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Technical discussions as supportive interventions in the process of constructivist teaching and learning

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1) Preliminary considerations and starting point

Over time, theories regarding the nature of learning have changed significantly. For two or three decades, a change of didactic paradigm towards a constructivist attitude on learning has been taking place (see Riedl 2010, p. 100). In vocational classes constructivist learning can be realized by the use of active learning concepts. Even though, empirical evidence does not unconditionally endorses for active learning in industrial-technical vocational training (for a summary see Nickolaus, Riedl, Schelten 2005, Nickolaus, Pätzold 2011), this way of teaching is – due to its integrated support of expert knowledge and methodical, social and emotional competences – a key concept of modern vocational education (Arnold, Gonon 2006, p. 211). A balance between lessons based on an autonomous, learning-centered knowledge construction and lessons based on teacher-led instructions is one of the key challenges to everyday teaching in constructivist learning. In this case, it depends on how the teacher supports individualized, student-centered learning phases. Further, it depends on the teacher’s success in cognitively activating the students (Riedl 2011, p. 103, 107).

Apart from the modified interpretation of learning processes, however, empirical knowledge of teaching efficiency has also changed. Until the end of the previous century, publications concerning meta-analyses of empirical studies repeatedly questioned the positive impact of school and teaching on learning (for a review of the results and a critical reflection see Weinert 2001, p. 73-76)1. Today, the current state of empirical studies on teaching points in another direction and shows: “Modern, profession-oriented, cognitively activating lessons during which the time available for learning is indeed used for teaching and during which the students (led by the teacher) have to deal with challenging but manageable tasks, have far more positive effects on learning efficiency than has been assumed in the past” (Köller 2012, p. 7). Thus, it can also be recognized that didactic measures (which can either be assigned to constructivism or to objectivism) have notable effect sizes on learning progress, when they are used at the right point in the lesson and if these measures are of correspondingly high quality.

Köller (2012), who summarizes Hattie’s work2 (2009), particularly points to the fact that a change of the conditions of the lessons, “which typically have political priority for education policies (e.g. reduction of the number of students per class, school structures), are irrelevant to a great extent” (p. 77). Thus, learning success, here in respect to the students’ acquisition of knowledge, primarily depends on variables which are to be understood as the underlying structures3 of lessons.

Studies carried out within the Munich-based research program so far, have largely been dedicated to highly developed, action-oriented lessons in technical vocational education. In these usually individualize lessons, students learn through complex tasks which are occupation specific. Here, the

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1 Here a crucial role in students’ development and education is ascribed to other variables such as the students’ genetic condition, domestic environment, social background and education duration.

2 Here, results obtained from empirical research on teaching were compiled from over 800 meta-analyses of more than 50,000 studies.

3 Compared to surface structures (e.g. social form, team teaching, open learning) which can be simply and objectively observed, underlying structures are hard to identify and often become apparent only through situational analyses of a learning phase. Underlying structures constantly encourage students’ cognitive activation.
students should be supported by the teacher in a way that best meets their requirements. Numerous results obtained from individual studies are mutually corroborative. However, specific individual results must also be considered (for a summary see Riedl, Schelten 2011). The different studies pursue their research questions on the basis of widespread methodological approaches, which often include aspects of design-based research (see Euler 2011, p. 530ff.). The process analyses of technical active learning concepts at vocational schools as well as parallel impact evaluations concerning the process character of constructivist learning show that the lessons considered were largely successful. Besides the positive effects, however, there is still potential for optimizing the teaching-learning arrangements. Concrete suggestions for possible improvements can be deduced from the specific weaknesses identified in particular lessons. Here, the focus is on recommendations for the role and the communicative behavior of the teacher, guidelines for self-learning materials and organizational teaching recommendations.

A current research emphasis outlined by this article builds on Buchalik’s work (2009). His research approach concentrated on identified demand on individual communicative support of students in student-centered lessons. Furthermore, this approach makes an explorative contribution to the process, general features and possible effects of technical discussions as teacher-student communication in systematically student-centered lessons. Here, the analyzed subject area is created by four proven, high-quality teaching concepts of the professional fields of electrical engineering, information technology, metal technology as well as nutrition and home economics. Each of these teaching concepts were developed over a period of many years. The research identifies the actual state of the teacher-student communication within this concept of teaching by analyzing these case studies using different research question in exemplary form. Procedural aspects studied include how much time of the overall lesson is used for technical discussions, how often technical discussions are initiated by the teacher and/or the students and how conversation sequences during a technical discussion are distributed between the teacher and the students. Functional aspects studied include targeted cognitive processes and activated knowledge types, both intended to foster learning during technical discussions. Buchalik transfers the data collected to a self-developed set of categories (ibid. p. 112). This set of categories transfers categorizations with respect to cognitive processes (Anderson, Krathwohl 2001 with the revised taxonomy of Bloom) as well as knowledge types in lessons (Schelten 2010) to the didactic variable “technical discussion”. The different types of knowledge refer to factual knowledge, causal knowledge and procedural knowledge. According to this system, cognitive processes during lessons can be divided into remembering, understanding, applying, analyzing, evaluating and constructing. This set of categories helps to better define the term “technical discussion”, which has been defined in a relatively general way so far. It thus helps to set up objectives regarding technical discussions as a didactic requirement for a successful teacher-student communication in constructivist lessons of technical training (see also Riedl 2011, p. 211ff.).

Buchalik’s results (2009) concerning the analysis of technical discussions are very complex. The study clearly proves the function of technical discussions as an essential part of action-oriented lessons which, at the same time, support self-organization. Here, both obligatory dialogues as well as facultative dialogues can show a high content level corresponding to the objectives. In the analyzed discussions, teachers usually dominate in teacher/students communication. This holds true both for initiating technical discussions as well as the quantity of verbal input to the dialogues. Generally, the observed technical discussions show high potential for profound and complex

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4 Together with the results, they are shown in detail in the respective publication. Nickolaus, Riedl, Schelten (2005, p. 512-515) gives an insight into the scientific methods of the individual publications. These publications are described by Riedl, Schelten (2011).

5 The category “Constructing” refers to extremely challenging and complex demands on engineering, using Anderson and Krathwohl’s theory (2001, p. 84ff.). The process of construction results in a new, challenging development which serves as a solution for a wider range of responsibilities. However, this is probably not feasible at vocational schools.

6 For a review of results see Buchalik and Riedl (2009).
conversational situations which are considered to be positive for the efficiency of learning. As far as the quality is concerned, the research results imply an impact of teaching concept on cognitive processes and knowledge types. For instance, the research results regarding technical domains point to the extreme importance of declarative-systemic knowledge and cognitive processes demanding the analysis of vocation-specific situations.

Further conclusions can be drawn from the dominance of teachers in technical discussions which Buchalik identified (2009, p. 192f.). Scheduled technical discussions during the lesson (e.g. suggestions in the guidance texts) foster this trend. Technical discussions which evolve on the spur of the moment from the students’ problem solving tend to show a higher proportion both of student initiative and of student participation. The clear dominance of teachers concerning quantity and time of speech acts results in two lines of argumentation (see ibid. p. 192f.). On the one hand, even teachers with long experience in active learning concepts are often observed to relapse into traditional instructive monologue communicative patterns, even though technical discussions do particularly aim at students’ individual learning. On the other hand, the teacher does have a role as moderator of the teacher/student group. Here, the teacher is responsible for the integration and possible correction of contributions made during the discussions as well as for the results of learning. This role can require a higher proportion of speech acts. Furthermore, the data collected from the field of electrical engineering suggest that these results do not correlate to the teacher’s personality.

2) Technical discussions during lessons

Didactic objectives of technical discussions

Technical discussions are the communicative assistance rendered by a teacher. They take place in a student-centered learning environment in which students act autonomously to a great extent. Here, two determinants, definable with respect to the lesson’s organization, have a key function. These determinants have a significant influence on the learning process and success (Riedl 2005, p. 258f.). From the point of view of the organization of lessons, these determinants are both self-learning materials for students (1) as well as supporting interventions by the teacher (2). The individualized dialogue between teacher and individual students or small groups aims at a high-quality communication in class, which can refer to both the learning material as well as the learning process. This is based on the assumption that the communication in class is particularly learning supportive if high-quality questions demand high-quality replies and thus profound explanations. In qualitatively demanding conversational situations, students have to structure and organize their knowledge in order to verbalize it. This supports the construction, strengthening and structuring of new cognitive concepts. Various studies of communication in class prove the correlation between the quality of the questions asked by the teacher and the quality of students comprehension. Furthermore, the frequency and the quality of the questions asked by students depend on the social form of teaching. According to this, teaching in small groups encourages content questions. Timid students tend to ask significantly more questions in small groups than in teacher-centered classes. All in all, the number of questions increases considerably in this social form. At the same time, the quality of questions increases due to the fact that more questions require explanations rather than short answers.

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7 Student-centered teaching can be action-oriented and can foster constructivist learning. However, this is not necessarily the case. The idea of student-centered teaching is broadly defined and includes teaching methods in which processes of learning are individualized in the long run and in which self-learning materials as well as the teacher-student communication in technical discussions are important.

8 Other influencing variables concerning the process of learning are e.g. the learning requirements of the students with their prior knowledge, the teaching requirements of teachers as well as extracurricular influences such as training in the companies.

9 Existing results of research are summarized by Buchalik (2009).
Technical discussions are an important didactic element in a student-centered lesson and they are crucial to high quality communication. Specific communication possibilities arise due to the often long-term learning in small groups working with challenging tasks and problems. Compared to teacher-centered lessons, technical discussions in student-centered lessons enable the teacher to demand more reflections about analyses and syntheses of the contents. At the same time, the teacher can focus on aspects of argumentation and contexts of explanation regarding the topics covered. Thus, cognitive processes can be initiated which encourages in depth reflection of learning contents.

In action-oriented vocational teaching, causal knowledge for the theoretical support of vocational proficiency has priority (Schelten 2011).

During the process of active learning, students tend to a final orientation of their learning actions (Riedl, Schelten 2011, p. 151). As far as this final orientation is concerned, the students want to achieve the required aims directly and within a short period of time. Their learning aims at practical sequence of the theory-based tasks. From the students’ point of view, the legitimate aim is the success of their actions and not primarily the theoretical knowledge of contexts and origins. Regularly scheduled technical discussions, however, can solve this problem as they demand reasoning and encourage the students to theoretically reflect their actions, even if this is not absolutely necessary. In a complex teaching-learning environment, technical discussions are a crucial didactic scaffolding instrument. For knowledge acquisition during lessons they maintain balance between construction and instruction in a learning approach which is open towards self-organization. Due to this balance, constructivist learning becomes effective and has a positive effect on the students’ learning progresses. Once a culture of technical discussions in class has been established, it rapidly becomes clear to the students that the teacher will repeatedly demand theoretical arguments concerning practice-oriented learning actions. Students are interested in the acquisition of basic knowledge and contexts of argumentation if this is called for by the pedagogical organization of the lesson. In technical discussions, the focus is on theoretical aspects of learning actions with causal explanations.

Function of technical discussions

Technical discussions in student-centered and active learning arrangements aim at the regulation of the students learning process by initiating individual reflecting and understanding processes. In the content-related dialogue, they refer to the learning items, the process of learning and the organization of learning. In the broadest sense, this can also include social processes if they have an effect on the content learning processes. Administrative communication content, however, cannot be categorized under the term “technical discussion”.

The diagnostic function of technical discussions should provide the students and teachers with information on the individual’s learning progress. Thus, the teacher can take measures to encourage the individual student’s learning progress. The students get to know their achievement level as well as their deficits. However, technical discussions must not be perceived by the students as an exam situation 10 or as a performance appraisal, because the anxiety associated with such a situation would significantly lower the possible learning potential of these conversation situations. In addition, in technical discussions and/or by the reaction of the students towards the teaching/learning materials prepared, the teacher wins information on the structure of the learning environment which can thus be optimized. Diagnostic elements of technical discussions influence their control function by regulating the teacher’s monitoring actions.

Long-term active learning in individualized small groups changes the form of communication compared with instructive forms of teaching with the whole class. The students can ask significantly more questions. They overcome their inhibitions to ask a question. At the same time, the questions’ depth and thus the questions’ quality increase. In such situations, the higher proportion of speech acts shifts from teachers to students. A technical discussion in class can be

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10 See Breuer, Schmidt (2010).
initiated by the teacher, the students or structurally by tips or requests in the self-learning materials. The teacher initiates a technical discussion if he or she wants to gain information on the students learning progress or if further support is required for the progress in learning. The teacher can rely here on his/her teaching experience if students are repeatedly faced with particularly difficult progressive stages in problem solving which require support. However, students can initiate technical discussions themselves if they need support for current problems and unresolved questions. Structurally predefined technical discussions during predetermined content phases serve to give teachers and students feedback on knowledge acquisition in a complex learning situation. Furthermore, they help to formally close a learning sequence. The teacher’s role during technical discussions must ideally be understood as the role of a “senior researcher” who takes part in the problem solving process, who regulates the discussion and who attends to the use of adequate technical terminology and content correctness without presenting a final solution to the problem (Buchalik 2009, p. 45). The teacher can of course also be assigned responsibility for systematic knowledge dissemination through direct individual instruction when the teacher diagnoses knowledge gaps which can thus be rapidly filled.

**Efficiency of technical discussions during the lesson**

Regarding learning efficiency, technical discussions in action-oriented lessons can be analyzed using various categories, which are, in empirical studies, repeatedly referred to in cause-and-effect context for successful learning. From the predictors taken into consideration, conclusions concerning their relevance within a moderately constructivist learning approach can be drawn. The influencing variables cited by Köller (2012) (according to the work of Hattie, 2009) serve as the categories mentioned below. According to this, only some rather weak to moderate variables influencing learning performance arise for features, typical of constructivist learning in action-oriented lessons. Köller (ibid.) shows their effect sizes in several summaries. Individualized forms of learning (d=.22), discovering learning (d=.30) or inductive lesson structure (d=.33) show rather weak effects. Slightly larger effects can be seen e.g. in cooperative forms of learning (d=.41) which take place in small groups (d=.49).

According to the results obtained from Hattie’s study, constructivist learning in action-oriented lessons can develop its efficiency in particular by means of the didactic variable “technical discussion”, presented in this paper. This communicative assistance rendered by the teacher can be assigned to different variables, which are highly effective in successful learning (see Köller 2012, table 5, p.77). Technical discussions demand task-related, elaborating cognitive activities from the students. Here, various types of feedback have positive effects on knowledge acquisition (feedback, d=.73, formative evaluation d=.90). Such feedback encourages “the cognitive support of the students by the teacher. Feedback is always task-related and provides information to the students about their knowledge and shows possibilities to further increase” (ibid. p.77). Similar effects can be achieved by a positive teacher-student relationship (d=.72) if teachers and students set their sights on the same objectives, and if the students have confidence in the teacher’s assistance, which should be competent regarding both skills and pedagogical knowledge.

**3) University teacher training for technical discussions**

**Working hypotheses**

At this point in time, the Munich research program on teaching/learning processes in industrial-technical vocational education (Riedl, Schelten 2011) is developing Buchalik’s results, in particular, on their utilization for teachers training. This research approach aims at enlarging the empirical knowledge base on technical discussions which has been established at the Technical University (TU) of Munich. The second goal is the implementation of this didactic variable in everyday

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11 The evaluation of effect size d refers, regarding the results cited by Köller (2012), to the increase in learning within one school year in secondary education.
teaching/learning in technical vocational education. Here, the studies build on Buchalik’s hypothesis, which he deduces from the study results: “Appropriate training measures for teachers increase content quality of technical discussions” (2009, p. 200). This assumption can be linked to another statement made by Buchalik when he emphasizes that a modern teaching/learning structure depends on constructivist learning in regular, student-centered phases. Therefore, routine high-quality teacher-student communication in technical discussions is an essential requirement for self-organized learning (ibid.). Buchalik also points to the high domain specificity of technical discussions (ibid. p. 189).

Concept

Towards the end of the university program, students studying to become teachers of metal technology at vocational schools have the opportunity to do a traineeship in „automation technology: workshop programming“ (WOP). Implemented as a seminar, this entails six credit hours on one morning per week over the space of 12 weeks. The highly motivating seminar contains tutor-initiated instructive phases as well as a high ratio (about 70%) of active self-learning phases. This traineeship provides prospective vocational teachers with insights into the structure and programming of modular facilities. At the end of the traineeship, students should design and implements feasible multi-stage systems. The participants can include the marks for this seminar (6 ECTS) in the vocational teaching program of metal technology. This seminar takes place at the Munich-based vocational school of manufacturing technology and is carried out by a teacher of the school who is, at the same time, lecturer of the TU Munich for this seminar. An integrated classroom for lessons in automation technology at this vocational school is available for this traineeship (concerning equipment see e.g. Schelten, Riedl, Geiger 2003).

The technical contents of the traineeship are divided into twelve interlocking modules (see Liebelt 2011, p.35 ff). Didactic and methodology are similar to those within vocational training. Thus, the seminar presents exemplary active learning concepts regarding automation technology at vocational schools at its pedagogical concept. The focus in this traineeship has almost exclusively been on subject-related contents. However, as this traineeship is contextually and methodologically strongly related to teaching, the students are offered the opportunity of also taking a closer look at the didactic side of domain-specific automation technology and reviewing it with other participants.

The initiative for a modified seminar concept emerges from the further development and utilization of Buchalik’s research results (2009) on the subject of technical discussions. As the tutor is also interested in this objective, two former participants of this seminar had the opportunity of further conceptional development of this seminar with the aim of integrating didactic considerations regarding technical discussions in action-oriented automation technology lessons. At the same time, this pilot study will evaluate the modified conception. Implemented in the winter semester 2010/2011, the modified traineeship concept included four additional learning concepts (see Plankl 2011, p. 75ff.). These additional learning units, developed in close coordination with the tutor and the scientists of the TU Munich are carried out by the latter. The additional course modules contain a total of 12 lessons. They include theoretical and practical considerations in implementing technical discussions in the domain of automation technology. They aim to acquaint the students with the development of technical discussions. They also want to point out didactically important features by video analyses of conversation situations.

Of the four additional units, unit 1 first presents the objectives of the additional learning units and provides basic information about the term “technical discussion”. Unit 2 discusses the results of Buchalik’s studies (2009), involves the development of crucial features of technical discussions by

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12 The time slices of instructive phases are significantly larger at the beginning of the course whereas they constantly decline during the process of the course. During the self-learning phases, the participants have to deal with written documents, have to create programs via PC and control the hardware components of existing automation systems.

13 Director of studies Manfred Schauhuber, supervisor on automation engineering, vocational school of manufacturing engineering based in Munich.
means of a video example and emphasizes their relevance for everyday teaching. Unit 3 first addresses Buchalik’s categories theoretically in order to classify cognitive processes and knowledge types in technical discussions. The next step is the practical implementation by the coding of paradigmatic video recorded sequences of conversation. Unit 4 aims especially at individual experiences in leading technical discussions. The participants learn to competent conduct technical discussions in learning phases in which they alternately take on the role of the teacher and the student. The subject under discussion is their preceding technical work concerning automation technology. The technical discussions are video recorded and then reflected together with the scientists of the TU Munich. There are five video recorded technical discussions.

**Evaluation**

The evaluation of the additional course units concerning conducting technical discussions uses different approaches. The video-recorded sequences of the technical discussions are evaluated by categorizing the existing knowledge types and cognitive processes (see above). In addition to this there is a focused interview after the last sequence of technical discussions as well as a written survey of the students on quality and efficiency of the course units (regarding the survey instruments see Liebelt and Plankl 2011).

The data collected from the three evaluation approaches are mutually corroborative. The students verify that the additional course units were advantageous for them. However, due to the relatively short period of time available, it became clear that there are restrictions regarding to the depth and completeness of the didactic content of the courses. Nevertheless, substantial student development was shown in the increasing quality of the technical discussions conducted by them during the course. The basis of this finding is also shown in the increasing technical knowledge concerning automation technology, didactic insights into conducting technical discussions and growing interest in this subject. The five recorded technical discussions have the following running times (minutes:seconds): Technical discussion 1 – 1:11, Technical discussion 2 – 1:58, Technical discussion 3 – 2:08, Technical discussion 4 – 10:50, Technical discussion 5 – 7:11. The content evaluation using Buchalik’s (2009) categories of cognitive processes and knowledge types (see also Riedl 2011, p. 211ff.) shows an increasing number of categories as the course progresses, which shows a greater variety of coded cognitive processes and knowledge types. In technical discussion 1, recorded on the first training day, only the cognitive processes of remembering and understanding in the field of factual knowledge occur. In technical discussions 2 and 3 – recorded in the second course unit – all types of knowledge of the pattern of categories are already recognizable and occur together with analyzing and applying cognitive processes. Technical discussions 4 and 5 – recorded in the fourth and last course unit – shows all knowledge types and all five cognitive processes realizable for vocational schools at least once during each sequence of the technical discussion. Liebelt and Plankl (2011, p. 106) trace this effect mainly to the students’ modified sensitization and interpretation of their role as the teacher. This evaluation once more confirms the fact that the competent conducting of technical discussions requires technically skilled teachers. In the recorded sequences of the technical discussions, especially the students were able to assume the teacher’s role competently and had high-quality technical discussions, which have the required technical expertise in the domain of automation engineering in a conversational context.

**4) Prospects**

“If you want to increase pupils’ success in learning in the long run, the lesson itself seems to be the decisive influencing variable. Associated with this are systematic, long-term programs for the professionalization of teachers” (Köller 2012, p.77f.). For a change in the teaching/learning culture which relies on successful self-organized learning in class, regular teacher-student communication in terms of high-quality technical discussions is a fundamental requirement. University teacher education gives access to the development of teaching skills in class in terms of technical discussions in student-centered lessons. This competency development must build on a university
education program in which the theoretical groundwork of constructivist learning in a student-centered active learning environment has already been laid. Another target group for competency development regarding conducting technical discussions are teachers in everyday teaching practice. They have to be sensitized and attuned to their modified responsibilities, which particularly arise in class communication in a student-centered environment. The magnitude of these challenges is accentuated by Buchalik (2009, p.199) who points to the fact that implicitly existing and traditional teacher-pupil conversational patterns still significantly moderate or even impair the quantity and quality of the communication in classes\(^\text{14}\).

Science and practice are only beginning to recognize the significance of technical discussions as a didactic variable in modern student-centered classes. “Technical discussions have developed into a new pedagogical challenge for vocational schools. Thus, vocational schools prove their modern teaching methods and give direction to educational science” (Schelten 2006, p. 107). Integrating a culture of technical discussions into the lessons must be regarded as a long-term task of modern vocational education.

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\(^{14}\) Here, it is recognized a latent tendency towards a shortened conversational behavior which is satisfied with curt replies. This is typical of the frontal phases of instruction.


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