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Tübinger Beiträge zur Hochschuldidaktik

Herausgegeben von
Christine Baatz und Regine Richter

Manfred Künzel and Daniel Inderbitzin

Strengthening Cooperation and Enhancing Activation in Problem-Based Learning through Concrete External Representations

Band 4/2
Tübingen 2008

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Eberhard Karls
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Eberhard Karls Universität Tübingen
Sigwartstr. 20
72076 Tübingen
Tel.: +49 (0) 70 71–297 77 96
Fax: +49 (0) 7071–25 48 34
hochschuldidaktik@uni-tuebingen.de
www.uni-tuebingen.de/hochschuldidaktik

Eberhard Karls Universität Tübingen
Wilhelmstr. 32
72074 Tübingen
Tel.: +49 (0) 70 71–297 28 46
Fax: +49 (0) 70 71–29 31 23
edl-publ@ub.uni-tuebingen.de
www.uni-tuebingen.de/ub/elib/tobias.htm

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Editorial

Im Januar 2003 startete in Baden-Württemberg der Zertifikatskurs „Erwerb hochschuldidaktischer Kompetenzen“. Inzwischen haben 41 Lehrende mit dem Gesamtzertifikat abgeschlossen.

Im Rahmen der dritten und letzten Ausbildungsstufe gibt es die Möglichkeit, zu ausgewiesenen hochschuldidaktischen Fragestellungen eine schriftliche Ausarbeitung zu erstellen. Von dieser Möglichkeit im Sinne einer Abschlußarbeit haben viele der Absolventen des Gesamtkurses Gebrauch gemacht. Die hohe Qualität dieser Modularbeiten hat uns veranlaßt, sie der hochschuldidaktisch interessierten Öffentlichkeit zugänglich machen zu wollen. Damit war die Idee einer Zeitschrift geboren.

Tübinger Beiträge zur Hochschuldidaktik – dieser Titel war schnell gefunden. Die Klärung unseres Anliegens auch: Wir möchten den hochschuldidaktischen Diskurs an der Universität Tübingen fördern und über die Universität Tübingen hinaus öffentlich machen. Der hohe Ertragswert der schriftlichen Arbeiten soll transparent werden, Anregungen, Hinweise und dokumentierte Erfahrungen sollen aufgenommen und zugänglich gemacht werden. Darüber hinaus soll die Zeitschrift eine Plattform für qualitätsvolle Beiträge bieten, die sich an hochschuldidaktisch Interessierte wenden, und damit einen Beitrag zur Gestaltung einer guten Lehre leisten.

Die Beiträge sollen Erstlehrenden und Lehrenden, die sich erstmals mit bestimmten didaktischen Herausforderungen konfrontiert sehen, Reflexionsaspekte und praktische Hilfestellungen bieten. In einer Zeit sich verändernder Lernbedingungen sollen jedoch auch erfahrene Lehrende in den Tübinger Beiträgen zur Hochschuldidaktik neue Anregungen finden können.

Themen wie die Planung, Vorbereitung und Durchführung von Lehrveranstaltungen, Evaluation, Feedback und Bewertung, alternative Lehr- und Lernformen, Beratungs- und Prüfungssituationen, Struktur- und Curriculumsentwicklung, berufliche Weiterentwicklung, etc. stehen im Zentrum der Beiträge. Die Zeitschrift will einladen, didaktische und wissenschaftliche Fragestellungen in der Hochschullehre als eng miteinander verknüpft zu sehen. Sie bietet einen Ort für fachwissenschaftliche Überlegungen, will jedoch vor allem auch bewußt interdisziplinären Dialog fördern. Damit spiegelt sie die interdisziplinäre Zusammenarbeit, die sich an vielen Stellen aus dem interdisziplinären Austausch im Baden-Württembergischen Zertifikatskurs ergeben hat.

Um unseren Leserinnen und Lesern die abgedruckten Materialien unmittelbar nutzbar zu machen, haben wir uns bewußt für die Veröffentlichung im Internet entschieden. Die *Tübinger Beiträge zur Hochschuldidaktik* erscheinen als Einzelhefte in loser Folge, wobei die Beiträge eines Jahres jeweils zu einem Band zusammengefaßt werden.

Wir hoffen auf viele Leserinnen und Leser unserer Zeitschrift und freuen uns über Ihre Rückmeldungen.

Regine Richter, Christine Baatz — Tübingen, im Dezember 2007

Strengthening Cooperation and Enhancing Activation in Problem-Based Learning through Concrete External Representations

Manfred Künzel and Daniel Inderbitzin

In this pilot study, an effort was made to strengthen cooperation and enhance activation in medical problem-based learning. We compared traditional problem-based learning sessions with learning sessions of smaller groups that used a concrete external representation tool. Our experience shows that the use of icons for representing problems and solutions has important advantages for collaborative learning and the way problems are positioned and connected to prior knowledge. Other advantages of this approach seem to be an increase of individual participation and a decreasing need for tutor supervision. The results of this pilot study encourage the investigation of this promising educational method on a larger scale.

In dieser Pilotstudie wurde untersucht, wie im medizinischen Problem-Based Learning die Kooperation zwischen Studierenden gestärkt und ihre Aktivität erhöht werden kann. Wir verglichen traditionelle Seminare mit Sitzungen kleinerer Gruppen, die Gegenstände für konkrete externe Repräsentationen benutzten. Wir fanden heraus, dass die bildliche Darstellung von Problemen und Lösungen die Zusammenarbeit stärkt, da Probleme besser erkundet und mit Vorwissen verknüpft werden. Des Weiteren beteiligten sich die Studierenden deutlich häufiger und hatten weniger Bedarf an Unterstützung durch Tutoren. Die Ergebnisse dieser Pilotstudie regen zur weiteren Erkundung dieser vielversprechenden Ausbildungsmethode an.

1 Introduction

1.1 The Project: Enhancing Problem-Based Learning

Problem-based learning is a widely used educational method, especially in the education of medical professionals. Wood [1] explains the problem-based learning approach as follows: Students meet in groups of eight to ten and use scenarios or triggers, which may be paper-based clinical scenarios, video clips, or simulated patients, to define the learning objectives needed to understand and solve the educational problem. After a period of independent study, they return to the group to discuss their newly acquired knowledge. The group elects a chair and a scribe, who have the responsibility to encourage participation and lead the discussion, and to record important aspects on a flip chart in order to structure the discussion. The tutor, who may be a specialist in the field, supports all group members, checks the accuracy of record keeping, and ensures that the group achieves appropriate learning objectives. The tutor should also ascertain that the students understand the material by asking open questions and encouraging them to explain the topic in their own words or with drawings.

There are some perceived problems with this approach, including the problem of the absence of cooperative learning, which could be addressed with alternative versions of problem-based learning. The following questions must be asked in the process of developing an alternative problem-based learning method:

- What do we want to attain with the established educational problem-based learning method?
- Does problem-based learning work?
- Why should problem-based learning work?
- Should we improve problem-based learning or choose another method?
- What kind of improvements should be made?

We address each question below; our answers formed the basis of the rationale for the pilot study we report here. The aim of this paper is to describe the development of a new version of problem-based learning using the design rationales (e.g. that collaboration enhances learning) of the established problem-based learning version (in which a group of ten students collaborates guided by a chair and a scribe) by making alternative methodological proposals (e.g. the group works in a self-guided manner with centrally accessible representations of their work).[1]

[1] The authors thank Glenn Regehr, Centre for Research in Education at the Faculty of Medicine, University of Toronto, for his encouragement and critical review of the first manuscripts.

1.2 Problem-Based Learning in Theory and Practice

1.2.1 What Is the Aim of Problem-Based Learning?

Answers to the question "What is the aim of problem-based learning?" can be found at different levels. We identify them in terms of process (e.g. study habits), output (e.g. scores on examinations), and outcome (e.g. professional performance).

On the process level, the minimum goal of problem-based learning is an enhanced work environment for students and faculty. Problem-based learning should have an impact on professional motivation, develop clinical reasoning, structure knowledge in clinical contexts, and promote self-directed learning. It is furthermore aimed at improving the context of learning and the process of imparting knowledge and feedback. [2]

On the output level, traditional and problem-based learning approaches may be compared through performance in final examinations, where better scores are expected to be associated with problem-based learning.

On the outcome level, competences such as problem solving, collaborating with others, and working independently are problem-based learning goals that are also useful for future physicians. [3]

Furthermore, problem-based learning is intended to be a method that allows teaching and learning in a more enjoyable and efficient manner than via lecture and traditional self-study, and that also develops learning and working skills which are useful in a professional context.

1.2.2 Does Problem-Based Learning Work?

Published reports of success with problem-based learning are one way to determine whether or not this approach achieves its goals. On the process level, problem-based learning is significantly superior to traditional educational methods with respect to the students' attitudes and opinions about their programs. [4] Unfortunately, there are also reports of dysfunctional problem-based learning groups which have a dominant, disruptive member, who makes it difficult for others to participate, or which have problems with group work – a generally recognized phenomenon. [5] Problems associated with group work include students who only pretend to be actively involved, students who let others do the work, and teachers who give away solutions. The discrepancy between self-reported statements ("group works well as a team") and observed behavior ("dysfunctional") is often wide. [6]

On the output level, Colliver [7] and Albanese [8] argue statistically about reasonable effect sizes and cite studies that show superior performances or no effect of problem-based learning curricula on national exams. The outcome level has been investigated by means of self-reports or tests, where graduates who studied with a problem-based learning curriculum show better competence in self-directed

learning, problem solving, collaboration with others, and independent work than those who studied with traditional curricula. [3]

There is no convincing argument that problem-based learning should not be part of the methodological repertoire of a medical school. But what is intriguing is Colliver's [7] comment that "the review of the available literature revealed no convincing evidence that problem-based learning improves knowledge base and clinical performance, at least not of the magnitude that would be expected given the resources required for a problem-based learning curriculum." Thus, we can conclude that even though there is a considerable general acceptance of the problem-based learning method, there is also room for improvement.

1.2.3 What Can Be Enhanced?

Before we look at the theories on which problem-based learning is based, we should start with Colliver's [9] cautionary note explaining that the theory underlying problem-based learning, in particular cognitive theory, is not a confirmed scientific theory. However, Colliver feels that there is nothing more broadly accepted and better understood by our collocutors than cognitive theory when we talk about learning. In addition, even if there is no unifying, tested cognitive theory, all the subcomponents, such as information-processing theory and cooperative learning concepts, have a solid research base. We have used the work of Albanese [8] and Norman and Schmidt [10] to provide an overview of the components of problem-based learning. Their publications can provide a more complete account. The following summary serves to support our arguments regarding potential improvements to problem-based learning.

Information processing theory states that learning can be improved by

- activating prior knowledge;
- encoding the knowledge in situations that resemble the specific work situation;
- elaborating knowledge by discussion, answering questions, and other activities that lead to better understanding and retention.

We suggest improvements in problem-based learning based on all three of these elements.

Cooperative learning theory provides ideas about how a group of people can work together as problem solvers: The group

- creates a cognitive representation of the task,
- plans a procedure,
- executes it and checks back.

Furthermore, cooperation has some elements that could, if present, result in a higher quality of problem solving, namely mutual rewards and feedback, shared resources, and complementary roles among group members.

We suggest changes in the cooperative aspects of problem-based learning regarding the manner of representation, planning procedures, mutual rewards, feedback, and opportunities to take complementary roles. In our modified problem-based

learning approach, students work in multiple small groups of four to six people, and no additional tutor time is necessary.

Self-determination theory tells us to look for autonomous motivators to promote conceptual understanding, creativity, positive feelings about failures and setbacks, and a preference for optimal challenges over easy success. To increase the number of autonomous motivators, a learning environment should:

- take the perspectives of students into account,
- provide opportunities for a choice,
- encourage students to accept responsibility for their individual learning,
- provide relevant information, and
- ensure meaningful teacher involvement.

In our proposals for an improved version of problem-based learning, we particularly try to enhance the expression of the students' perspectives, their responsibility for learning, and the meaningful involvement of teachers.

In summary, at the process level, the theory identifies several factors responsible for the success of problem-based learning as an educational method. These components may also be used to improve traditional problem-based learning further. We need to identify novel experimental methods to visualize these key elements. Research could then compare the new and traditional modalities of problem-based learning on the process level and measure the relative presence of important ingredients like student participation and activation of prior knowledge. In a second step, this experimental approach might lead to a solid and effective augmentation of the learning process.

1.3 Improve the Traditional Method or Use Another One?

If we want to optimize the current approach to medical education, should we change to an entirely new method or improve the standard problem-based learning approach? Problem-based learning has two very valuable assets: it is widely used and accepted, and it is directly derived from recognized learning theories, such as information processing theory, cooperative learning theory, and self-determination theory. But why does problem-based learning not generate more pronounced effects? The currently implemented model of problem-based learning might prove imperfect for a variety of reasons:

- **Cooperation:** Albanese [8] doubts that cooperative learning is an active ingredient of all problem-based learning interventions. In his work, he identifies the presence or absence of cooperative learning as one of the main reasons for the ambiguous results obtained from evaluations of problem-based learning curricula.

- **Cognitive representation and encoding:** Thinking abstractly about problems is a major difficulty for students. We are convinced that concrete external representations of a problem and its components can crucially facilitate the entire learning process. Given the limitations of the human working memory, mental resources are freed for problem solving by concrete external representations rather than being absorbed for abstractly remembering the issues and individual components of the actual task. Furthermore, there is no common representation or interpretation that a group can use to collectively understand and solve a given problem without concrete external representation.

The importance of the representation of the problem during the case presentation [11] and the modality and degree of abstraction in which a case is presented seem to be important factors directly influencing the learning outcome. [12] Videos are an important visual modality and can reduce the level of abstraction in the presentation. Norman et al. [13] observes that "video has such a strong influence on learners because text actually is an abstract representation of reality. Video brings the abstraction to a level where students can begin to describe. Dual-coding theory might suggest that having a visual example of abstract representations should promote retention of the concepts and assist students in constructing a mental model, especially when visual cues have a critical role in the diagnostic process."

We are convinced that addressing these main critical points – the lack of real cooperation and need of common representations to understand and solve problems and build mental models – could enhance the established problem-based learning and we do not have to develop a new method.

2 Designing the Improvement of Problem-Based Learning

2.1 Three Improvements

On the basis of the presented theories and thoughts, we propose methodological changes to traditional problem-based learning. Our improvements can be grouped as follows:

- **Strengthening cooperation and communication of the group.** We have experimented with a shift from group work led by a chair and a scribe working with a frontal flipchart to a more central moderation involving and activating the entire group.
- **Enhancing representation and information processing.** This goal was achieved by shifting from sole dependence on written or spoken communication to figurative and symbolic means of representation.
- **Enhancing activation of prior knowledge and construction of conceptual frameworks.** This goal was accomplished by using a constructional tool that organizes the activated knowledge into an evolving framework.

We refer to the tools used in this three-way improvement as concrete external representation. If used in problem-based learning, we call the method problem-based learning with a concrete external representation tool to distinguish this approach from traditional problem-based learning.

2.2 Concrete External Representation in Problem-Based Learning

Concrete external representation is both a tool and an instructional method. The concrete external representation tool is composed of a horizontal whiteboard onto which three-dimensional figures made of wood, metal, or glass are placed. These figures serve as symbols for organizations, information, people, and relationships. Additionally, movable tags and plasticine can take on extra symbolic meaning (e.g. impulse, pill, or heart). We consider concrete external representation to be a new case modality. It is built up by the students within the framework of the case.

Problem-based learning with concrete external representation has been used in Swiss Health professional education and university programs, and instructions for this method have evolved to look as follows:

I. Initial group work
   - I.1 Represent all people and items involved in the case (e.g. from patient care situations to the physiology of the lungs) with a concrete symbol.
   - I.2 Give these symbols the necessary attributes and interrelations.
   - I.3 Identify unclear attributes and relationships and get the information needed.
   - I.4 Identify the tasks and problems of each party involved (e.g. patient, family, doctor).

II. Individual tasks
   - II.1 Get the information needed to make attributes and relationships clear.
   - II.2 Develop strategies to obtain solutions and make representations of them.

III. Final group work
   - III.1 Check your representations with colleagues, mentors, or literature.
   - III.2 Record (e.g. pictures with legends) all results.
   - III.3 Reconstruct the problem-based learning procedure with concrete external representation with your mentor.

Figure 1

University of Bern medical students working with concrete external representations in a problem-based learning situation.

In problem-based learning students investigate a medical situation, elicit main problems, and plan the diagnostic process and the management of the patient and the situation. A problem-based learning session with concrete external representation could look like this: Medical students Sandra, Kim, Ollie, and Dan are at work

(Figure 1) on the following case: "You have your own practice as a family doctor. A patient (female, 35, married, two children) has to be hospitalized to determine the cause of elevated alkaline phosphatase serum values and an unspecified lump in the breast." On the table in front of them lies a concrete external representation tool. The team considers how the patient should be treated. They use the figures to represent the people and institutions involved in the patient's previous history and the current treatment (Figure 2). Dan explains the role of the patients' relatives. Kim adds two more people (the family doctor and a figure for the patient's home). As Dan finishes his explanations, he places a symbol for information next to the relatives. In the end, Sandra explains the questions she formulated from the point of view of the doctor in charge of treatment.

Figure 2

Students present and explain the results of the group work with a concrete external representation of the case.

The students explain the results of their group work with a concrete external representation tool: "The first step we took was to represent the people involved and their information needs. The mother needs to know how long she might be away from home and what the possible outcomes of the examination are because she has to explain the situation to her family and look for help with her various household duties. In her case the grandmother is able to take the children to school and look after the household, here symbolized by a car and flowers. Usually the family is not informed directly by the staff, but by the patient. The hospital doctors and nursing staff receive information from the family doctor and from the patient herself.

"We analyzed and symbolized the information channels. Then we represented the sequence of information flow and its direction. We had to ask ourselves if the

patient receives information directly or via a third person. Since we were able to look at the heavily loaded information nodes (patient, family doctor), as well as the direction of information flow, we were able to develop and characterize procedures and aids for the family doctor to allow information to flow freely, efficiently, and reliably."

During the group work Ollie takes digital photographs. The pictures are part of the electronic record of the meeting and help to remind the participants of the stages of the discussion. Sandra often regroups the figures to simplify the representation. In the end Ollie replaces complete groups of figures with new symbols – e.g. for the diagnostic process – thereby arriving at an abstraction of the situation, similar to what mathematicians do when they write a formula.

2.3 Pre-Test Observations

Although the model of problem-based learning with concrete external representation is still evolving and the evaluation of the program has so far been more informal and formative than formal and summative, we have made several important observations. Compared to problem-based learning groups using the more traditional flipchart model of problem listing and discussion, we found out that in problem-based learning with concrete external representation:

- students focus on the problem for a longer time;
- the representation of the problem is substantially more sophisticated;
- group conversation is more interactive and engaged, leading to multi-perspective problem-solving approaches;
- group dynamics lead to mutual reinforcement, better definition of worthwhile problems, and work-sharing procedures;
- the students construct easily recallable external configurations that they can later refer to in their practical work as useful internal memory schemata;
- a kind of flow effect often develops during the cooperative construction of a symbolic world.

When asked about the differences between working with concrete external representation tool and a traditional flipchart, the students and their moderators explained that with the concrete tool set up in the middle of the group, there was no real need for a moderator or chair. Since then, we have used the terms "distributed or central moderation" to describe the autonomously organized form of learning and working that the concrete external representation engenders.

3 Experimental Comparison of Results of the two Approaches in Medical Education

In a first comparative pilot study at the medical school of the University of Bern, we investigated the assumed effect of increased student cooperation and activity in problem-based learning with a concrete external representation tool. We were interested in the students' opinion regarding the benefit from the tutor and the group under the conditions of traditional and modified problem-based learning, and in the learning performance at the end of each session. To obtain this information, we used the following methods:

- a written exam with three open questions;
- a questionnaire (10-point scale) about the efficiency of learning, and profit from group and tutor;
- an analysis of the transcript of the video observation of the two learning sessions, and an analysis of the questions asked, including hypotheses formulated, and answers given.

Two groups of students (group A with five students; group B with seven students) participated in two problem-based learning sessions. In period 1, group A was the intervention group doing problem-based learning with a concrete external representation tool, and group B did a traditional problem-based learning session. In period 2, the learning methods were exchanged.

Our hypotheses were as follows:

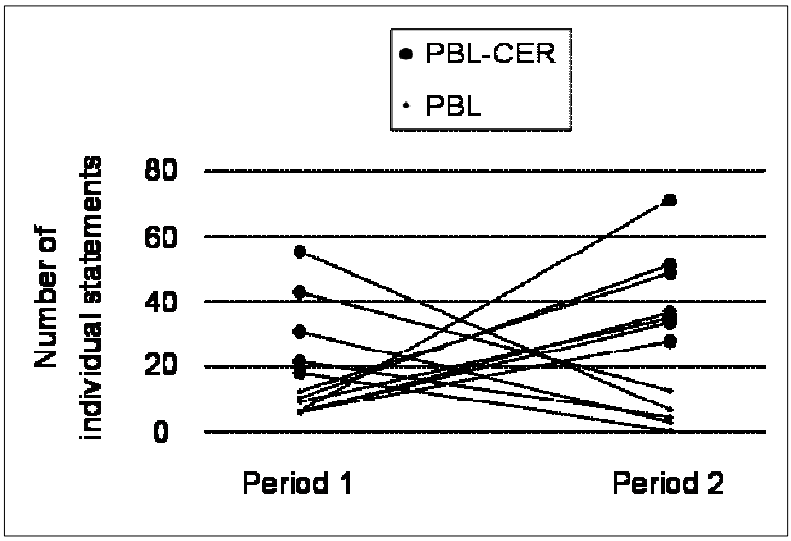
1. There are no differences between the enhanced and the traditional problem-based learning groups in terms of the number of questions asked and answers given during the problem-based learning process.
2. There is no difference between the groups in the scores obtained from a brief written exam.
3. There are no differences in the reported efficacy of learning or profit from the group or tutor.

4 Results

4.1 Activation of Individual Students

Individual student participation during the traditional and the enhanced problem-based learning processes at periods 1 and 2 is outlined in Figure 3.

Figure 3: Activation of individual students



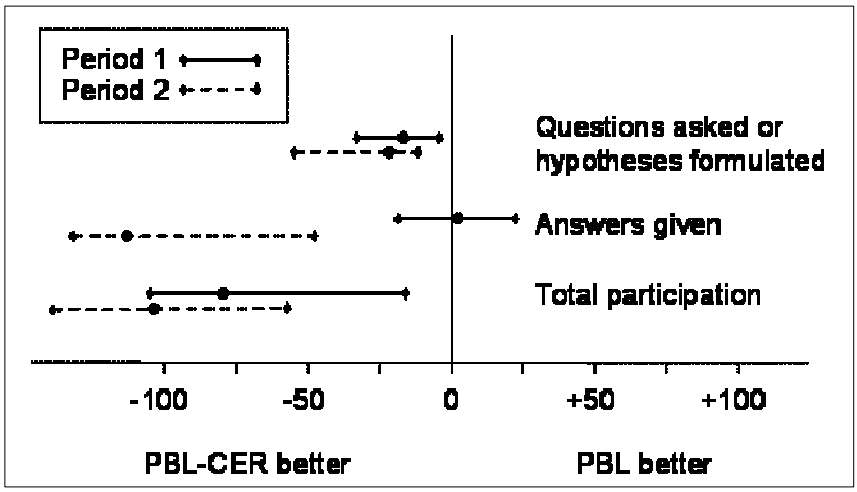
Depicted is the number of individual statements (questions asked, hypotheses formulated, answers given) of each individual student. Each dot represents a student. The lines indicate a rise or decline of the number individual statements. In period 1, group A (n = 5, full circles) worked with the new approach (PBL-CER), and group B (n = 7, small circles) with traditional problem-based learning (PBL). In period 2, the tasks were exchanged.

A shift from problem-based learning with a concrete external representation tool to traditional problem-based learning resulted in a decline of the number of statements of each individual, whereas changes from problem-based learning to the new approach enhanced the participation of individual students. In general, student activation was significantly higher in problem-based learning with concrete external representation in comparison to traditional problem-based learning.

4.2 Total Student Participation, Collaboration and Investigation Activity

The groups who studied with the new approach (group A in period 1, group B in period 2) formulated a significantly higher number of questions and hypotheses, and the number of total participation was higher than in traditional problem-based learning. Figure 4 shows the 95%-confidence intervals for the local differences of questions asked, hypotheses formulated, answers given, and overall participation. We investigated the students' behaviour as to the number of "questions asked or hypothesis formulated", "answers given to their colleagues" and "participation in the discussion" as indicators of collaboration in the group and investigation of the problem. To compare the two small groups, we used a special statistical procedure, which calculated the confidence interval of the numbers of group B minus group A with a localization appraiser to indicate the difference between the groups.

Figure 4



95%-confidence intervals calculated according to Hodges-Lehmann, $p < 0.05$, with a localization appraiser (black dot); the lines are an indicator for the distribution of values.
On the left (minus), the group using problem-based learning (PBL) with concrete external representation (PBL-CER) scores better. In period 1 (line), group A used the new method, in period 2 (interrupted line) group B used it.

As shown above, the numbers of questions asked, hypotheses formulated, and overall participation were significantly ($p < 0.05$) higher in problem-based learning with concrete external representation. There were no differences in the number of answers given. In both periods, the investigation of the problem and total participation was higher in the groups that used problem-based learning with concrete external representation (scores on the left of 0).

4.3 Performance in Written Exams and Benefit from Group and Tutor

Before conducting a larger study, we wanted to estimate whether the students reported a similar learning efficacy and the same benefit from the group and the tutor in the group using problem-based learning with a concrete external representation tool, and scored at least a comparable result on a short exam after the traditional learning session.

The performance in the exam was equal after period 1, and better in the group that used the enhanced method after the second period. The students who worked with the enhanced method reported a greater benefit from the group and the tutor in period 1. All other comparisons were not significantly different.

4.4 Cost Efficiency

While in the traditional problem-based learning setting a tutor can normally only be responsible for a group of up to ten students, the chess-tournament-like atmosphere of problem-based learning with concrete external representation makes it possible for a single tutor to supervise up to thirty students all by himself. Student groups use the concrete external representation as a central board to mark questions and unclear points. The tutors do not have to follow the entire process because they see enough context and traces of it on the board to interpret the questions or identify unclear points. Thus, one tutor can deliver specific feedback to each group in turn; there is no need for constant supervision.

The optimal group size for problem-based learning with a concrete external representation tool seems to be 5 to 6 students. Two groups may pair up to compare their representations regularly, therefore enhancing active learning and reducing tutor time. When working with small groups, a tutor supervises 3 to 4 pairs of groups; as a consequence, tutor time is diminished by at least a factor of 3 in the enhanced method when compared to traditional problem-based learning.

5 Discussion

Our experiences suggest that the use of three-dimensional figures to represent problems and solutions in a problem-based learning session has important benefits for the way collaborative learning happens. Problems are easily identified and connected to prior knowledge, concrete situations are remembered, and individuals' stories told. Our observations are linked to the foundations of problem-based learning, namely cognitive processing, prior knowledge activation, and contribution of group discussion, as summarized by Schmidt and Moust [3].

We think that the enhanced approach (problem-based learning with a concrete external representation tool) works because concrete external representations permit and encourage the external visualization of thinking processes, thus overcoming the limitations of the human working memory. Mental resources, that would otherwise be required purely for memory retention, are freed up for learning. [14] At the same time, external representation offers a means of communication that replaces complicated verbal expression with an external context. This characteristic also serves to facilitate understanding and group cooperation. Concepts do not have to be abstractly defined, but can gradually evolve on the concrete external representation board and are under constant mutual construction. Concrete external representation also satisfies the needs of novices for concrete, step-by-step representation and quick action. [15] Further research questions could focus on these aspects of collaborative learning, representation, and retention. The students of the pilot groups had at least the same scores in the brief exam after the enhanced problem-based learning sessions and had the feeling that they profited well from group and tutor despite considerably reduced tutor presence. These facts help us to justify larger studies with this improved problem-based learning approach.

The aim of the study at hand was to describe the development of an alternative problem-based learning procedure. The pilot investigation was intended to focus on the important teaching and learning effects of problem-based learning with a concrete external representation tool in a small-group investigation. Methodological questions and transferability of the results to a long-term application of the method will be addressed within our ongoing larger studies.

Another research project will involve the detailed investigation of an essential personal observation made when analyzing the results of the written exam in nursing education. In this scenario, concrete external representation did not only enhance individual scores, but also narrowed the standard deviation in the performance of the learning group.

Furthermore, we will also explore what we called "cover effect." The average number of questions asked per student in the traditional problem-based learning control groups was independent of the group and the topic discussed, and was

rather low (Figure 3). The intervention groups that studied with concrete external representation showed greater differences and significant enhancement of individual participation as if a cover had been lifted. This "cover effect" would suggest a kind of suppression of student activation in the actual problem-based learning context. We will investigate this cover effect and, if it is confirmed, its causes.

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Notes on the Contributors:

Manfred Künzel, MD, MEd, MME, is a faculty and curriculum developer, coordinating a European research project on Communities of Practice at the University of Fribourg, Switzerland. He works at the Department of Higher Education of the University of Fribourg.

Daniel Inderbitzin, MD, is a staff surgeon and research coordinator at the Department of Visceral and Transplantation Surgery of the University Hospital Bern, Switzerland. He is regularly involved in the curriculum of practical medical student education at the University of Bern.

Anschrift der Autoren:

Manfred Künzel

Université de Fribourg
Centre de Didactique Universitaire
Boulevard de Pérolles 90
CH-1700 Fribourg
Switzerland
manfred.kuenzel@unifr.ch

Daniel Inderbitzin

Department of Visceral and Transplantation Surgery
University Hospital Bern
CH-3010 Bern
Switzerland
daniel.inderbitzin@insel.ch

Anschrift der Herausgeberinnen:

Regine Richter

Leiterin der Arbeitsstelle Hochschuldidaktik

Kontakt:
Arbeitsstelle Hochschuldidaktik
Eberhard Karls Universität Tübingen
Sigwartstr. 20
72076 Tübingen
+49 (0) 70 71–297 77 96
+49 (0) 7071–25 48 34
regine.richter@uni-tuebingen.de
www.uni-tuebingen.de/hochschuldidaktik

Christine Baatz

Akademische Mitarbeiterin
Kompetenzzentrum für Hochschuldidaktik in Medizin Baden-Württemberg

Kontakt:
Kompetenzzentrum für Hochschuldidaktik in Medizin Baden-Württemberg
Medizinische Fakultät
Eberhard Karls Universität Tübingen
Elfriede-Aulhorn-Str. 10
72076 Tübingen
+49 (0) 70 71–297 7942
+49 (0) 70 71–29 5218
christine.baatz@med.uni-tuebingen.de
www.medidaktik.de

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