Concept Mapping or Summary Writing as Learning Tools in Problem-Oriented Vocational Education and Training

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Abstract

One central goal of vocational education and training (VET) is to help students attain and develop competence so that they can meet current and future professional challenges. Learning environments, which address authentic problems, contribute to reach this aim. However, students need instructional support, e.g. in the form of learning strategies, when dealing with authentic problems. In this study, we investigated whether concept mapping or summary writing as learning strategies better support students in learning from authentic problems in the field of business. We hypothesized that concept mapping is superior to summary writing. Twenty-six students of pre-university education who attended a VET course participated. They were randomly assigned to the concept mapping or summary writing condition, and they worked in pairs. All students took a knowledge pre-test and post-test. In addition, students’ discussions, their concept maps or summaries, and the final product—a written advice—were analysed. The results show that the groups did not differ in knowledge neither before nor after the intervention. Unexpectedly, the quality of summaries was better than the one of concept maps. However, concept mapping better supports the reasoning of students (demonstrated in the discussions) and insight into the topic (as measured by the quality of the advice) than summary writing.

Keywords: problem solving; concept mapping; summary writing; meaningful learning; vocational education and training (VET); learning strategy.
Introduction

The leading paradigm for educational innovation in the vocational education and training (VET) system in the Netherlands over the past decade has been that education must be competence-based (Mulder, 2017a; Mulder, 2017b; Wesselink, de Jong, & Biemans, 2010). One main aim of competence-based education in VET is to support students in developing problem-solving competence, that is to say in acquiring knowledge and applying it to authentic problem situations and tasks (Baartman & de Bruijn, 2011; De Bruijn & Leeman, 2011; Jessup, 1995). Problem solving also requires students to make decisions and, for that purpose, to employ their knowledge, skills and attitudes (Jonassen & Carr, 2000). While solving problems, students actively participate in learning processes as well as in learning domain concepts and theories, the discourse of the domain and the process of problem solving itself (Kneppers, van Boxtel, & van Hout-Wolters, 2012). To solve authentic professional problems, knowledge as well as general and domain-specific higher-order skills are needed. Students must perform a broad analysis of the domain (De Jong, 2005; Manlove, Lazonder, & de Jong, 2006), create a problem-solving route and regulate and monitor their learning (Hagemans, van der Meij, & De Jong, 2013, 1-24).

For students to develop problem-solving or decision-making competence, they must learn within or with regard to suitable contexts, that is they must learn to cope with professional problems (Wesselink et al., 2010). Without context, knowledge remains abstract, has little meaning for the student and presumably hampers competence development. In contextual learning, students also recognise the purpose for which they need knowledge and presumably are more motivated to learn. However, everyday practice in schools primarily focuses on teaching facts, concepts or theories, while constructive, authentic learning hardly takes place (De Bruijn & Leeman, 2011; Schaap, Baartman, & de Bruijn, 2012). Students are often not encouraged or motivated to solve problems and learn actively. Consequently, rote learning is more likely to occur than meaningful learning (Canas & Novak, 2014; Mayer, 2002; Slaats, Lodewijks, & van der Sanden, 1999).

Rote learning hinders the application of domain concepts in daily and professional life or the transfer of what is learned in school to the workplace (Van Merriënboer & Kirschner, 2013). Practice and theory are rarely combined. In a workplace, however, employees are expected to solve authentic problems by integrating declarative with procedural knowledge and with cognitive and metacognitive skills (Baartman & de Bruijn, 2011). Van Schaik, Van Oers and Terwel (2010) postulate that learning should be embedded in authentic learning environments inside and outside vocational schools and that it should be an integral part of school instruction.

Authentic learning environments are challenging for both teachers and students. For teachers, it is difficult to translate competence-oriented goals into actual learning activities (Biemans et al., 2009), to design tasks and to guide more self-directed learning (Cremers, Wals, Wesselink, &
Concept mapping and summary writing as learning tools

Mulder, 2016; Khaled, Gulikers, Biemans, Wel van der, & Mulder, 2014). For students, the skills needed to perform the learning processes are not easily mastered. Until students reach a certain degree of self-directed learning ability, they require scaffolding while solving problems (Kirschner, Sweller, & Clark, 2006). Scaffolding must focus on general planning and monitoring, problem-solving and the coverage of the domain content (Hagemans et al., 2013). Scaffolding can be supported by learning strategies such as organisation and elaboration (Weinstein & Mayer, 1986). Organisation strategies aid in structuring the learning contents, while elaboration strategies help learners activate their prior knowledge and combine it with the given information. Both organisation and elaboration result in a rich knowledge base (Christmann & Groeben, 1996). In turn, this knowledge base may result in a better understanding, a better memory of the learning material (Reder, 1980) and, consequently, better problem solving. Concept mapping (CM) and summary writing (SW) can be regarded as organisation and elaboration tools that can support students in problem solving and decision making.

In this study, students had to solve an authentic financial problem. They were asked to decide between different options for financing the cars of a taxi company. Different solutions were possible. In order to support the students, CM and SW were used as scaffold in structuring the information about forms of financing. Our research investigated whether CM or SW was more effective in promoting students’ learning from authentic problems and thus promoting meaningful learning in the field of business VET.

2 Concept mapping and summary writing as learning tools

2.1 Concept mapping and summary writing

Both CM and SW are active and reflective processes which help in organising information and integrating it with prior knowledge. This process can lead to meaningful learning (Jonassen, 2003). Concept maps are two-dimensional structural representations of a topic, consisting of nodes and labelled lines between the nodes (Novak, 1998). The nodes represent important concepts; the lines represent relations between the concepts. The combination of two nodes and a labelled line is called a proposition, a basic semantic unit which can be assessed as true or false (Ruiz-Primo & Shavelson, 1996). In the process of CM, students use their prior knowledge to recognise and translate (text) information into a visual format which displays the main ideas and their interrelations. Concept maps help students to structure information and elaborate upon the knowledge by active and reflective thinking processes (Nesbit & Adesope, 2006).

In summaries, words are related to each other to formulate sentences, and all the sentences collectively form a written scheme (Friend, 2001; Van Dijk & Kintsch, 1983). In the process of SW, students must select important information, omit irrelevant information and construct information which either does or does not identically exist in the text (Christmann & Groeben, 1996). Casazza
(1993) defines the following steps necessary to write a summary: select the most important information to include, delete minor and redundant details, combine similar ideas into categories without indicating the relations between the ideas and write in one’s own words.

Although SW and CM are both active and reflective processes, concept maps are assumed to be advantageous due to their format. Concept maps consist of visuospatial and verbal information and display all relations between concepts in a network structure. In contrast, summaries comprise several sentences, but the interrelationships as well as potential hierarchies might not be as clear as in the graphic format (Nesbit & Adesope, 2006; Nesbit & Adesope, 2013).

Each format in turn can lead to different information selection and processing strategies. First, according to dual coding theory (Paivio, 1986), visuospatial information and verbal information are processed in different channels at the same time. Therefore, dual coding might lead to deeper and more efficient information processing than solely verbal data as they appear in summaries. Secondly, decisions about the order and structure of information in summaries do not necessarily need to be as precise as those for the concept map. As a result, the network structure which requires students to look for the relationship between concepts in the information may better support meaningful learning. Hay, Kinchin and Lygo-Baker (2008) found that concept mapping can ‘significantly add to the quality of teaching’, as it promotes meaningful learning.

2.2 Research on concept mapping and summary writing as learning strategies

Research studies concerning the effectiveness of CM and SW have been carried out in different fields, among them problem solving and, more specifically, collaborative problem solving. In general, CM is a powerful learning strategy. A meta-analysis run by Nesbit and Adesope (2006) found that the achievement of students constructing maps is remarkably higher than that of students attending lessons. However, CM has only a small advantage over other construction tasks, such as note-taking and SW. While some research studies found significant differences between CM and other interventions, such as SW, others did not (Redford, Thiede, Wiley, & Griffin, 2012).

Problem solving: CM and SW can support students in developing well-organised and integrated domain knowledge which is essential for problem solving (Jonassen, 2003). Both summaries and concept maps can be scaffolds for problem-solving activities which would otherwise be overly difficult (De Jong, 2006). However, research into the effects of CM while problem solving is limited. Even worse, research directly measuring the effect of summarising in problem-solving environments can hardly be found. In general, concept maps provide students with a structured overview of the domain to be learned. This overview is helpful in selecting the domain content and planning the problem-solving activities (Hagemans et al., 2013). Visualisation of information in a concept map helps students identify their needs to better understand the problem and plan a
learning route (Johnstone & Otis, 2006). Summaries help students organise the conceptual knowledge and the problem situation in a linear way. Apart from summaries, however, concept maps offer problem-solving support, because they display the relation between conceptual knowledge and the problem situation (Larkin & Simon, 1987). Tseng et al. (2011) found that scaffolding a group of nursing students in problem solving with concept maps resulted in a long-term effect on the students’ competencies of critical thinking and self-directed learning. Young-min and Nelson (2005) compared a completed concept map constructed by an instructor with a generative concept map constructed by the students. The generative map group outperformed the completed map group. Slof, Erkens and Kirschner (2010; 2012) divided a problem into three steps — orientation, solving and evaluation — and created a different scheme (concept map) for each step. Some of the students were provided with all the schemes, whereas other students in other conditions received only one or two of them. In one condition, the participants were not provided with schemes at all, and they had to create the concept maps themselves. Those in this group outperformed those in the other conditions in solving the problem, and these students displayed more effective communication and cooperation. Kneppers et al. (2007) also reported a positive effect of constructing concept maps on communication and cooperation skills.

**Collaborative problem solving:** In many studies, it is stated that collaboration is effective for learning. Student collaboration processes provoke discussions which support understanding and problem solving (Van Boxtel, Van der Linden, Roelofs, & Erkens, 2002). In discussions with peers, students are encouraged to think critically, and they engage in self-reflection and in reflection on peer participation (Tseng et al., 2011). Other studies agree that collaboration is effective for learning. A study of web-based learning concluded that group activities with peers and instructors and with appropriate materials enhance students’ meaningful learning (Inayat, Amin, Inayat, & Salim, 2013; Laine & Hämäläinen, 2015). Laine and Hämäläinen (2015) described a case study in VET entrepreneur education. They found factors which hindered and factors which enabled computer collaboration in working on a task. The (non-)complexity of the task and the variation of the task structure are important conditions for successful collaboration. During collaborative SW or CM, advantages of collaboration can be exploited.

More research has been performed on collaborative CM than on collaborative SW. Chi (2004) and Roth and Roychoudhury (1994) concluded that collaborative CM can lead to effective discussions about concepts, which supports learning. Roth and Roychoudhury (1992) viewed collaborative CM as an activity which contributes to the development of discursive practice; it forces students to communicate in a scientific manner. Thus, students become, as the authors call it, members of a community of knowledge and practice. They learn strategies to negotiate in the domain language and other typical communication forms in the domain. This type of interaction
is described in the literature as explorative talk (Mercer, Wegerif, & Daws, 1999) and as con-
found that collaborating students who created concept maps showed improved learning outcomes.
Other studies found significant results concerning the collaborators’ knowledge while working
on computer-supported collaborative problem solving and digital concept maps (Kneppers et al.,
2012; Laine & Hämäläinen, 2015). The mentioned studies about SW and CM in problem solving
included participants with different educational backgrounds and ages, and the studies imple-
mented many different interventions. Therefore, they are difficult to compare. However, scaffold-
ing tools such as CM or SW seem to support learning, although it has not been clear to this point
which strategy is more advantageous. In addition, collaboration seems to be an effective interven-
tion if the tasks, materials, scaffolding and feedback are well structured.

3 Method

3.1 Research questions

By conducting this study, we aimed to deepen our understanding of the potential of CM and SW.
We specifically focused on collaborative CM and SW to investigate which of the two problem-
solving strategies is more effective for learning. We have raised the following research questions:

1. Does CM lead to better learning of conceptual knowledge than SW while collabora-
tively solving an authentic problem?
2. What differences appear in reasoning and arguing between CM and SW?

Hypotheses/presumptions

1. The CM condition performs better in gaining conceptual knowledge than does the SW
condition.
2. The CM condition performs better in reasoning and arguing than does the SW condi-
tion.

3.2 Participants and design

The study took place in the Netherlands, where VET is part of secondary education. After primary
education, students choose either general education or the preparatory VET track. The general
education track is divided between university preparatory education and senior general secondary
education. In addition, in general education (university preparatory education and senior general
secondary education), a VET-oriented course is offered, which should prepare students for the
VET track or for business studies in research universities or universities of applied sciences.
Participants included 32 students 16 to 18 years old from two classrooms in one school (22 and 10 students, respectively) in their second-last year of university preparatory education. The students followed a three-year VET-oriented course called Management and Organisation in addition to their other economic and general education. The aim of this subject is that students in the general education track take over the perspective of a future employee or entrepreneur or of a private person who must make important financial decisions. We chose these students — not studying in a vocational school — because they were motivated to continue vocational studies after finishing secondary school and because it was important to give them an idea of a work environment in which problems were situated and had to be solved using conceptual and theoretical knowledge. The course can be considered a VET course within general education.

We performed the study with two conditions, CM and SW, and the students were randomly assigned to one of these two groups. They worked in pairs, most of the time on the computer. The pairs were formed using the ‘middle group-method’ (Pijls, Dekker, & Van Hout-Wolters, 2003). This method resulted in pairs that were somewhat, but not overly, heterogeneous.

3.3 Materials and procedure

The subject chosen for the study — a loan from the bank for investment and leasing — had not been part of the students’ previous instruction. The students had to solve an authentic problem (Figure 1) and, in doing so, to learn different forms of financing, specifically bank loans and financial and operational leasing. The problem was to find out what kind of financing is preferable for a small enterprise. The students received text information about forms of leasing and were also provided with data concerning the problem situation (e.g. a balance sheet and the firm’s profit and loss account of the last year). According to the curriculum, the students had prior knowledge about small enterprises with respect to balance sheets, profit and loss accounts, equity, liabilities, financing, etc., so they were able to understand and interpret what to do.

The study covered five lessons. In the first lesson, we assigned the pre-test to the students, while the instruction followed in the second, third and fourth lesson. The second, third and fourth lesson comprise five instructional steps to systematically support the students in their problem-solving process (steps 2–6 in Table 1). SW and CM were part of the instruction. Prior to the research period, the students in the CM group had received training (in two of their economic lessons) in using the CMapTools program (cmap.ihmc.us) to construct concept maps. The students in the SW group were experienced with word processing in writing summaries; therefore, no special SW training was applied prior to the study. In the fifth lesson, the students took a post-test. The instructions and the tests were part of the regular schedule at school.
The taxi firm *Speedy Rite* is a one-man business. The owner, Mister Simons, is also the manager. The firm possesses 6 cabs. All of the cabs are from trademark Cicero. Two of the cabs are 6 years old, two are 4 years and two are 2 years old. The economic working life of the cabs is 6 years; therefore, two of the cabs must be replaced. Until now, Simons has purchased all new cars using a bank loan. He is wondering, however, if it is wise to continue this habit in face of financial uncertainties. Besides, he is asking himself if the bank is willing to give him a loan again. Simons considers whether he is better off leasing the cabs. Unfortunately, he is not capable of deciding which form of financing will best meet his needs. Furthermore, he does not understand the meaning of the two different forms of leasing – financial and operational – and the consequences that they will have for his business.

Therefore, he is asking you for help. Figure out what is best for Simons: taking up a bank loan or lease the cabs (financial or operational). The advice that you give to Simons must be reported in a clear manner.

Figure 1: Authentic problem

Table 1: Course of instruction

<table>
<thead>
<tr>
<th>Steps instruction in CM/SW condition</th>
<th>1. The CM/SW condition received the authentic problem. The students were scaffolded through problem solving process.</th>
<th>45 min.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. The students had to think about what they know about forms of financing. They had to construct a concept map, or write a summary individually. Then, they were requested to add the information they needed to solve the problem.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Moving forward, the students worked in pairs. They compared their work, discussed it and possibly changed it.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Then, they received the information about the forms of financing. They were instructed to construct one concept map/summary on the computer together using their individual concept maps/summaries and the information given.</td>
<td>45 min.</td>
</tr>
<tr>
<td></td>
<td>5. The students must formulate priorities for the firm in a given table and write down what differences the forms of financing make for these priorities (with the help of their CM/SW).</td>
<td>45 min.</td>
</tr>
<tr>
<td></td>
<td>6. The students must write the advice also in pairs.</td>
<td></td>
</tr>
</tbody>
</table>

3.4 Data gathering and analysis

3.4.1 Tests

A pre-test was performed to determine whether the groups differed in prior knowledge. The test consisted of 14 open questions, and the minimum and maximum scores were 0 and 24, respectively. The Cronbach’s α was 0.72. A post-test measured the effect of the intervention on learning concepts. It also consisted of 14 open questions. The minimum and maximum scores were 0 and 31, respectively, and the Cronbach’s α was 0.71. The pre-test differed from the post-test in that the pre-test measured the knowledge necessary to understand and cope with the problem, that is to say the knowledge students had learned in previous lessons (e.g. completing a balance sheet). The post-test measured the knowledge to be learned through the intervention (e.g. calculating the liquidity and solvency of a company as a basis for deciding about a form of financing). A coding scheme was used for both tests to score the results. We carried out a t-test for both tests, and an ANCOVA, controlled by the pre-test scores, was performed to discover whether the pre-test
scores influenced the post-test scores. Minimal two researchers coded all tests and products until agreement was reached.

3.4.2 Quality of concept maps and summaries

There were two CM: the individual one based upon previous knowledge, and the one based upon the individual maps and collaborative work (Table 1).

To analyse the student pairs’ maps regarding size and quality, we extracted the propositions from CMapTools. Size equals the number of propositions in a concept map, and a greater number of propositions indicates students’ greater elaborative activity but not necessarily better quality. Therefore, we measured the quality by rating the correctness of each proposition (0 pts: inaccurate; 1 pt.: incomplete; 2 pts: correct). Because in this case there was not only one possible solution that best reflected the structure in the domain, we did not use a criterion (or expert) map (Ruiz-Primo & Shavelson, 1996). In Figure 2, an example of a student’s pair concept map is displayed.

![Concept Map Example](image)

**Figure 2:** An outcome of a collaborative concept map

**Table 2 exemplifies the coding procedure.**

<table>
<thead>
<tr>
<th>No</th>
<th>Propositions</th>
<th>Points/Proposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>bank loan as annuity – means – fixed amount per period</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>buying a car by bank loan leads to ownership</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>financial lease is disadvantageous due to higher costs</td>
<td>0</td>
</tr>
</tbody>
</table>

**Example 1:** *bank loan as annuity* – *means* – *fixed amount per period* is correct: If the bank loan is performed in an annuity, the amount to be paid is the same in every period over the complete loan term.
Example 2: *buying a car by bank loan – leads to – ownership* is incomplete: There is indeed ownership when taking out a bank loan, but the student did not explain which kind of ownership (legal or economic).

Example 3: *financial lease is – advantageous due to – higher costs* is inaccurate: The student did not explain why, or compared to what, the costs are higher.

Regarding the student pairs’ summaries, we aimed to develop a rating system comparable to that of the concept maps. We extracted propositions from the text, counted the propositions and judged their quality in the same manner as for the concept maps. An example of part of a summary is displayed in Figure 3.

At the bank one borrows an amount at a certain percentage rate, versus leasing, where one rents the product. When leasing, the product does not become your own property which is the case when borrowing money from the bank. For financial leasing, the leasing company is the legal owner, and the taxi company is the economic owner. The taxi company pays a fixed sum to the leasing company, but the taxi company is responsible for maintenance and insurance costs. For financial leasing the car will be included in the balance sheet of the taxi company, in addition to the debt, so that the solvency ratio increases. For operational leasing, the leasing company has economic and legal ownership, meaning that the leasing company assumes all risks and therefore pays all costs. As a consequence, the cars are not included in the balance sheet of the taxi company.

Figure 3: Extract of a students’ summary

An example of the coding is displayed in Table 3.

<table>
<thead>
<tr>
<th>Propositions</th>
<th>Points/ proposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>bank loan</td>
<td>depended on</td>
</tr>
<tr>
<td>leasing</td>
<td>is equivalent</td>
</tr>
<tr>
<td>bank loan</td>
<td>leads to</td>
</tr>
<tr>
<td>leasing</td>
<td>leads not to</td>
</tr>
<tr>
<td>financial lease</td>
<td>taxi firm is</td>
</tr>
<tr>
<td>financial lease</td>
<td>taxi firm pays</td>
</tr>
<tr>
<td>concept 1</td>
<td>interest percentage</td>
</tr>
<tr>
<td>concept 2</td>
<td>hire-purchase</td>
</tr>
<tr>
<td></td>
<td>car ownership</td>
</tr>
<tr>
<td></td>
<td>car ownership</td>
</tr>
<tr>
<td></td>
<td>legal owner</td>
</tr>
<tr>
<td></td>
<td>economic owner</td>
</tr>
<tr>
<td></td>
<td>fixed price</td>
</tr>
</tbody>
</table>
3.4.3 Quality of advice

We analysed the written advice which the students provided for the taxi firm (Figure 4).

Our advice for the ‘Speedy Rite’:

Although the bank costs are the lowest, we do not opt for a bank loan, because:

- The solvability of the firm is critical. In the case that Simons chooses the bank loan the solvability will grow and exceed the limit of 200% making it difficult to obtain a new loan in the future.
- Simons is responsible for costs due of maintenance. Because of this he may face unexpected costs. Whenever he has to pay these unexpected costs, then liquidity will decrease and Simons has less money for other things.
- In addition, buying a car financed with a bank loan, one faces depreciation costs and lost revenue.

Figure 4: Part of an advice.

We discerned the arguments in favour and the arguments against every kind of loan. Then we assessed the arguments as correct (1 point) or incorrect (0 points). Table 4 shows the coding for the advice of Thom and Sherilyn with respect to the CM condition. They advised that the firm take out an operational lease. They gave arguments for the operational lease but not against it. They also gave arguments against a financial lease and one argument for a bank loan and three against it.

<table>
<thead>
<tr>
<th>Advice of:</th>
<th>Thom and Sherilyn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advice</td>
<td>for/against</td>
</tr>
<tr>
<td>Operational lease</td>
<td>for</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td></td>
<td>against</td>
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<tr>
<td>Financial lease</td>
<td>for</td>
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<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Bank loan</td>
<td>for</td>
</tr>
<tr>
<td></td>
<td>against</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Remarks - wishes Speedy Rite</td>
<td></td>
</tr>
<tr>
<td>Remarks - situation Speedy Rite</td>
<td>1</td>
</tr>
</tbody>
</table>
3.4.4 Quality of students’ discussions

We analysed the protocols of the student pairs’ discussions in the CM and the SW conditions. We focused on the portion of the protocols in which the pairs compared their findings, obtained new information and worked on a concept map or a summary together. We selected fragments which showed a right or a wrong insight into the key concepts and coded these fragments based on the Process Model for Interaction for Mathematical Level Raising (Dekker & Elshout-Mohr, 1998). This model discerns the following key activities: to tell or show one’s work, to explain one’s work, to justify one’s work and to reconstruct one’s work (Table 5). These key activities are crucial for insightful learning and for evoking mental processes such as becoming conscious and thinking about one’s own work. Students can regulate the performance of these key activities by asking each other to show their work, asking them to explain their work and criticizing each other’s work.

<table>
<thead>
<tr>
<th>Regulating activities</th>
<th>Mental activities</th>
<th>Key activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>A asks B to show his/her work</td>
<td>B becomes conscious of his/her own work</td>
<td>B shows his/her own work</td>
</tr>
<tr>
<td>A asks B to explain his/her work</td>
<td>B thinks about his/her own work</td>
<td>B explains his/her own work</td>
</tr>
<tr>
<td>A criticises B’s work</td>
<td>B thinks about A’s critique</td>
<td>B justifies his/her own work</td>
</tr>
<tr>
<td></td>
<td>B criticises his/her own work</td>
<td>B reconstructs his/her own work</td>
</tr>
</tbody>
</table>

We coded and counted the occurrence of key and regulating activities in the right and wrong fragments. To illustrate this procedure, we provide an example of a short fragment of a discussion of a pair in the CM condition, Mat and Jim, in the following:

1. Mat: Well, for a company it is clear because you have a fixed amount each month that will be paid, or the price per mile.
2. Jim: But you don’t know how many miles you will drive.
3. Mat: Yes, but here it says ‘operational lease will take care that the constant price per mile will be guaranteed because a fixed amount per month will be paid for the cars’.
4. Jim: OK, the other lease … a kind of rent buy. Economical risk is here with the taxi company.
5. Mat: Yes, that is a big difference. He is the economic owner but not legal owner. He does not finance the car, but it is on his balance.

The insight is revealed in Mat’s final phrase, in which he justified (in 5) his solution. However, this insight was triggered by the fact that he first showed (in 1) his thinking and explained (in 3)
it and that Jim provided a specified criticism (in 2+4). We counted the pairs’ activities, in this case: justifying 1, showing 1, explaining 1, criticising 2.

4 Results

4.1 Pre- and post-test

Thirty-two students participated, among whom six did not attend all the lessons and/or tests. These students were excluded from the study. Data for the remaining 26 students were analysed. T-tests showed (Table 6) that the two groups did not differ in knowledge neither before \( t(1,24) = 1.55, \ p = 0.134 \) nor after the instruction \( t(1,24) = 0.81, \ p = 0.94, \ d = 0.33 \).

Table 6. Results of pre- and post-test: means and (standard deviations)

<table>
<thead>
<tr>
<th></th>
<th>CM (N=14)</th>
<th>SW (N=12)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (in % of max. score)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Pre-test</td>
<td>10.68 (44.5)</td>
<td>9.68 (40.3)</td>
</tr>
<tr>
<td>Post-test</td>
<td>8.64 (27.9)</td>
<td>8.75 (28.2)</td>
</tr>
</tbody>
</table>

The scores in the post-test are comparatively small (Table 6). Thus, the students are far from the level of conceptual knowledge they could have reached. Nor is the level of prior knowledge very good, indicated by the fact that the pre-test scores are not very high. An ANCOVA, controlled by the pre-test scores, showed that the pre-test had no significant influence on the post-test scores \( F(1,23) = 0.77, \ p = 0.78, \eta^2 = 0.107 \). Therefore, better prior knowledge cannot explain better learning from the problem.

4.2 Size and quality of maps and summaries

The results of the coding of concept maps and summaries are shown in Figure 5. The SW condition outperformed the CM condition slightly in terms of the mean number of propositions (size) and strongly in terms of the value of the propositions (Table 7). The assumption that SW can lead to copying adequate information (Redford et al., 2012) while CM requires connecting concepts by relations and therefore is more challenging, might explain the results.

Table 7. Results: Values, numbers and standard deviations of concept maps

<table>
<thead>
<tr>
<th>Pairs N</th>
<th>No. of propositions in means (total)</th>
<th>Value propositions in means (total)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SD</td>
<td>SD</td>
</tr>
<tr>
<td>CM</td>
<td>7</td>
<td>6.55</td>
</tr>
<tr>
<td>SW</td>
<td>6</td>
<td>14.17 (85)</td>
</tr>
</tbody>
</table>
4.3 Quality of the written advice

The results of the analysis of the advice which the pairs wrote were remarkable. As shown in Figure 6 and Table 8, there was little difference between the two conditions concerning the number (83 vs. 72) and mean number (11.86 vs. 12) of arguments, but the value of the arguments was considerably higher in CM (55 points) compared to SW (38 points) and mean value (7.86 vs 6.33) (Table 8). Students in the CM condition had more insight than those in the SW condition.

Table 8. Results: Number and value (means) and standard deviations of arguments

<table>
<thead>
<tr>
<th>Pairs</th>
<th>Number of arguments in total (means)</th>
<th>SD</th>
<th>Value of arguments in total (means)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM</td>
<td>83 (11.86)</td>
<td>1.68</td>
<td>55 (7.86)</td>
<td>3.95</td>
</tr>
<tr>
<td>SW</td>
<td>72 (12)</td>
<td>3.67</td>
<td>38 (6.33)</td>
<td>3.56</td>
</tr>
</tbody>
</table>

Figure 5. Mean numbers and values of propositions

Figure 6. Mean number and value of arguments in written advices
4.4 Students’ discussions

The analyses of students’ discussions show that CM seemed to be a good tool to stimulate students’ reasoning about the problem so that they were better prepared to provide advice. In the CM condition, we found 65 fragments in which the students expressed a good or a wrong insight into the key concepts. In 52 out of 65 fragments the students expressed a good insight, and in 13 fragments a wrong one. In the SW condition, in 39 out of 68 fragments, the students expressed a good insight and in 29 a wrong one (Figure 7). This result clearly demonstrates a difference in quality in favor of the CM condition.

Figure 7. Amount of good and wrong insight fragments

An analysis of the coded key activities in the fragments (to explain one’s work, to justify one’s work) revealed that in the CM condition, 333 key activities were found, of which 54 involved explaining and 102 justifying. In the SW condition, 330 key activities were found, of which 36 involved explaining and 55 justifying, while most of the other key activities involved showing one’s work. In the CM condition, 47% of the key activities involved reasoning (explaining and justifying), while in the SW condition, this value was 28% (Figure 8). Therefore, reasoning was much more evident in the CM condition than in the SW condition. More insightful learning can be the result. An explanation for this finding might be that students in the CM condition had to base their arguments on the concept map, which possibly required more discussion than basing
discussion on a summary. A summary can more easily reproduce original material without a lot of discussion.

The following is an example of a wrong insight discussion between Nick and Ooske (SW):

1. Nick: Loan from the bank has a disadvantage: it costs a lot of interest. You pay more than the car costs.
2. Ooske: Hmmmm…
3. Nick: But there is a big shareholder’s equity. If you use a part of it to pay the car instead of taking a loan, you don’t have to pay much interest.
4. Ooske: But when you lease, the costs are always the lowest.

Nick shows and explains (1.) his ideas, which reveal a wrong insight. Ooske seems to think (2.), but she does not criticise Nick’s ideas. Nick goes on showing and explaining (3.) his ideas, which still reveal a wrong insight. Again, Ooske does not criticise Nick’s ideas but shows (4.) her own idea. Therefore, Nick does not have to justify his ideas, which could have led to a better insight.

This is in contrast with the discussion between Mat and Jim in the CM condition, presented in section 3.4.4. The criticism of Jim in that example was crucial for the justification of Matt. We counted the pairs’ activities in this case (Nick and Ooske): showing, 3; and explaining, 2.

5 Summary and discussion

In this study, both pre- and post-test scores were a little higher in the CM than in the SW group. However, we did not find significant differences in the pre- and post-test scores between the groups. In both conditions, the test results were comparatively low. Thus, students learned only a little relevant conceptual knowledge, far from what they could have learned, at least as measured by the knowledge test. Possible explanations for this result might be either that the test was too difficult or that the perceptions of the task demands (using information to solve a problem) were too different from the test demands (acquiring deep conceptual knowledge). Thus, the students could apply knowledge in the problem-solving process but were not aware of the underlying concepts. In addition, the time needed for processing deep conceptual knowledge might have been too short (Broekkamp & van Hout-Wolters, 2007).

Based on an ANCOVA, we concluded that prior knowledge did not explain post-test scores. Aside from other explanations, this might be because prior knowledge was comparatively low and focused on other concepts than assessed in the post-test. Another possible explanation might be that the intervention better supports argumentation and reasoning than conceptual understanding. This seems especially true for the CM condition.
The analysis of the quality of the concept maps/summaries showed that the SW condition performed better than the CM condition in terms of the number of propositions (slightly) and in terms of the value of the propositions (strongly). Presumably, the good summary values result from accurate surface processing of information, meaning that students were able to adequately select and copy sentences from a source (Redford et al., 2012). The problem that the potential of concept maps is not strongly reflected in their quality may be attributed to the relatively new format of knowledge explication required by CM. The students may not have been sufficiently familiar with the technique and, thus, could not apply it confidently.

However, in contrast to summary writers, concept mappers must employ more thought to distinguish the concepts and capture the relations. They must also transform the linear format of written material into a structure (network) format. Thus, the format of concept maps naturally might better support students’ thinking (arguing and reasoning) than that of SW. Consequently, it potentially promotes meaningful learning (Beyerbach & Smith, 1990; Hay et al., 2008). In our study, the potential of CM was especially evident in the quality of the advice and in the stimulation of both pair arguing and individual reasoning about a topic. The value of the arguments in the CM condition was greater than the value of arguments in the SW condition. This corresponds with the conclusion of Johnstone and Otis (2006) and of Hagemans et al. (2013), who argue that CM is helpful for selecting domain content and planning problem-solving activities. We also found that CM promotes peers’ argumentation and thus learning, as Chi (2004) described. We saw that reasoning was much more evident in the CM condition than in the SW condition.

To sum up, in our study, there is no clear-cut result which shows the superiority of one or the other strategy concerning the learning of concepts. However, by trend, collaborative CM with peers better fosters important dialogue and better supports reasoning and argumentation while learning in a problem-oriented way. This result is supported by research underlining the potential of concept mapping as a collaboration tool (Bruhn, Fischer, Gräsel, & Mandl, 2000). And, from another study we conducted with the same material in a similar context, we also assume that both learning strategies support students in problem-oriented learning. In that study, groups using a strategy outperformed a control group using no additional strategy (Fürstenau, Kneppers, & Dekker, 2012). Finally, concerning methodology, we conclude that a qualitative approach reveals good insights into students’ learning processes, which can be helpful in further studies.

Limits of the study can be seen in the small number of participants. Besides, the knowledge test focused on conceptual knowledge and should be complemented by problem solving and reasoning tasks. Those tasks may better reflect the intention of the instructional setting. In turn, learning material and instructional scaffolds could include prompts guiding students in connecting problem-situations and conceptual knowledge. In addition, we have to assure that students have enough experiences in constructing concept maps so that this cannot be an obstacle to learn from
the problem-situation and might not cause extraneous cognitive load (Sweller, 1988). More training in CM prior to the study might have led to other results. Concerning summaries, it is necessary to avoid that students simply copy sentences from the original learning material without thinking about content. To foster deep understanding, prompts aiming at self-explaining or comprehending information can be implemented. Last, but not least, students might should have more time to perform the task.

What can be learned from this study for VET education? As proclaimed over the past three decades, it is important in VET education to situate learning and to bridge the gap between theory and practice. Against the background of competence-based education in particular, this aim has again come to the fore. Therefore, (complex) authentic learning environments are used as instructional interventions. Authentic learning environments require holistic thinking and action, including finding information, weighing arguments and making decisions. However, authentic learning environments are anything but self-propelled (Achtenhagen 1992, 3-9). They need instructional support provided by materials, specific methods and/or by the teacher.

In our case, students used learning strategies aimed at organising and elaborating knowledge and, thereby, making informed and justified decisions. Teachers should support this process by guiding and monitoring cooperative learning. They are often not used to such a process, so teacher training is necessary. It is also necessary to support students in combining the situated knowledge and more abstract knowledge learned in schools (Fürstenau 2003, 85-118).

We conclude that the use of strategies is also useful for the workplace to help employees in making adequate decisions for authentic situational problems. Concept mapping especially fosters collaborative argumentation.

6 References


