen</a> <a href="#">Bearbeiten</a> <a href="#">Antworten</a></p>								
Step 7	<p><b>Übersicht: Schritt für Schritt auf dem Lempfad</b></p> <p> Wählen Sie die zu beantwortenden Fragen</p> <p> Forum: Fragen 1-3</p> <p> Forum: Fragen 4-6</p> <p> Erklärung des Review-Prozesses</p> <p> Test: Fragen beantworten</p>	<p>2 Eine wichtige Aufgabe bei der Eröffnung einer Operationalisierungsliste ist die Festlegung eines Forschungsthemas und die Eingrenzung eines Problems.</p> <p>Punkte: 1</p> <p>Durch welche Eigenschaften zeichnet sich ein Forschungsproblem aus.</p> <p>Kreuzen Sie die zutreffenden Aussagen an.</p> <p>Antwort wählen:</p> <ul style="list-style-type: none"> <li><input type="radio"/> Untersuchung einer ungewöhnlichen, einzigartigen Situation</li> <li><input type="radio"/> Diskrepanz zwischen Ideal und Realität (zwischen Erwartung und Beobachtung)</li> <li><input type="radio"/> Wiederholung einer bekannten Studie in der Absicht, bestehende Hypothesen erneut zu prüfen.</li> <li><input type="radio"/> Vielfalt und Vielschichtigkeit von Themen, damit eine sehr grosse Anzahl verschiedener Forschungsfragen entworfen werden können.</li> </ul>								
Step 8		<p><b>Group order</b></p> <table border="1"> <tr> <td>1. Andigone</td> <td>100%</td> </tr> <tr> <td>2. JEEV</td> <td>100%</td> </tr> <tr> <td>3. Mui-Bien</td> <td>100%</td> </tr> <tr> <td>4. Wall-E</td> <td>95%</td> </tr> </table>	1. Andigone	100%	2. JEEV	100%	3. Mui-Bien	100%	4. Wall-E	95%
1. Andigone	100%									
2. JEEV	100%									
3. Mui-Bien	100%									
4. Wall-E	95%									

Fig. 1. Extracts of students' screens working through the exercise within collaborative scaffold (original course in German).

## V. METHOD

### A. Participants and Sampling

41 psychology undergraduate students (33 female, 9 male, mean age = 24.10, SD = 1.93) from a Swiss University participated in the investigation. They were remunerated with 40 CHF for their participation.

### B. Learning Material and Assessment

The MCQ were selected from an exercise course book and dealing with the topic of human blood circulation [22]. The learning assessment consisted of six questions for each testing condition. The questions were formulated as word problems with multiple-choice answers (A-Type: this means 4 – 5 possible answers, of which only one is correct). In order to prevent a systematic difficulty bias, the presentation of questions was balanced between the two experimental conditions. For each condition, the subjects had a maximum time of 60 minutes to solve the assignments.

### C. Measurements

One option for measuring task difficulty is a rating to that effect [23]. Therefore a nine-point subjective symmetrical self-reporting scale for use in cognitive load measures [24] ranging from 1 (very, very low difficulty) to 9 (very, very high difficulty) was applied. Ratings were carried out after each problem during the assessments. For measuring mental effort, dual-task procedures are applicable. Brünken, Plass and Leutner classify this method as an objective measurement [23]. To measure effects, the subjects had to solve a primary task, consisting of the above-mentioned learning process steps 3 to 8. In addition, they had to solve a secondary task (Dual Task Method) consisting of the presentation of letters in the lower left corner of the screen. Presented with two letters, the subjects had to decide which one comes first in the alphabet and push a corresponding button on the computer keyboard (F4 or F8). The dual task was refreshed at a rate of 30 seconds. As a variable for measuring mental effort we used errors that had occurred in the dual task assessment. We operationalized the third variable motivation by four items on a four-point Likert scales: 1) Compared to the individual assessment, was the collaborative assessment more motivating? 2) Did working with a partner motivate you? 3) Which learning activity motivated you more? 4) If you could choose, which manner of learning you would prefer for future learning activities? For these four items, a good reliability of Cronbach's  $\alpha = 0.80$  was achieved.

### D. Procedure

The experiment was devised as a within-subjects balanced Latin square design ( $2 \times 2$ ) with the collaborative learning condition (scaffold) and an individual learning condition (classic MCQ). Learning-dyads were randomly formed in advance. After the reception, the subjects took their places in remote labs and were informed about the experiment procedures and trained in learning either individually or collaboratively on the platform. After the demographic data assessment, the participants started in either the collaborative or the individual condition by reading and learning the text and solving the MCQ-assessments.

### E. Data Analysis

The data were analysed using the IBM SPSS Statistics Version 21 (Paired t-test, Pearson correlation, and ANCOVA). The ANCOVA was calculated with a General Linear Model (GLM) with a mean effect (dichotomized values) for mental effort measurements (dual task errors), and the covariates of task difficulty and motivation.

## VI. RESULTS

For the first step, we conducted a t-test to evaluate the performance of the learners within the two conditions. The performance was measured by allocating 1 point for every correct answer (min. 0, max 6). In the collaborative learning condition the mean of performance reached a higher score  $M = 3.58$  (SD = 1.13) whereas in the individual learning condition  $M = 2.45$  (SD = 1.45) with a statistically significant effect,  $t$ -value = -4.27 ( $p = .000$ ).

In a second step, we performed correlation analysis (Pearson) of the collaborative learning condition with the cognitive load variables and motivation and performance. Only one significant correlation appeared (see Table I). Motivation correlates with performance ( $r = 0.41$ ).

TABLE I: CORRELATIONS (R) OF THE VARIABLES

Collaborative Learning	Task Difficulty	Mental Effort (Dual Task)	Motivation
Mental Effort			
-Dual Task Errors	0.10		
Motivation			
-Score	-0.022	0.26	
Performance			
- Score	-0.04	-0.018	<b>0.41</b>

Note: Bold = significant at  $p > .050$ ;  $N = 41$

To investigate deeper, we calculated partial correlations of the cognitive load variables and performance. Firstly, we correlated mental effort with performance, controlling for task difficulty, resulting in a non-significant correlation  $r = -0.18$ . Secondly, we correlated mental effort with performance, controlling for task difficulty and motivation resulting in a significant correlation  $r = -0.35$  ( $p = 0.029$ ). This second partial correlation indicates a relationship between extraneous load (mental effort) and performance.

To consolidate this result, we conducted an ANCOVA with one factor (mental effort) and two covariates (task difficulty and motivation) by splitting the sample at the mean score of mental effort into two groups. In addition, we investigated the effect size by performing Cohen's  $d$ . Table II shows the means and standard deviations of performance by splitting the groups.

TABLE II: MEANS AND SD OF PERFORMANCE BY GROUP SPLITTING

Group for Mental Effort (Dual task errors)	N	Mean	SD
Low	18	4.00	1.04
High	23	3.17	1.18
Total	41		1.11

This model was significant ( $F[3,37] = 5.59$ ;  $p = 0.003$ ) with an explained variance of 31% and showed a main effect between the two groups with an effect size of  $d = 0.73$  ( $F[1,39]$

= 6.86;  $p = 0.013$ ). Task difficulty showed no significant influence  $F[1,39] = 1.57$  ( $p = 0.218$ ) on mental effort. In contrast, motivation had a significant influence  $F[1,39] = 13.73$  ( $p = 0.001$ ).

## VII. DISCUSSION

Looking at the data the following results stand out. Firstly, findings reveal that learners learning in pairs (collaborative condition) performed better than they did within the individual learning scenario. Secondly, performance in the collaborative condition (scaffold) is affected by mental effort, task difficulty, and motivation. The model explains about one third of the variance of the performance, and effect size is also considerable. Thirdly, mental effort measured by dual task errors performance is only affected by motivation but not by task difficulty. The results are in line with the CLT-research, which supposes that collaborative learning scenarios can lead to additional impacts affecting performance. As previously mentioned, collaborative scaffolding leads to additional cognitive load because subjects must perform mutual coordination. This leads to either a) to an additional extraneous load that requires additional mental effort or b) to an intrinsic load associated with a higher element interactivity causing higher task difficulty. Thus in collaborative learning arrangements, the relation between task difficulty and mental effort in the form of coordinative learning activities must be properly managed in order to avoid negatively affecting performance. Furthermore in our investigation, a positive correlation between motivation and learning performance ( $r = 0.45$ ) occurred. Such a positive relationship between motivation and performance has also been found in other studies of cognitive load [25]. However, the data in Table 1 shows no significant correlations for task difficulty and mental effort. One possible explanation for this can be that in our investigation using a specific scaffold, extraneous load (measured by mental effort respectively dual task errors) affected performance in addition to motivation, whereas intrinsic load (measured by task difficulty) did not. Cierniak, Scheiter, and Gerjets' paper supports these findings, declaring that dual task measurement is an optimal instrument for predicting extraneous load differences [26]. In our view this points out the importance of managing extraneous load properly.

## VIII. CONCLUSIONS

In pedagogical terms, this study exemplifies that scaffolding collaboration represents a way of supporting collaborative learning in pairs. We have applied three important principles in our study. First, enriching prior knowledge by executing an instruction and an exercise to learn about the working process in order to decrease additional coordination effort in collaboration. Second, defining a simple and explicit collaborative process to induce a favourable relation between invested mental effort and learning performance. Third, we used justification to stimulate learning collaborative learning activities.

Considering the role of motivation, we understand that motivation affects the collaborative learning performance.

However, it is important to differentiate between motivation and mental effort. Effort in CLT is conceptualised as an estimator of cognitive load. If the relationship between mental effort and task difficulty is inappropriate, cognitive overload arises and learning performance is hampered. In contrast, the motivation representing task involvement (to work collaboratively in our experiment) shows a positive relationship with performance. However, further investigations must determine accurately whether high motivation can lead in some groups to high effort investments towards either effective or perhaps also ineffective learning activities.

In our study, two other important aspects have not yet been addressed. The first point considers, which collaborative learning activities generate either additional mental effort or which increase or decrease task difficulty. The second concerns the impact of group size. Therefore, two further research directions arise.

First, future research should carve out more clearly than our study design, which collaboration processes generate additional mental effort either affecting intrinsic load in form of task difficulty or extraneous load in form of more transactional costs.

To do this, we need an approach that combines process-oriented with cognitive-load-oriented research [20]. However, we could determine no significant correlation between task difficulty and mental effort. Therefore we suppose a focus on inter-individual coordination and regulation while learning collaboratively would help to create fruitful instructional designs and foster our understanding of the relationship between task characteristic, task involvement, and learner- and group characteristics that affect performance. Second, we have developed a scaffold for learning in pairs that represents a simple collaborative constellation. If the number of group members increases, probably additional cognitive costs will give rise to other characteristics and processes and it would lead us to investigate whether task difficulty is also affected, and if task characteristics (e.g. justification sequences) need to be changed. Nevertheless, the findings of this study reveal that collaborative scaffolding is a promising method for stimulating effective collaborative learning.

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