International Journal for Research in Vocational Education and Training (IJRVET)
2022, Vol. 9, Issue 2, 216–238
https://doi.org/10.13152/IJRVET.9.2.4

A Processual Perspective on Whole-Class-Scaffolding in Business Education

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Received: 20 January 2022, Accepted: 06 May 2022

Abstract

Context: Scaffolding is a form of process-adaptive learning support that is relevant in numerous contexts, including informal learning, workplace learning as well as school teaching. While scaffolding can be well conceptualised for individual learning situations (especially for tutoring situations), there is a difficulty in measuring process adaptivity in heterogeneous learning groups, such as school classes.

Approach: In this paper, we develop a measurement method that targets the deep structure of teaching and learning in whole class settings. Processes of shared knowledge constructions are taken into account, since whole-class-scaffolding (WCS) means to shape and develop common or joint knowledge spaces rather than to scaffold a multitude of individual construction processes at the same time. To achieve a coding procedure for WCS interactions, we integrate scaffolding principles and principles of dialogic teaching and explicated a set of rules that can be correlated to the quality of WCS-episodes rated on distinct Likert scales.

Results: The measurement method developed in the paper provides a solution to the problem of how to measure process-adaptive learning support that is not only related to individual learners, but is directed at a heterogeneous group of learners in which different support needs may be present simultaneously. The coding procedure systematically links scaffolding principles and principles of dialogic teaching and enables us to capture the dynamics of teaching and learning processes in larger group settings. In this respect, concepts such as joint- and common space, representing entities to which WCS refers, are operationalised.

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ISSN: 2197-8646
https://www.ijrvet.net

Conclusions: When methods for measuring the dynamics of teaching and learning processes are available, research on instructional support is no longer limited to global ratings of whole learning units. Furthermore, the codings allow for a more fine-grained analysis of trajectories of scaffolding interactions. Such an analysis reveals information about local specifics of WCS that can explain further learning differences between students and that can be used to derive implications for effective instructional techniques.

Keywords: Scaffolding, Dialogic Teaching, Shared Knowledge Construction, Adaptivity, VET, Vocational Education and Training

1 Introduction: Scaffolding

Effective support of learning processes is a major remit of educational practice. On the one hand, learning should be active, open and self-directed. On the other hand, learners should not be left alone with learning difficulties, ambiguities or misconceptions. Finding an appropriate level of support therefore involves not only supporting students individually according to their abilities, but also being adaptive with respect to the course of learning itself. Such a tailor-made support is referred to as "scaffolding".

Scaffolding is investigated in numerous contexts, including informal and workplace learning (Dobricki et al., 2020; Greenfield & Lave, 1982; Khaled et al., 2014; Schwendimann et al., 2015), self-directed learning (Azevedo et al., 2011; Beckers et al., 2019; Kicken et al., 2008) and second language learning (Gibbons, 2015; Heatley et al., 2011). It is of particular importance in complex learning settings with many degrees of freedom and when situation-specific individual learner needs are to be taken into account. On the one hand, scaffolds can be implemented in the learning environment (macro-scaffolding). This includes the development of learning materials and the design of learning opportunities and tasks (e.g., worked out examples, Boldrini & Cattaneo, 2013). On the other hand, scaffolds can be built up successively by teachers, tutors or trainers in the course of the learning process to support individual knowledge construction or the co-construction of shared knowledge spaces (micro-scaffolding).

In the field of business education, scaffolding is studied in vocational educational settings, in higher education and in business contexts. Results show that scaffolding leads to a more positive classroom experience (students' overall satisfaction, motivation) and has a positive effect on achievement variables (knowledge acquisition, examination scores) (Yang & Liu, 2021). In higher education, scaffolding plays a role especially in promoting procedural learning (Cowen et al., 2011), deep learning (Green et al., 2015), critical thinking (Chandler et al., 2015) and in technology-mediated learning (Janson et al., 2020). It can be stated that scaffolding always plays an important role, when learners are engaged in authentic procedural tasks (such as constructing a personal finance plan; Cowen et al. 2011) and in linking algorithmic procedures or process outcomes (e.g., statistical data) with "real-world-meaning" (Green et al., 2015, p. 325) in the context of economic problem solving or decision making. In addition, the scaffolding of social skills and the development of a corporate culture are focused on in business contexts and vocational training programs. For example, Remidez Jr. et al. (2010) show that scaffolding of the communication process in virtual teams supports the formation of trust between team members in a significant way.

Therefore, we may conclude that the function of scaffolding in the field of business education is no longer limited to the individual support of knowledge construction processes among learners. Rather, scaffolding techniques are systematically linked to (virtual) conversational discourses in order to promote collaborative real-world decision making in vocational and business contexts and to foster the corresponding skills among learners.

The problem, however, is that process adaptivity, which underlies the scaffolding concept (see Wood et al., 1976), is directed toward a single learner (or a homogeneous group of learners) and does not apply to heterogeneous learning groups or teams. Therefore, either normative assumptions must be made about which scaffolding techniques are adaptive to learning, or learning settings with only one or a few learners can be addressed (see Hermkes et al., 2018; van de Pol et al., 2017; Wischgoll et al., 2019). Against this backdrop it seems worth our while, or even necessary, to think about how to scaffold large heterogeneous groups, in particular entire school classes or groups of trainees. In other words, what we lack so far is a conception of adaptive whole-class scaffolding (WCS).

A promising way of conceptualising WCS is to incorporate principles of dialogic teaching and to use these principles when determining adaptivity of scaffolding interactions (Bakker et al., 2015; van de Pol et al., 2017). However, there are at least two aspects to consider. First, focusing on classroom communication would not be sufficient. Rather, the deep structures of teaching and learning would have to be captured. This means that knowledge construction processes and learning difficulties that arise among students have to be identified and understood. Second, we would have to get a handle on shared knowledge spaces constructed through collective activity, since whole-class-scaffolding means to shape and develop such dynamic spaces rather than to scaffold a multitude of individual construction processes at the same time. In this respect, different kinds of knowledge spaces have to be differentiated and a distinction has to be made between student solutions that are introduced into the classroom discourse for a critical discussion, on the one hand, and jointly constructed knowledge that all learners should possess in order to successfully complete subsequent learning steps, on the other hand.

The aim of this paper is to develop a method for measuring WCS based on the coding of shared knowledge space constructions taking place during classroom talk. In Section 2, we give a short overview of forms and principles of dialogic teaching. In Section 3, we introduce the concepts of shared knowledge spaces needed for coding WCS. Based on these concepts, we develop the conception of WCS in Section 4 and explicate the coding procedure. Section 5 provides a conclusion and an outlook on the next research steps.

2 Classroom Discourse and Principles of Dialogic Teaching

As has been shown in numerous studies, the default pattern of classroom discourse is IRE, which stands for "initiation", "response", and "evaluation" (Atwood et al., 2010; Cazden, 1988; Greeno, 2015; Mehan, 1979; Wells, 1999). This tripartite form of classroom talk conventionally consists of teacher initiation, student response, and teacher evaluation (Cazden, 1988). Despite its frequent use, IRE is often negatively associated with superficial displays of previously learned knowledge (Newmann, 1990). It was found that questions initiated by the teacher during recitations tended to be asking for already-known answers and to involve lower-order thinking (Nystrand et al., 2003). IRE is often referred to as *recitation* (O'Connor & Michaels, 2007) and is identified as being monologic (Alexander, 2006) or authoritarian – in contrast to the approach where open dialogue and the exchange of students' ideas are involved (Nystrand et al., 2003). Moreover, students who have internalized the IRE-pattern tend to maintain their predominantly passive role in classroom talk. As Greeno (2015) puts it: "An individual learns to activate cognitive resources that prepare him or her to take turns that are likely to happen later in the sequence" (p. 257). In the case of the IRE scheme, this leads to students preparing for the 'response'-term but expecting that evaluation, feedback, clarification, correction, etc. will be provided by the teacher.

Bakhtin's concept of dialogical meaning-making entails that the learners play an active role in developing a personally constructed understanding of the curriculum through a process of dialogic interchange (Bakhtin, 1981). In this respect, dialogic forms of classroom talk such as exploratory talk or accountable talk also aim at "joint construction of knowledge in classrooms" (Mercer et al., 2019, p. 188). Exploratory talk enables the students to try out ideas and to see what others make of them (Barnes, 1976) whereas accountable talk involves students not only presenting their ideas or understandings but also explaining them to classmates (Resnick et al., 2018). The principle of dialogic teaching entails that *all* students are involved in the classroom discourse, which shifts the focus to participation. In this sense, students are encouraged to take responsibility for their statements and thus their own learning process. Ultimately, this results in the co-construction of knowledge. In contrast to IRE, expressing different views is encouraged – and needed in order to create a joint knowledge space.

3 Dialogic Teaching and Shared Knowledge Construction

Dialogic teaching aims to promote students' learning processes in phases of classroom talk. In this section, we focus on such classroom conversations in terms of co-construction of shared knowledge spaces. We differentiate systematically forms of knowledge spaces and reconstruct co-construction processes as inferential processes.

3.1 Co-Construction of Knowledge Spaces in Classroom Talk

The concept of knowledge spaces is well known in educational research (see Falmagne et al., 1990, 2013). However, depending on the domain and the research interest, knowledge spaces are defined in different ways. One such distinction concerns joint spaces and common spaces. Joint space refers to the set of all non-redundant contributions (propositions) in classroom talk up to the present time. The joint space constructed by the contributions grows accordingly with the duration of the class discussion. The concept of joint space has to be distinguished from the concept of common space. Common space refers to the knowledge shared (or to be shared) by all interactants and accordingly serves as the basis for subsequent learning phases. Therefore, one also speaks of common ground (Reusser, 2001).

A key difference between joint space and common space is that a joint space does not have to satisfy the property of consistency. Different mutually incompatible pieces of content can constitute it, e.g. when learners introduce fundamentally different solutions to a task or differ in their conceptual understanding of a certain issue (see, for example, the concept of sustainability in economic contexts; Vidal et al., 2015). In contrast, both consistency and coherence are required, or at least aimed at, for common space, since this kind of knowledge space is supposed to be structurally equivalent to cognitive structures of an individual. In other words, common space denotes the common understanding shared by a group of people, whereas joint space denotes the set of views or understandings shared by a group. Joint space requires that every member of the group understands the views expressed by other members of the group, but not that they endorse each other's views. Moreover, depending on the research focus, we can relate to the notion of common space in different ways (see Table 1).

Table 1: Definition of the Common Space-Concepts

Common space concept	Definition
Intended common space (CS_{int})	Common space as the educational objective the teacher plans to achieve for all students in a particular lesson, which can be reconstructed from the teacher's lesson plan
Potential common space (CS_{pot})	Common space that comprises all spaces that are compatible with CS_{int}; in this respect, it concerns the content of the overall domain beyond the selected CS_{int}.
Effective common space (CS_{eff})	Common space co-constructed in the course of a lesson; unlike CS_{int} and CS_{pot}, CS_{eff} is dynamic

The differentiation of the three types of common space makes it possible to precisely measure spontaneously occurring deviations in the course of the lesson. One type of deviations from the lesson plan concerns amendments, which occur when CS_{eff} contains elements that belong to CS_{pot} but not to CS_{int}. The respective contributions may be either made by the teacher (teacher's constructive activity) or permitted (learners' constructive activity) by them. The second type of deviations concerns digressions from the subject matter, which occur when CS_{eff} contains elements that do not belong to CS_{pot}.

An example from the lesson will illustrate the role that the relationship between spaces plays in coding decisions. In the subject matter of "procurement processes", the quantitative and qualitative criteria for the comparison of offers are an essential part of CS_{int}. This means that no (reasonable) lesson plan is conceivable without a well-defined set of quantitative criteria including delivery costs and discounts as well as a set of additional (qualitative) criteria that go beyond the calculated price (like sustainability, maintenance and durability of products). It is worth noting that the question of which of the qualitative criteria to include and how to weigh them depends on the type of product to be procured. If, for example, offers for office computers are compared, the teacher could spontaneously go into more detail about qualitative criteria like sustainability and durability and add some new aspects that were not included in the lesson plan. Thus, the teacher's remarks do not belong to CS_{int} reconstructed from the lesson plan. However, they are included in the reconstruction of CS_{eff} because they are part of CS_{pot} for this learning unit. If, on the other hand, the teacher explains hardware features or technical details and how they work, then such explanations would belong neither to CS_{int} nor to CS_{pot}. As a consequence, these explanations would be excluded from empirical reconstruction of CS_{eff}.

It should be emphasised that the common space does not only concern the learning objectives, but also the understanding of the learning problems. Therefore, the common space (CS_{eff}) also indicates whether the learners have a shared problem, they are working on (see section 3.2.1).

Albeit implicit, the concept of a shared knowledge space is also contained in the concept of the "collective student". As Bromme and Steinbring (1994) put it, the collective student "is constituted from the contributions of the various individual students" (p. 243f). From a cognitive point of view, this just corresponds to the joint space: "The classroom dialogue between the students and the teacher then results in the joint representation of the subject matter" (p. 244). Moreover, as Bromme and Steinbring point out, this kind of instructional dialogue occurs mainly with experienced teachers, while novices tend to treat "the contributions of individual students as statements of individual learners. Hence, the discourse of the lesson is fragmented into the subtopics of individual students or student groups, and has no consistent dialogue referring to connected topics" (p. 244). In order to reconstruct co-construction processes and the emergence of knowledge spaces, the inferential conception can be employed, as will be shown in the next section.

3.2 Cognitive Modeling of Co-Constructive Processes

In the following section, we introduce the inferential approach. This approach enables a cognitive modeling of classroom conversations and allows us to differentiate co-constructive processes of different knowledge spaces. Moreover, the inferences can be considered as specific steps in problem-based learning cycles.

3.2.1 Inferential Approach to Knowledge Construction

Successful collective co-construction of knowledge requires that the teacher and the students create a common space with respect to the task and the goal of the respective lesson, that learning unfolds from there in a joint space, so that each individual is able to follow the discourse and participate in it, and that finally the teacher and the students end in a common space of knowledge, as far as the educational goals are concerned. How can we describe the states (especially initial and final common space) and the processes from a cognitive point of view?

We suggest an inferential approach to knowledge construction, in which the whole course or lesson, but also specific learning tasks can be reconstructed as a sequence of (i) stating premises (which may include, for example, prior knowledge or the task at hand), (ii) deriving results and (iii) drawing conclusions. Any reasoning starts from premises, produces results, some of which are dismissed and some retained, based on final conclusions.

This is not restricted to deductive inferences. Modern logic is much broader and covers also inductive and abductive inferences. With this move, logicians aim at naturalising logic in the sense of developing formal models that allow us to reconstruct (all) the ways in which real people think – whether they think correctly or whether they make mistakes (Woods, 2013, 2017).

Thus, analysing scaffolding from a logical point of view means that we have to understand the specific inferences learners are involved in, how they form premises, come up with results and evaluate them, so that teachers can join them in their inferential states and processes and guide them along by, e.g., hinting at neglected aspects, false premises or conclusions and so forth. Not only deduction, but also all other inferences we are going to distinguish, run from premises to conclusions. In particular, making an inference can be described as a cognitive process including three characteristic sub-processes, i.e. (1) gathering the premises from which to infer something, (2) observing to premises in order to discover some result, (3) establishing whether the result actually follows from the premises.

Based on Peirce's original approach (see Minnameier, 2004, 2010, 2017), we differentiate between three basic types of inferences, which are abduction, deduction, and induction. And we call the three subprocesses that apply to any inference "colligation", "observation" and "judgement" (according to Peirce, 1893/1932 [CP 2.442-444][1]; see also Minnameier, 2017).

In the following subsections we introduce the inferences, then discuss how they are combined in problem-based reasoning. Finally, we add a brief account on what we call "inverse inferences".

3.2.2 Abduction, Deduction and Induction

Abduction is the inference that starts from a puzzling situation, e.g. consisting of incoherent explanation-seeking phenomena, with the aim to explain them, i.e. to derive a coherent account of those phenomena. For instance, in business education students might be confronted with the situation where a company manufactures a product that yields losses rather than profits, and continues production rather than stopping it. Assuming that the management is not irrational or ill-motivated, how could this be explained?

This is a typical abductive question. As an inference it starts by colligating the relevant premises as described, which are then observed in order to find a coherent account. Ideas in this respect will spring to the mind spontaneously in the phase of observation. However, not all these ideas necessarily fit. Therefore, the final judgmental part consists in evaluating whether the generated ideas really remove the problem. If they do, the abduction is valid. For instance, differentiating between fixed and variable costs allows us to solve the above-mentioned problem, because selling at a loss is rational as long as it yields positive contribution margins (that cover the variable and at least part of the fixed costs, which the firm incurs anyway). Grasping the very idea pertains to observation, accepting it to judgment.

Note that abductive validity does not imply or entail that the account be "true". This is why there can even be a number of accounts that are all abductively valid at the same time, although they might exclude each other. In science, this denotes the all too familiar case, in which theories compete with each other. They are all explanatory valid, although only one can actually be true (if they are not false altogether, which is also possible).

Deduction starts from such theoretical accounts and allows us to infer consequences of them, based on additional premises from our background knowledge. In particular, we can deduce what we would expect under certain experimental conditions (or what we could rule out based on those premises). Again, it starts with colligating premises, leads to observations of results which are finally analysed to make sure that the consequences really follow *necessarily* from the premises. Since deduction essentially means that the conclusions are already implied by the premises, this is the essential criterion for deductive validity.

1 Instead of page numbers we refer to the standardised reference to Peirce which indicates the work (CP as in "Collected Papers", followed by the numbers of the volume and the paragraph).

Deducing what would have to happen, based on a theory and suitable situational conditions, is one thing. Observing and evaluating what happens in reality is something else. Hence, deduction pertains to deriving empirical hypotheses, while *induction* pertains to testing them. The colligated premise of induction consists of those empirical hypotheses and the experimental result as it has occurred. This is then observed with respect to the question, whether it confirms the theory or not (or maybe even disconfirms it).The final judgement can be that the theory is confirmed (so far)[2] or disconfirmed, or that the matter is unresolved as yet and requires further probing.

3.2.3 Problem-Based Reasoning, Inferentially Reconstructed

Problem-based learning is currently something like the gold standard in modern didactics. Therefore, we reconstruct in inferential processes that characterise problem-based reasoning in its entirety. Abduction is often regarded as the starting point. However, since it presupposes a problem, a natural process of inquiry does not actually start with abduction but with the *induction* of a (new) problem.

Cognising and actually seeing a new problem can be understood as an inductive process. For instance, if an experiment does not yield the expected results or if a medical treatment fails, we might first explain this (away) by drawing to additional and hidden causes and retain the underlying theory. However, if such anomalies persist and if no good explanations for them are available, our belief in the theory might not only be reduced in degrees, but collapse altogether. This discontinuity indicates an inductive inference, in which the previous positive judgment is overridden by a negative one, i.e. the agent gives up a previously held belief, which raises the (new) problem of what to think and believe instead. This is a *negative* induction in that it does not lead to establishing the truth of a theory but its falsity, and therefore has the function of cognitive disequilibration. Hence, first a problem must be induced, before it can be solved across the triad of abductive, deductive and inductive reasoning, i.e. searching for possible explanation, deriving consequences and test hypotheses so as to determine which candidates for a solution should be chosen in the end.

The standard case for problem induction is that certain phenomena disconfirm established theories or other kinds of prior knowledge, which are revealed by a suitable experiment. However, problem induction could also refer to demonstrating that certain common strategies in one's occupation fail to work, e.g. craftsmen who realise that the tools and techniques they commonly use are inapplicable or inappropriate for a certain task.

This takes us to a second important point to notice with respect to problems. Abduction is mostly discussed in the context of explanatory problems, based on the observation of surprising phenomena. However, the inferential approach lends itself also to problems of strategic or technological reasoning, which do not aim at truth or falsity but at effectiveness

2 It is one of the main tenets of pragmatism that nothing can be ultimately confirmed. Rather, any confirmation can only relate to the current state of affairs and past experiences, while any new knowledge or experience might either reconfirm theories but also call them into question. Hence, any future application of knowledge implies (implicit) retesting.

or ineffectiveness of certain courses of action in relation to the goals agents pursue. Moral or ethical problems constitute yet another domain, where the aim is to determine what is just or unjust. Thus, there are at least three fundamentally different domains of reasoning, and all the cognitive processes of seeing and solving the respective problems can be precisely understood, and scaffolded, based on the inferential learning theory (see Minnameier, 2017, 2019).

3.2.4 Inverse Inferences

So far, we have explained reasoning processes in (ordinary) feed-forward loops. However, inverse inferences, which proceed in the opposite direction, are possible as well. Peirce himself coined the idea of "theorematic deduction" as opposed to "corollarial deduction", which we interpret in this very sense of an inverse inference and extend it to abduction and deduction (see Minnameier, 2017, for a detailed account). Mathematical proofs are the paradigmatic example for inverse (or theorematic) deduction, which run from the theorem to be proved to the premises from which it can be derived deductively. Therefore, the theorem is the result, the conclusion, of an ordinary deduction.

As for abduction, the inverse inference starts from some theory and asks for concrete examples of it. For instance, a teacher might explain the concepts of fixed and variable costs and ask for examples in the car manufacturing industry.

Inverse induction starts from the result of ordinary induction, i.e. the confirmation or disconfirmation of some theory and ask what kind of experiment – or empirical research setting in general – would confirm or disconfirm the theory. A paradigmatic example is the crucial experiment based on the original Einstein-Podolsky-Rosen paradox (Einstein et al., 1935) that was carried out by Aspect et al. (1982). Only one experiment was sufficient, because it was clear from the outset that the outcome would immediately (dis)confirm quantum nonlocality (which Einstein considered an absurd idea but which was actually confirmed).

In everyday life, inverse induction is relevant when it comes to convincing others of a certain strategy or a belief, which we think is correct. Here, we reason backwards form our own conviction to derive a certain experience or thought experiment (based on previous knowledge) that should immediately convince our counterpart or disconfirm their beliefs or reservations.

4 Whole-Class-Scaffolding: A Conceptual Approach

In the following, we develop a conceptual approach for whole-class-scaffolding, based on the inferential reconstruction of student learning processes, and present a coding procedure for measuring such scaffolding processes.

4.1 Dynamics of Whole-Class-Scaffolding

Scaffolding interventions start when learning difficulties arise. On the one hand, learning difficulties can be hurdles that the learners face and cannot overcome without teacher support. In classroom talk, this is the case when grounding does not succeed and, accordingly, not all learners reach common ground. On the other hand, learning difficulties may be misconceptions that have been formed along the learning path and are now being carried along. The presence of such misconceptions may not necessarily have been noticed by the learners until then. In student group discussions this occurs when a wrong solution is agreed upon (common space). Accordingly, common space and CS_{eff} are disjunct sets.

WCS aims to achieve CS_{int}. CS_{int} can be reconstructed from the lesson plan by including the explicated learning objectives. We have reconstructed CSpot for the teaching unit (cf. 4.2). That is, CS_{int} can be obtained as a subset from CS_{pot}.

To identify learning difficulties, we use videotaped tablet streams to code the current *student level of attainment* at the beginning of a classroom discussion period (see Hermkes et al., 2018). If the discussion takes place right at the beginning of a lesson, then a default value is assumed and this default value is corrected if learning difficulties become apparent in the course of the conversation (e.g., learners make erroneous contributions to the conversation, ask questions, or are unable to give answers when asked by the teacher to contribute).

Process adaptivity of WCS is represented by the variable *teacher strength of intervention* (TSI; Hermkes et al., 2018).[3] The variable is ordinally scaled. Table 2 shows the six values of this variable. Note that "revealing the solution" (TSI = 4) in problem induction tasks can also mean that the teacher explains the problem, thus establishing common ground regarding the task.

Table 2: Teacher Variable "Strength of Intervention"

Teacher Strength of Intervention	
0	Diagnostic utterance/ mere confirmation
1	Indexing an element of the knowledge space constructed by the students
2	Explicit judgment of falsity (or correctness) of an element of the knowledge space
3	Introducing a new element in knowledge space
4	Revealing the solution (intended knowledge space)
5	Explaining the revealed solution

The higher TSI, the more constructive activity is taken over by the teacher (input into CS_{eff}, transformation of CS_{eff}) and the lower is the learners' activity. Conversely, low TSI values

3 Note that only micro-scaffolding is considered here. Macro-scaffolding in structuring the learning content and sequencing the lesson etc. is not included.

mean that the teacher encourages the learners' own constructive activity. This can be done by directing the learners' attention to certain facts (indexing; TSI = 1) or by giving feedback as to whether a contribution is correct or incorrect without already correcting errors that have occurred (TSI = 2).

4.2 Reconstruction of Potential CS for the Teaching Unit

The lessons analysed in the study are located in the learning field "procurement processes" and include the quantitative and qualitative comparison of offers. Carrying out a quantitative comparison of offers requires the development of a calculation scheme that includes all relevant cost factors. Qualitative comparison of offers involves conducting a utility analysis that includes, for example, social and ecological aspects. In order to decide on the ultimately best offer, it is necessary to integrate both procedures. This can be done in various ways. For example, cost factors can be included as one aspect in the utility analysis. In any case, integration leads to a higher level of abstraction where quantitative and qualitative factors can be assessed within a unified concept of "value creation". Figure 1 shows the inferential architecture of the learning unit in which each lesson can be placed.

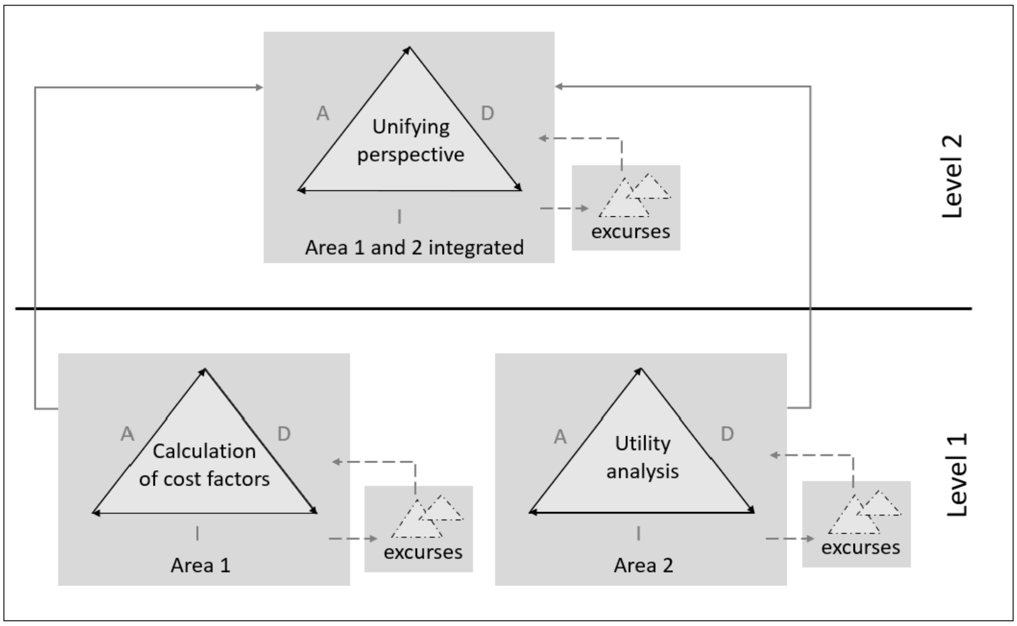

Figure 1: Inferential Architecture of the Learning Unit; A = Abduction, D = Deduction, I = Induction.

The architecture comprises two levels. The lower level is divided into two areas. The area on the left concerns cost factors (quantitative comparison of offers), the area on the right concerns qualitative criteria (utility analysis). A conclusion for the best offer can be drawn separately in both areas. The two areas are integrated at the upper level. Integration can also take place in iterative steps. For example, in the area of qualitative criteria, social aspects can be first integrated to decide on a best offer. In subsequent steps, further aspects like sustainability can be added so that a complete integration can be achieved iteratively.

The characteristics of learning processes (knowledge co-construction) are represented by the triangle. Each triangle indicates an inferential cycle consisting of abduction, deduction and induction (as explained in section 3.2). Moreover, classroom talk can go beyond the predefined areas. Such additional elements, which are part of the CS_{pot} (see 3.1), can themselves have an inferential structure. In Figure 1, this is represented by the fields labelled "excurses". As the arrows indicate, excurses should be inferentially linked to the respective content areas.

4.3 Coding Procedure

Against the background of the learning goals and content explicated in the previous section, the coding procedure for whole-class-scaffolding can now be introduced. The procedure includes the sequencing of the lesson and the corresponding learning steps, the coding students' knowledge construction processes that take place within each sequence and the assessment of the adaptivity of the resulting scaffolding-interactions.

4.3.1 Sequencing of the Lessons and Identification of Student's Learning States

The course of a lesson can be modelled as a series of sequences, each of which involves a specific process, such as working on learning tasks, shared knowledge construction in classroom discussions practice, consolidation, or performance assessment. The basis for sequencing is the lesson plan developed by the teacher. For the measurement of scaffolding, learning tasks and co-construction processes in class discussions are of particular importance. When focusing on WCS in classroom discussions, one problem is that heterogeneous learning states may exist among students to which scaffolding must be adapted. Some students may have successfully completed the previous learning task or step, others are slower and still in the middle of the process. Yet others are stuck at a certain point and cannot move on or may not even have understood the task.

The state vector of the variable *student level of attainment* reflects the students' capabilities and predicts the quality that a classroom discussion can have on shared knowledge construction. If the students are completely ignorant, then there is an increased likelihood that teachers will be misled into taking on too much of the constructive activity themselves and the students are only left to comprehend the explanations. The problem for the students then is not only to understand the teacher's contributions, but also to systematically integrate them into existing knowledge structures. The challenge in operationalising the construct of WCS, then, is to relate adaptivity in scaffolding not just to particular students or an imagined "average student" but to the heterogeneity of the class.

4.3.2 Shared Knowledge Construction Processes and Adaptive Scaffolding

Sequences involving knowledge co-construction processes can be reconstructed as single inferences or inferential cycles. Joint space and common space have different relevance at different points of a cycle. Common space is most relevant in problem induction at the beginning of a cycle, because the teacher has to make sure that all students understand the basic problem, as well as in the final (confirmatory) induction. In contrast, between these two fixed points in the process, alternative routes of inquiry and construction are possible, if not desirable – in particular if students are meant to be creative in solving problems. In this respect, joint space becomes relevant, because students ought to be able to partake in and benefit from each other's ideas and thoughts. Joint space in whole-class interaction means that students can learn from each other and engage in fruitful classroom discourse (leaving no one behind). Accordingly, WCS would basically have to scaffold joint space, i.e. teacher interventions would have to aim at upholding joint space and instigate inferential moves within it.

Depending on where the classroom discussion starts, co-construction processes are related to either joint space or common space (or both). If learners are first allowed to present their abductive thoughts and ideas (or even complete inferential cycles including deduction and induction), their aim is to create and uphold joint space, in which the different approaches are evaluated for their own sake and in comparison to competing approaches. Ultimately, the comparative analysis should converge to a common space brought about by eliminative induction.

Figure 2 shows how the co-construction of knowledge spaces occurs through inputs from learners and teachers. Adaptive scaffolding implies that the teacher does not take over any constructive activity that the learners are capable of doing.

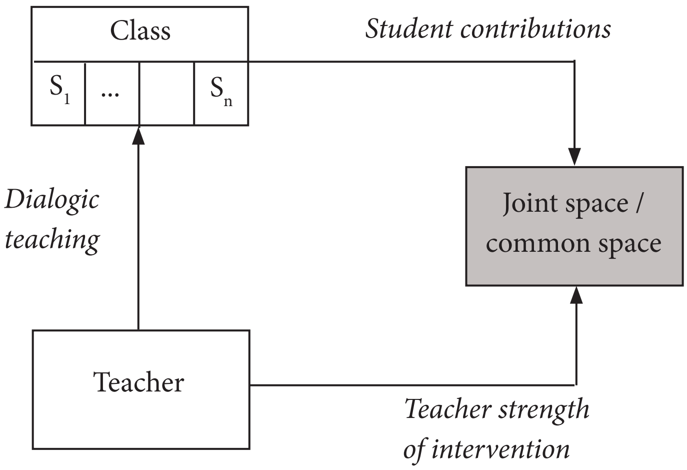

Figure 2: Joint/Common Space Construction by Students si and Teacher.

The constructional activity of the teacher is represented by TSI. In addition, the teacher initiates classroom talk and establishes discourse rules (arrow from teacher to class/students), also in order to let students provide the necessary support and engage them in mutual support. Student contributions can be ordinary questions, answers or comments, which can include misconceptions inferential mistakes.

To capture adaptivity, Wood et al. (1976) formulated the *contingent-shift-principle* (CSP). "Contingent shift" refers to the trajectory of teacher interventions over the course of learning, given a student's learning state (for details see Hermkes et al., 2018). Such a trajectory should develop as follows:

(1) At the beginning, students' solutions and ideas should be debated discursively in class. In establishing such a discourse, the principles of dialogic teaching play a role (accountable talk, exploratory talk; cf. Section 2). Learners should do the main part of the co-constructive activity, not the teacher. Initial teacher activities concern TSI of value 0, which codes for (merely) *diagnosing* students' level of attainment or confirming their contributions and encouraging them (a purely communicative function, not to be understood as a judgment of correctness or incorrectness of students' contributions). Since it is a true zero of the TSI scale, such activities do not constitute interventions in students' knowledge construction processes.
(2) When a learning difficulty (misconception, inferential mistake) occurs, the teacher intervenes and actively participates in students' knowledge construction processes. The contingent-shift principle applies here: Starting low and if it does not help learners to progress, then successively increasing the strength of intervention.

(3) When the learning difficulty is overcome, the teacher should start fading, i.e. the students get back the responsibility for the construction of the joint or common space.

A critical issue is how to deal with heterogeneity that exists among students. This problem involves two aspects. One is the question of how the teacher should deal with overt heterogeneity. The other is the question of which coding rules to apply when heterogeneity and students' need for support are unknown?

A promising solution strategy is to combine the rules of adaptive scaffolding with the principles of dialogic teaching and social learning (see Fernández et al., 2001; Ramstead et al., 2016). In dialogic teaching, all students are involved in the classroom talk, so that the likelihood that learning difficulties will be revealed is increased. Moreover, students are encouraged to take responsibility for their learning process and to carry out the main part of the constructive activity. In this respect, dialogic teaching is in accordance with the contingent-shift principle. However, the general principles of dialogic teaching have to be translated into a set of coding rules. The rules must ensure that a reliable and sufficiently fine-grained measurement of specific teaching and learning processes can be carried out.

We start by introducing rules that map the principles of dialogic teaching (first and second rule) and combine them with CSP (third and fourth rule) to operationalise contingent WCS:

(1) Participation and joint progress: The teacher involves all students in the classroom talk. Since the discussion is conducted in the spirit of a generative co-construction of knowledge, the reaction to the students' contributions does not have to come from the teacher (as in the IRE-scheme). Rather, other students have the opportunity to express their views on the contributions of their classmates. So, the teacher would pass the ball on to other students rather than playing it back to the student directly.

(2) Engaging differences: Different solutions and ways of solving problems are allowed. The students can bring their ideas, strategies and points of view into the discussion, but are also required to justify them and relate them to other viewpoints. This holds in particular when the aim is to create joint space.

(3) Corrective intervention: Once false statements or judgements are contributed, which are not corrected by the students themselves, the teacher has to intervene (albeit according to the rules of contingent support).

(4) Remedial support: If contributions by other students are non-contingent and cannot be understood properly by those with the learning difficulties, the teacher would either have to engage other students to close the gap or intervene in order to provide contingent support to meet the learning difficulties.

These rules function as guiding principles for contingent WCS. Teachers may follow them only implicitly, and they may not meet them in every respect all the time, because they lack information about each student's state, because they may not be able to engage every student, and because they cannot determine the students' contributions in dialogic sequences. They can only call up students wisely (so that they might deliver contingent support) and react to their statements. However, based on these combined principles, we aim at rating WCS-episodes with respect to their adaptivity.

4.3.3 Rating and Coding Whole Class Scaffolding

To analyse WCS, we suggest a combination of (more coarse-grained) ratings and fine-grained codings of specific scaffolding episodes. A prerequisite for both is the sequencing of the lesson to determine the units to be rated and coded. This leads to the following steps:

1. Sequencing the lesson: Using the inferential approach, the sequences (problem induction, abduction, and so forth) are identified. If available, teachers' lesson plans can be used as basis. However, since teachers might deviate from their plan, we have to reconstruct the actually implemented lesson based on the videos. With respect to WCS such sequences may be further divided, where necessary, into subsequences in which first joint space is created and a subsequent one in which common space is created. Moreover, a WCS phase may relate to different learning problems, so that a sequence could be subdivided accordingly. Overall, this procedure yields a set of separate and thematically distinct episodes that are the units to be rated and (later) coded.

2. For the rating of the co-construction processes with respect to their adaptivity, we use three analytically distinct three-point Likert scales (0 = not applicable, 1 = partly applicable, 2 = fully applicable). The first scale concerns the students' attentiveness, i.e. whether they are on task or not. The second measures the extent to which the teacher engages students in the co-construction process, i.e. passes the ball on them or back to them and keep a constructive whole-class dialogue going. The third relates to the logicality of this whole-class conversation, in particular whether and how the teacher monitors and moderates the logicality of this dialogue. These three scores are finally added to yield an overall seven-point Likert scale (0 to 6) for the adaptivity of WCS.

The coding of scaffolding episodes within the sequences is carried out in two steps:

3. Identifying students' learning states (including learning difficulties): This can be done based on (video) data, which show the students' learning status at the beginning of a class discussion. In both cases, students' learning states can be determined on the basis of the inferential taxonomy and thus assigned to the knowledge construction processes according to their inferential reconstruction.

4. Coding of shared knowledge construction: This includes the variable *teacher strength of intervention* for teacher contributions as well as students' contributions to the creation of a common or a joint space (see Fig. 1 above). Rules derived from the CSP are used to assess the contingency of the coded scaffolds (see Hermkes et al., 2018).

The rating and coding measures can be triangulated, since high scores in the more intuitive global rating should be correlated positively with highly-adaptive scaffolding interactions in terms of the rule-based codings.

5 Conclusion

In our paper, we developed a scaffolding conception that not only concerns the communication structure of classroom interactions, but also targets the deep structure of teaching and learning. Processes of shared knowledge constructions are taken into account, since WCS means to shape and develop common or joint knowledge spaces rather than to scaffold a multitude of individual construction processes at the same time.

It should be noted, that the focus on processes of shared knowledge construction is also associated with an important limitation concerning coding step 4: It requires a minimum level of subject knowledge on the part of the coder. The coding of shared knowledge spaces is based on correct contributions articulated in classroom conversations. Erroneous contributions should be identified so that they do not enter the constructed knowledge space. This also applies to cases where false contributions are simply ignored and not corrected by the teacher. To ensure the necessary expertise among coders, a more detailed coder training would be required.

Nevertheless, by focussing on processes of shared knowledge construction and integrating scaffolding principles and principles of dialogic teaching we have achieved a valid procedure for coding scaffolding interactions (WCS) and explicated a set of rules that can be correlated to the quality of WCS-episodes rated on distinct Likert scales. These results enable the creation of research variables that can be empirically studied as predictors of student learning outcomes. Furthermore, the codings allow a more fine-grained analysis of trajectories of scaffolding interactions that occur, for example, in the context of collaborative decision-making- or problem-solving processes in (heterogeneous) groups, or in the development of group-level variables such as trust in teams and working groups. Such an analysis reveals information about local specifics of WCS that can explain further learning differences between students or group members, as well as differences in the developmental dynamics of group-level variables between different groups.

Acknowledgement

This work was supported by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG) [grant number MI654 13-1].

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