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Towards a manager's mental model: Conceptual change through business simulation

Lauri-Matti Palmunen *, Timo Lainema, Elina Pelto

Turku School of Economics, University of Turku, FI, 20014, Finland

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ABSTRACT

Mental models are relevant in both managerial decision making and management education. Decision-making studies have demonstrated how managers benefit from more accurate mental models by gaining higher-quality heuristics and better performance. However, management education studies assessing mental models as learning outcomes remain rare. This study aims at understanding how students' mental models change during a business simulation course. We designed a pre- and post-simulation concept map assignment that illustrated students' mental models as number of concepts, connections between concepts, and written explanations. The findings of our study demonstrate that students' mental models changed through two interconnected processes: addition of new knowledge and change of misconceptions in existing knowledge. Based on these results, we composed a model of conceptual change through business simulation gaming. Our study contributes to the research on learning from business simulations and addresses the recent call for more conceptual change research in social sciences by enhancing the conceptual change discussion in the management education literature.

1. Introduction

The importance of mental models has been recognized in the context of both management education (e.g. Hogan & Warrenfeltz, 2003; Liang & Wang, 2004; Nadkarni, 2003) and managerial decision making (e.g., Gary & Wood, 2011; Osborne, Stubbart, & Ramaprasad, 2001). Mental models are cognitive representations of reality that are linked to how we know, perceive, make decisions, and behave in various contexts (Johnson-Laird, 1983; Magzan, 2012). In a managerial context, mental models represent managers' understanding of the business environment and influence their strategic choices. Hence, managers' more accurate mental models have been found to lead to higher-quality heuristics and better performance (Gary & Wood, 2011).

Mental models develop over time through education, experience, and interaction with others (Magzan, 2012). Consequently, one could assume that experiential and interactive learning activities, such as business simulations aimed at developing analytical and decision-making skills (Lovelace, Eggers, & Dyck, 2016; Xu & Yang, 2010), would enhance the development of students' mental models particularly well. In previous management education studies, the level of cognitive learning has been gauged by the complexity of mental models (Nadkarni, 2003; Palmunen, Pelto, Paalumäki, & Lainema, 2013; Scherpereel, 2005; Xu & Yang, 2010) and by the change in pre-determined concept pairs, whose similarity to a reference model is assessed (Capelo & Dias, 2009; Riemer & Schrader, 2016; Wouters, Van der Spek, & van Oostendorp, 2011). Arguably, these two approaches have studied different types of change in

* Corresponding author.
E-mail addresses: lauri-matti.palmunen@utu.fi (L.-M. Palmunen), timo.lainema@utu.fi (T. Lainema), elina.pelto@utu.fi (E. Pelto).

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mental models. Whereas the former has examined the addition of new knowledge into mental models, the latter has focused on the quality of knowledge in mental models.

Although these two types of change in mental models have been recognized, *conceptual change* has been mostly overlooked in management education studies (Halldén, Scheja, & Haglund, 2013). The study of conceptual change examines misconceptions and their persistence in mental models (Duit, Treagust, & Widido, 2013). The conceptual change approach may be especially important in management education, where novice students' initial mental models of economic and business concepts—based on their personal experiences as consumers—are often inaccurate (Lundholm & Davies, 2013). This can hamper students learning and generate inaccurate mental models (Chi, 2013), which may lead to flawed analysis and bad decision making (see Gary & Wood, 2011).

We acknowledged these different approaches and the need for more studies on mental models in management education contexts. The purpose of this research is to examine how students' mental models change during a business simulation course. Based on this purpose, we formulated the following research questions:

1) How does the complexity in students' mental models change during a business simulation course?
2) Does conceptual change occur in students' mental models during a business simulation course?
3) How are the complexity and the accuracy of students' mental models intertwined?

We aimed to answer these questions by using a self-developed concept map assignment as a method for collecting data from 119 students participating in a business simulation course. We collected these data before and after the course, and analyzed them with an inductive approach following Gioia et al.'s (2013) methodology, thus proceeding from empirical observations to the creation of a theoretical model.

We make two contributions to previous studies. First, we contribute to the literature on learning from business simulations (Anderson & Lawton, 2009; Faria, 2001; Hernández-Lara, Perera-Lluna, & Serradell-López, 2019; Washbush & Gosen, 2001) by demonstrating that learning in simulations occurs through intertwined knowledge addition and conceptual change processes, which are both needed to make learners' mental models more complex and accurate. Second, by applying the conceptual change discussion to the management education literature, we answer the call for more conceptual change research in social sciences (e.g., Lundholm, 2018; Murphy & Alexander, 2013). This addition challenges the traditional approach, which regards mental model complexity as an indicator of learning (Davis & Yi, 2004; Day, Arthur, & Gettman, 2001; Nadkarni, 2003), by pointing out how this approach struggles to explicate students' misconceptions and their persistence.

2. Literature review

2.1. Research on learning and business simulations

Previous studies have applied various methods for assessing learning from computerized simulation games (see Pasin & Giroux, 2011). Studies on business simulation games (later business simulations) can be categorized on three groups based on how they have assessed learning. The largest group is composed of studies comparing simulation performance to career success (e.g., Schumann, Anderson, Scott, & Lawton, 2001; Wolfe & Roberts, 1993). Another body of research has relied on self-reports in examining students' attitudes towards simulations (e.g. Farashahi & Tajeddin, 2018; Liao, Huang, & Wang, 2015; Lin & Tu, 2012; Sierra, 2020). A third group of studies are cognitive learning studies that use simulation performance rankings (Coffey & Anderson, 2006; Faria, 2001) and exams (Anderson & Lawton, 1988; Gopinath & Sawyer, 1999) as a proxy for learning.

Each of these methods has its advantages and limitations. Studies based on collecting data about career success fail to demonstrate whether the change is based on habituation created by repeated actions or conscious decision making. Studies based on student self-reports offer a comparable research setting in which students' attitudes toward simulations and their perceptions about learning can be compared with more traditional teaching methods (Gosen & Washbush, 2004; Lu, Hallinger, & Showanasai, 2014), but such studies only demonstrate students' subjective beliefs about learning. Finally, studies based on simulation performance rankings and exams may be seen to offer data that can be compared in various ways. However, these studies manage to assess learning of only basic knowledge and not the understanding of more challenging issues like problem solving and synthetizing (Anderson & Lawton, 2009; Faria, 2001; Washbush & Gosen, 2001).

The prevalent problem of studies on learning from business simulations is that the learning objectives of business simulations are usually application and analysis, while the studies assess learning based on methods appropriate to basic knowledge and comprehension (Anderson & Lawton, 2009; Gentry & Burns, 1981). However, a few studies on business simulations have attempted to solve this problem by concentrating on change in mental models (Capelo & Dias, 2009; Palmunen et al., 2013; Scherpereel, 2005; Xu & Yang, 2010).

The studies assessing learning by evaluating mental models, built upon the insight that mental models are simplified representations of reality that comprise concepts and relations between these concepts (Craik, 1943; Jones, Ross, Lynam, Perez, & Leitch, 2011). A mental model has been defined as a mechanism for meaningful explanations (Clarke & Mackaness, 2001), a reasoning mechanism (Johnson-Laird, 1983), and a prediction mechanism for alternative scenarios in the real world (Collins & Gentner, 1987). The complexity of mental models has been found to be a valid indicator of how learners make sense of a particular problem or organize information (Davis & Yi, 2004; Day et al., 2001; Nadkarni, 2003).

Together, the literature on learning outcomes of business simulations and the literature on mental models offer at least two insights into the theoretical underpinnings of learning from business simulations. First, learning has been assessed with various methods, which has created discord between empirical findings and theory development. Second, mental models can be used as a proxy for assessing the level of complexity in students' cognitive learning.

However, one theoretical underpinning of learning appears to be absent in the business simulation literature: the complexity and the content of mental models are distinct entities. A mental model can gain full complexity by advancing from basic knowledge to evaluation and yet contain information and produce evaluations, predictions, and synthesis that are incorrect by objective standards. In order to expand our understanding of this missing theoretical component, we reviewed the literature on conceptual change.

2.2. Learning as conceptual change

The conceptual change literature makes a distinction between an individual's subjective beliefs and socially accepted knowledge of the world (Nersessian, 2017), and argues that people's existing ideas about a given subject greatly influence their cognitive learning about this subject (Lee, 2010; Scott, Asoko, & Leach, 2007). The term *conceptual change* was introduced by Posner, Strike, Hewson, and Gertzog (1982) and can be defined as "a form of learning that can be differentiated from other types of learning because it requires fundamental changes in the content and organization of existing knowledge as well as the development of new learning strategies for deliberate knowledge restructuring and the acquisition of new concepts" (Vosniadou, 2013, p. 1). Thus, in conceptual change, learners are not only filling gaps in existing knowledge, but also changing naïve conflicting knowledge to correct knowledge (Chi, 2013).

Chi (2013) proposed four types of naïve conflicting knowledge, each of which differ in their relations to the complexity and persistence of misconceptions. First, *false beliefs* are naïve knowledge that can take the form of a single idea presented in one sentence or statement. Second, *flawed mental models* are an organized collection of individual beliefs that produce coherent internal representations that consistently lead to explanations and predictions that contradict the correct model. Third, *category mistakes* are naïve conceptions that have laterally or ontologically incompatible dimensions with the correct conceptions, for instance, misplacing whale into the lateral category of "fish" instead of "mammals" and "electricity" into ontological category of "matter" instead of "process" (Chi, Slotta, & de Leeuw, 1994; Jonassen & Easter, 2012). Fourth, *missing schemas* is a type of naïve knowledge that has either laterally or ontologically incompatible dimensions and lacks awareness of the alternative category to which a concept belongs. When moving from false beliefs toward missing schemas, misconceptions become increasingly difficult to change (Chi, 2013). However, in practice, it may be difficult to categorize different misconceptions as belonging to just one of these classes.

Although conceptual change research has been conducted in many science domains (see Vosniadou, 2013), including science simulations (Schneps et al., 2014; Sengupta, Krinks, & Clark, 2015; Srisawasdi & Kroothkeaw, 2014, Trundle & Bell, 2010), it has remained scarce within the social sciences (Grimes, 2015; Lundholm & Davies, 2013). This is likely due to an insufficient level of objectivity caused by contesting theories in social sciences (Lundholm & Davies, 2013; Murphy & Alexander, 2008). Yet, misconceptions are not limited to the mathematics and natural science domains but are present in all fields of human knowledge (Murphy & Alexander, 2013).

For instance, business students generally have more experience as consumers than producers, which naturally affects their initial understanding of many key concepts (Davies & Mangan, 2007). Studies on students' conceptions of price (e.g. Pang & Marton, 2005) indicate that students often fail to see price as reflecting both supply and demand. Conceptual change can be observed when students transform their earlier conception of price as a property of a product into an outcome of a relationship between demand and supply (Davies & Mangan, 2007). Other similarly challenging concepts include *opportunity cost* in the field of economics (Davies, 2011) and *cash* and *profit* in the field of accounting (Lucas, 2000). Hence, learning in economics and business administration requires students to shift from conceptions limited by the context of their personal experience to conceptions endorsed by the disciplinary community (Lundholm & Davies, 2013; Wright & Gilmore, 2012).

3. Methods

3.1. Methodology

The purpose of this research was to examine how students' mental models change during a business simulation course. We used concept maps at the beginning and end states of the course, which is a reasonably common method for studying mental models (Loyens, Jones, Mikkers, & van Gog, 2015; Sellmann, Liefländer, & Bogner, 2015; Srisawasdi & Kroothkeaw, 2014). A concept map is an attempt to explicate individuals' mental models so that others can review them (Kinchin & Hay, 2000; Sellmann et al., 2015) and estimate learning by evaluating their content and structure (Liu & Lee, 2013). The structure includes concepts, lines indicating relationships between concepts, and words that specify the relationship between the two concepts (Novak & Cañas, 2008, p. 1).

In our learning intervention, the students acted as business decision makers who built their mental models as they interacted with the business system they managed (Capelo & Dias, 2009). A hierarchical concept map (see e.g. Novak & Cañas, 2008), would not facilitate the mechanism of feedback, which is an integral part of mental models of business dynamics, so we followed the viewpoint of Morecroft (1994), suggesting that a mental model is better described as a network of familiar facts and concepts, together comprising a causal map of a system. Like Harrison and Treagust (2000), we do not claim the ability to have accurately accessed any student's mental models in our study. However, we believe that the students' concept maps gave us an opportunity to interpret what appeared to be the students' mental models of business entities and different causal relationships between business functions. We studied the changes between students' pre-simulation and post-simulation concept maps to identify outcomes and processes of learning that students experience as a result of a business simulation course.

3.2. Empirical setting

We conducted the study with a convenience sample of 119 students, of which 82 were female and 37 were male. These students participated in a business simulation course at the University of Turku as part of their studies in the Business Competence Study Module (BCSM). The business simulation course, instructed by two of the authors, was typically taken during the first semester of study in the BCSM, suggesting that the students had rather limited understanding of business topics before the course. The aim of the simulation course was to provide an overview of business operations and increase participants' understanding on the dynamics between different business functions. Students were expected to learn to analyze financial reports for business decision making. These aims were pursued via three intertwined means.

First, the students played, in consecutive weeks, three 5-h sessions of a computer business simulation called RealGame (Lainema, 2003). In this simulation, there are eight companies that are managed by teams of two or three participants. The simulation has an internal clock, which advances independent of the simulation participants' actions. The simulation clock speed is defined by the game operator. The students are not restricted to making decisions in batches at specified time points. Rather, they execute decisions whenever the situation requires them to act, either reactively or according to their plans. The simulation was designed to reflect the decision-making challenges in a company's supply chain management process. The simulated customers in the market create demand according to the companies' sales offers, image, and product quality. The core of the simulation companies' decision making includes supply chain related activities, like purchasing raw materials, managing inventories, steering the production process, and delivering finished goods to customers.

Second, the course included in-game debriefing sessions. Debriefing—reflection and generalization of the experienced things (Jaques, 1995)—is one of the most important parts of the learning experience in simulation games (Hughes & Scholtz, 2015; Onofrei & Stephens, 2014). During the in-game debriefings, the game facilitators presented for example the simulation companies' business results, market positions, supply chain performance, and cash flow development. These in-game debriefings included also discussions on basic business concepts and how they are present in the simulation.

Third, learning was reinforced by four assignments, which were placed before, in between, and after the game sessions. By completing them, the students reflected on their decisions and analyzed their firms' performance. The information needed in these assignments was the same the facilitators had presented during the in-game debriefings.

3.3. Data collection and analysis

We collected the data with a concept map assignment developed by one of the authors, who had also created the business simulation used in the course. The assignment was created to indicate learning produced by the business simulation course per se, without any additional interventions. Consequently, we analyzed the concept maps only after all the courses had ended and informed the students that the concept maps were to be used solely for research purposes. The students did the assignment both in the beginning of the first simulation session (pre-map) and immediately after the final simulation session (post-map). The assignment lasted 15 min, in which the students could freely add their own concepts, draw connections among the concepts, and explain these connections in writing.

As a result of the data collection, we had 119 students' pre- and post-maps, each including a varying number of concepts, connections, and written explanations. Both the sheer amount and visual nature of our qualitative data posed analytical challenges. Our data could not be easily categorized by theory-driven coding themes, thus we adopted a more inductive approach and let the coding themes emerge from the data. The analysis was an iterative process, whereby new ideas that emerged from the data were constantly confronted with the literature, thereby providing a means to review the data with emerging categories (Bansal & Corley, 2012; Gioia, Corley, & Hamilton, 2013).

Although quantifying qualitative data is generally not advisable (Pratt, 2009), the large amount of data in our study made quantification inevitable to a certain extent. First, we defined the units of analysis as *concepts* in the concept map, *connections* between concepts, and *written explanations* that described each connection type. We entered the data from each concept map into a spreadsheet application, and calculated the number of concepts, connections between concepts, and words in written explanations in each concept map. We then analyzed their differences with respect to each student's pre- and post-maps. Hence, our data contained both numerical and non-numerical data, which we determined to be consistent with our methodology and design (see Twining, Heller, Nussbaum, & Tsai, 2017).

To gain an overview of the change in concept map accuracy between pre- and post-maps, we defined assessment categories for concept maps. We tested the categorizations by selecting a random sample of 10 pre- and post-concept map pairs, which were independently assessed by two of the authors. Based on this test, the assessment categories were modified to a 3-point scale: 0 = no errors, 1 = some imprecision, and 2 = clear errors. Category *some imprecision* included statements that are not explicitly right nor wrong, for example, *high turnover leads to a good profit*. Category *clear errors* included statements that are explicitly wrong, for example, *the profit can be seen on the cash balance*. This led to more similar assessment results from the two authors, although we acknowledge that this sort of analysis is always based on somewhat subjective interpretations. Nevertheless, we determined that the reliability of the modified assessment categories was acceptable and put each concept map into one of the three categories.

In the next stage, we were interested in the deeper meanings embodied in the concept maps. We analyzed the written explanations and compared students' concept map figures and explanations in their pre- and post-maps. We looked for different types of misconceptions (see Chi, 2013), and marked them with different colors in text. We then evaluated whether misconceptions had been corrected, as well as whether new misconceptions had appeared in the post-maps.

We analyzed the nature of changes between individual students' pre- and post-maps based on the emerging themes from the data. The analysis followed Gioia et al.'s (2013) methodology: We formed 1st order categories based on the empirical observations, from which we proceeded to form a 2nd order theoretical level of themes. In a further step of the analysis, aggregate dimensions were formed, and with the help of this data structure, a theoretical model was created.

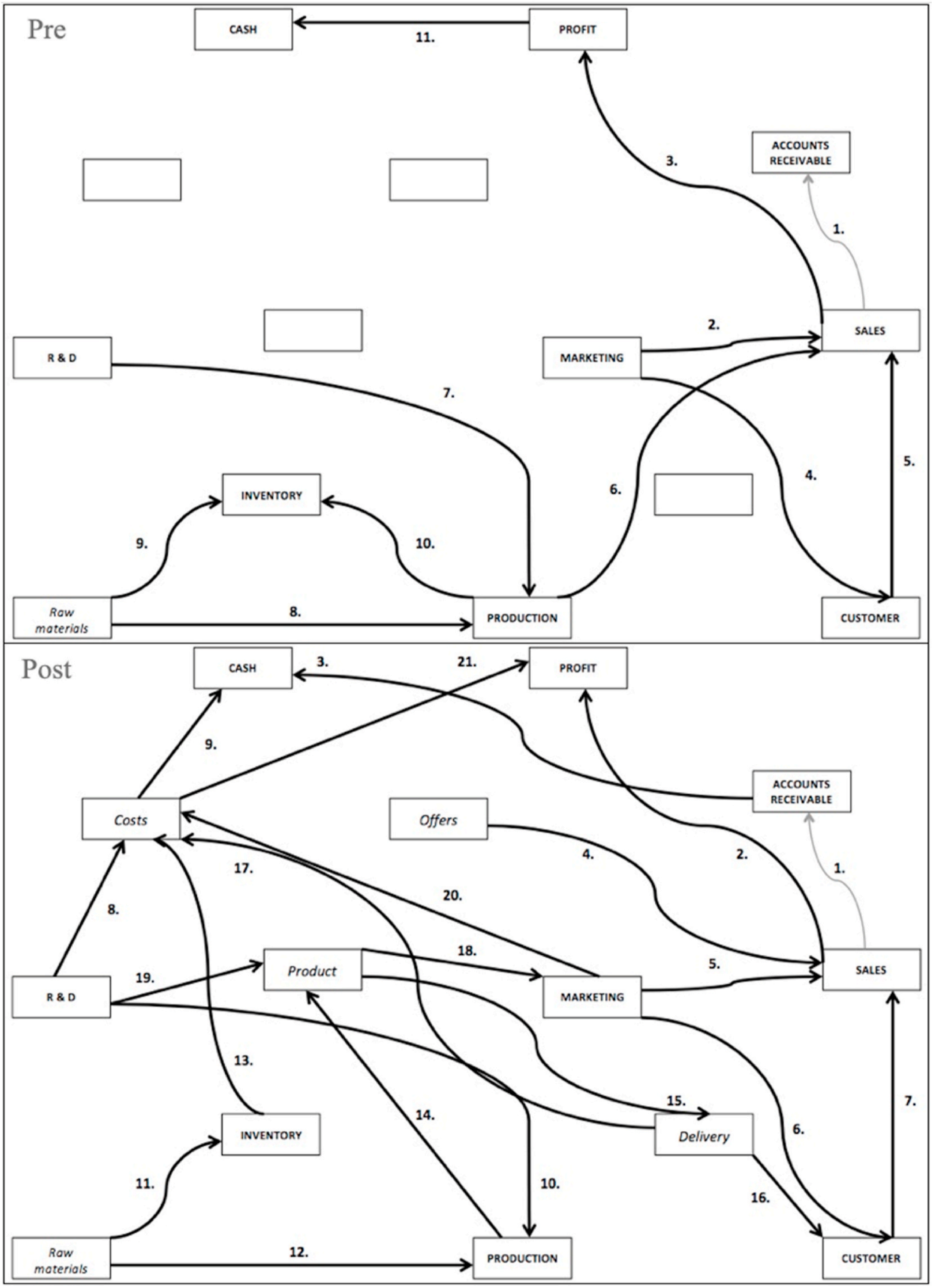

Fig. 1. An example of change in the complexity of a student's pre- (upper section) and post-simulation (lower section) concept map.

4. Results

4.1. Development in perceptions of connections between concepts

To answer our first research question *"How does the complexity in students' mental models change during a business simulation course?"*,

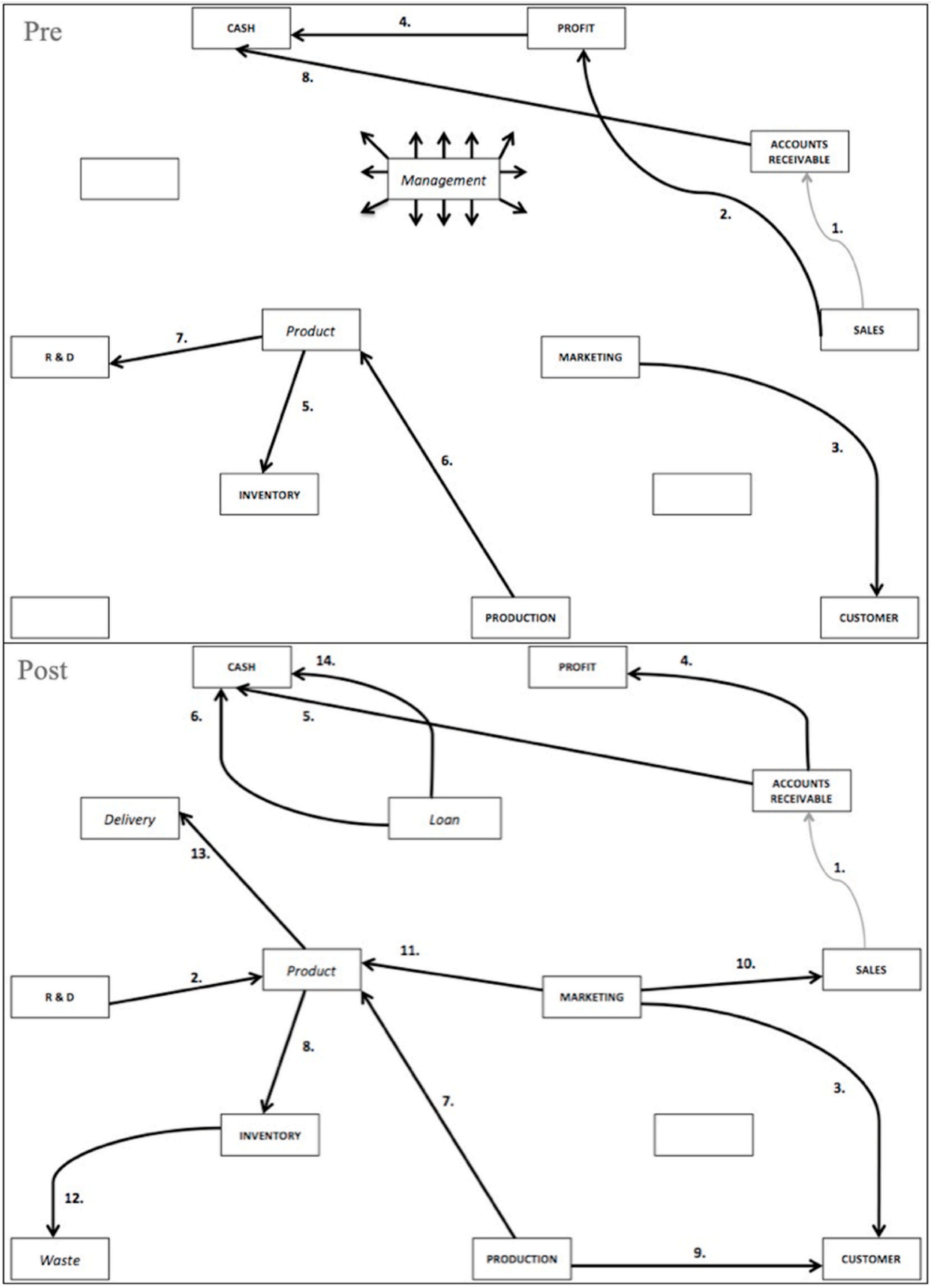

Fig. 2. An example of increased integration in a student's pre- (upper section) and post-simulation (lower section) concept maps.

we studied the development in perceptions of connections between concepts. In pre-maps, the number of connections between concepts that students had marked differed substantially, from 7 marked connections to as many as 33 connections, suggesting differences in the levels of students' prior knowledge and understanding about business processes. The average number of connections in pre-maps was 15.4. In post-maps, this number varied from 7 to 35, with an average of 17.6. Majority of students (78 out of 119) perceived more connections in their post-maps, which can be interpreted to indicate learning.

Further, the increase in the perceived linkages depended on the students' initial level of knowledge. Among those students who perceived more than the average number of connections before the simulation, the average increase was from 19.9 connections to 20.2 connections (2% increase). Among those who marked fewer than the average number of connections before the simulation, the average increase was from 11.7 connections to 15.4 connections (32% increase). This seems to indicate that the knowledge-level differences between the less and more knowledgeable students decreased during the simulation course.

In general, students' concept maps became denser and more complex after the simulation. Fig. 1 illustrates this change. In this example, the pre- and post-maps indicate an especially dramatic increase in concepts and the connections between them. In general, students often perceived direct connections between various concepts in their pre-maps and more indirect causal connections between the concepts in their post-maps.

In addition to being more complex, the post-maps were often more integrated and coherent in terms of the various processes in which companies are involved. This type of change, which indicates a better overall understanding of the linkages between various business processes, is in line with the aim of the simulation course. The pre- and post-maps in Fig. 2 illustrate change toward a more integrated mental model. As Fig. 2 demonstrates, in the pre-simulation phase, the student perceived three different processes of a company: one related to product, one to marketing, and one to money. The concept of *management* was positioned in the middle, indicating the only connector among these three separate processes. However, all these processes were integrated with a number of

Fig. 3. The frequency of concepts in pre- (upper section) and post-maps (lower section).

connections in the post-map, suggesting that the student understood how various functions form the overall dynamics of a business company and how this relates to the monetary process.

Many students' post-maps were more diverse and comprehensive than their pre-maps. Whereas many students focused strongly, for instance, on cost-related or marketing-related themes in their pre-maps, they perceived more concepts and connections related to also other categories in their post-maps. This suggests a more holistic understanding of business processes.

4.2. Development in the level of recognizing and naming concepts

Regarding our second research question *"Does conceptual change occur in students' mental models during a business simulation course?"*, we studied developments in the level of recognizing and naming concepts and in written explanations of the connections between the concepts. In general, students' concept maps were greatly different from each other. The number of self-named concepts students added to their pre-maps varied from 0 to 7, and the average number was 3.1. In their post-maps, this number varied from 0 to 10, with an average of 4.2. Altogether, 21 students (out of 119) marked fewer concepts in their post-maps than in their pre-maps. Exactly the same number of concepts in both maps were marked by 24 students, while the majority of students (74 out of 119) marked more concepts in their post-maps. Hence, the majority of students had more new concepts in their post-than pre-simulation mental models.

To obtain a deeper insight into students' learning, we analyzed the concepts they had marked in their concept maps. In pre-maps, we identified a total of 53 different self-named concepts. The number of distinct concepts decreased to 49 after the simulation, which suggests that the concepts in students' maps became slightly more similar after the simulation. All self-named concepts found in students' pre- and post-maps are presented in Fig. 3, where the size of each word illustrates the frequency of the particular concept.

As Fig. 3 illustrates, *raw materials* was the most common self-named concept in pre-maps (found by 34 students), followed by *costs* (31) and *delivery* (31). In post-maps, the most common self-named concept was *borrowed capital* (64), followed by *raw materials* (58) and *delivery* (41). The significant growth in the occurrence of *borrowed capital* (from 15 to 64) is likely due to the content of the simulation, where it is practically impossible to run the company without taking bank loans.

The content of the simulation seemed to influence the type of concepts that students perceived after the simulation. To analyze this further, we grouped the various concepts into three categories: First, a "*Market & management*" category, which included concepts such as *marketing, customer, brand, competitors, regulation, strategy, organization,* and *HRM*. Second, a "*Basic processes*" category, which contained concepts such as *offers, orders, delivery, price, suppliers*, and *research*, which students could control or decide on directly in the simulation. Third, a "*Finances*" category, which included concepts such as *accounting, costs, fixed costs, bank account, own capital, borrow capital, turnover, taxation, profit*, and *loss*, which are related to a company's balance sheet and profit and loss statement. Table 1 demonstrates how the number and frequency of concepts in all three categories changed between pre- and post-maps.

As Table 1 indicates, the number of concepts increased only in the *Basic processes* category. In the other two categories, the number of self-named concepts decreased from pre-to post-maps. However, the frequency of concepts in each category increased, indicating that more students had named concepts in their post-than pre-maps. This increase in frequency was particularly large in the basic processes category. Thus, the simulation appeared to fill knowledge gaps related to these basic processes, which was one of the intended learning objectives of the simulation course.

4.3. Development in written explanations of the connections between the concepts

We analyzed the qualitative changes in written explanations in pre- and post-maps in two phases: First, we assessed the correctness of each pre- and post-map independently. Second, we compared each student's pre- and post-map and assessed the differences between them.

4.3.1. Corrections of explanations

In general, the misconceptions or ambiguities in written explanations were most commonly related to the concept of *profit* and its relationships with *cash, sales*, and *turnover*. The following example demonstrates an imprecise explanation in a pre-map: "*The sums circulating in cash tell the profit of the company*…." The answer is vague and unclear—a suspicion remains that the student has not fully understood how profit is calculated. In her post-map, this student was able to develop her explanation significantly: "*When the customer pays the invoice, money becomes cash. With borrowed money, the company can keep its cash positive, but only the loan interest affects profitability. The sales volume increases turnover. Big turnover usually means good profit, if costs are low*." It is as if, in the pre-map, the student avoided giving a comprehensive description of the topic; but in the post-map, she was willing to explicate more about her

Table 1
Number and frequency of self-named concepts in different categories.

Category	Number of concepts in pre-simulation maps	Number of concepts in post-simulation maps	The frequency of concepts in pre-simulation maps	The frequency of concepts in post-simulation maps
Market & management	15	10	79	84
Basic processes	16	20	159	256
Finances	20	19	126	172

increased understanding and thereby provide longer explanations.

We found it difficult to count the exact number of corrected misconceptions: As the students redrew their whole concept maps after the simulation, the connections they marked and the explanations they gave were often significantly different between the two maps. Although many misconceptions in the pre-maps were corrected in the post-maps, we occasionally found new misconceptions in the post-maps. However, this does not suggest that a previously correct understanding would have changed into a misconception. Instead, the new misconceptions in students' post-maps appeared to concern connections between concepts that were missing in the pre-maps. It seems that while students added some new beliefs into their mental models, they did not necessarily acquire the correct conceptions immediately.

In general, the quality of explanations improved after the simulation course. While around 60% of students exhibited either some ambiguities or clear mistakes in their pre-map explanations, only approximately 33% exhibited misconceptions or ambiguities in their post-map explanations. Furthermore, even though many students still expressed some misconceptions or ambiguities in their post-map explanations, the number of unclear or false explanations often decreased.

4.3.2. More professional understanding of concepts

Many students' explanations in their pre-maps were clearly based on their experiences as consumers, and thus the meanings of various concepts in a business context were unclear to them: "*Part of the sales income becomes cash. Part of the sales income comes to a bank account. Money is transferred between a bank account and cash.*" Hence, this student was thinking like a consumer, who can have money in both cash and a bank account, and who can withdraw money from—and deposit money to—a bank account. However, in the accounting context, *cash* refers not only to money at hand, but also to bank account balances. After the simulation, this business definition of *cash* became clear to most students, including the student quoted above. In the post-map, the same student simply stated, "*When a customer pays a bill, money comes to cash.*"

The single most common misconception in the students' pre-maps concerned the relationship between *profit* and *cash*: "*Profit is calculated from cash*"; "*Profit – costs = cash*"; and "*Profit is marked in cash.*" These could indicate a category mistake-type of misconception (Chi, 2013), as *profit* and *cash* occupy the same category. However, *cash* and *profit* belong to different lateral categories: *Cash* is a balance sheet item, while *profit* is an item in the income statement. This type of mistake can be a sign of a missing schema (see Chi, 2013). It is possible that students did not have a schema of the balance sheet prior to the simulation, but our data do not clearly demonstrate this. However, our data demonstrate that the misconception concerning *cash* and *profit* was relatively persistent, as it was also found in many students' post-maps. In this respect, our data confirm Chi's (2013) claim that category mistakes and missing schema types of misconceptions are especially difficult to change.

Nevertheless, after the simulation, the understanding of the concepts of *cash* and *profit* improved in many explanations. For instance, pre-map statement "*Profit shows in cash,*" became "*Account receivables are taken into account in profit. Account receivables do not show in cash. Loan increases cash. Cash is not the same as profit*" in the post-map, indicating this student no longer placed *cash* and *profit* in the same category.

Hence, some students were able to correct the category mistake type of misconceptions. In the example above, the concept of *loan* was added to the accurate category in the mental model, thus affecting only *cash*, not *profit*. Indeed, the addition of *borrowed capital* was very common in students' post-maps. In their corresponding explanations, students usually referred explicitly to the correct conception, in which a bank loan transferred to cash does not increase profitability.

4.3.3. Improved understanding of causal relationships

The comparison of the explanations in students' pre- and post-maps indicated a better understanding of complex and indirect causal relationships between various concepts after the simulation. For instance, the connection between *sales* and *profit* was often considered simple and linear in the pre-map; after the simulation, students seemed to be more aware of the importance of costs and their control for a company's profit formation. For example, a student's pre-map explanation "*The more sales, the better profit*" contrasts with her post-map explanation that indicates a better understanding of factors influencing a company's profit formation: "*The more sales, the higher turnover. With high sales margin, the profit is high even if the turnover is not that big.*"

Students' post-map descriptions were generally more detailed and informed about the causalities: "*Product development affects quality and through that purchase behavior of customers*" and "*Through investing in product development, a company can increase the quality of its products*". We compared the word frequencies in every student's written pre- and post-map explanations and noticed a significant increase in words that describe causality or processes. The frequency of each of the following concepts increased over 50% from pre-map to post-map: *quality, waste, pricing, delivery, investment, debt, demand*, and *order*. Further, the frequency of the following verbs increased at least 44%: *improve, decrease, increase, cause*, and *grow*. This increase indicates that after the simulation, students paid more attention to causal linkages between concepts and various business processes.

4.3.4. Relation between concept map complexity and accuracy

More detailed scrutiny of the perceived connections informed us that the increase in the number of connections in post-maps was linked to the self-named concepts. While the number of connections between the given concepts (i.e., the concepts that were written on the concept map by the researchers) remained approximately the same (average of 8.4 in pre-maps and 8.1 in post-maps), the number of connections in which at least the other concept was self-named increased from an average of 6.9–9.5 from pre-to post-maps. We interpret this increase as the addition of beliefs into students' mental models.

We also compared the improvement in explanations between the students with different initial levels of knowledge; i.e., between those who had perceived more than the average number of connections in pre-maps and those who had perceived less. Since fewer connections naturally mean fewer explanations, and thus fewer possibilities for erroneous explanations, we calculated the rate of errors, which took into account the number and length of students' explanations (see Table 2). Consequently, we observed that those students with fewer than the average number of connections in their pre-mapshad clearly more errors per word. This suggests that students with initial knowledge gaps also had more misconceptions.

After the simulation, both students with above average and below average initial business knowledge managed to decrease errors at a rather similar rate, and they both produced more accurate conceptual maps. Hence, whereas the students with a lower initial knowledge level (measured by the number of connections between concepts in their pre-maps) seemed to add more beliefs into their mental models, conceptual change-type learning seemed to be approximately equal for both groups. This means that when analyzing the accuracy of mental models, the initial differences between more and less knowledgeable students seem to remain the same after the simulation course.

5. From empirical findings to theoretical model

The main findings are summarized in Table 3 that links our empirical data analysis of concepts, connections, and written explanations to the theoretical constructs we derived from the study. Together, the main findings presented in Table 3 answer our third research question *"How are the complexity and the accuracy of students' mental models intertwined?"*, in following ways. The analysis of concepts in students' pre- and post-maps demonstrated that students acquired new knowledge especially regarding concepts related to a company's basic processes. This is natural as the case simulation illustrates business processes. The addition of new knowledge contributed to the complexity of students' mental models. The change in perceived connections between concepts in students' post-maps suggests that they not only added new knowledge, but also acquired a deeper comprehension of business concepts and processes, which in turn made their mental models more accurate, coherent, and better integrated.

Conversely, analysis of students' written explanations demonstrated that new knowledge was not always correctly understood. Hence, the increased complexity of a mental model was sometimes accompanied with a decrease in its accuracy. However, the data also showed more positive examples of new knowledge additions with correct conceptions. The explanations also indicated increased understanding of complex, indirect causal relationships between business concepts, as well as increased accuracy and decreased misconceptions in students' mental models.

Based on our empirical findings, we can distinguish two interconnected processes that form the basis for our model of conceptual change through business simulation. The first process is *addition of new knowledge*, in which mental model complexity increases when the learner adds new beliefs and knowledge to the existing mental model. However, this increase in mental model complexity does not occur in a vacuum. Thus, the second process is the *change in existing knowledge*, in which the mental model's accuracy improves through corrections of misconceptions and inaccuracies. These processes and their interconnections are illustrated in Fig. 4.

The simplest form of learning from business simulation is the *addition of beliefs*. Occasionally, a learner's mental model lacks concepts and connections that are obviously required. This lack of knowledge has a relation to *misconceptions and inaccuracies* of the mental model. Based on our findings, we propose that a smaller number of connections in a mental model denotes relatively more misconceptions than a greater number of connections. Hence, the addition of beliefs occurs through evaluations performed by the learner's existing mental model. Based on this evaluation, added beliefs may contain misconceptions and decrease the mental model's accuracy. The persistence of misconceptions is related to the complexity of the learner's existing mental model: With most persistent misconceptions, learners lack the ability to evaluate the added beliefs. With less persistent misconceptions, students have the ability to correct their earlier misconceptions. In addition to these corrected misconceptions, added beliefs may also contain *correct conceptions*. Together, corrected misconceptions and correct conceptions contribute to *deeper comprehension*.

Deeper comprehension can be defined as an increased understanding of relationships between concepts. In our data, this meant more indirect causal connections between concepts and an increased understanding of various business processes, both of which increased the complexity and accuracy of the mental models. However, we also noticed a decrease in mental model complexity, in which the discrepancy in mental models diminished and the patterns of connections became more similar. The likely reason for this integration is that when mental models become more accurate, they approach a normatively ideal model, in which connections can be presented with only limited variations.

Finally, as less complexity in mental models indicated more misconceptions and new misconceptions in post-simulation mental

Table 2
Qualitative assessment averages of pre- and post-maps.

	Students with pre-connections > avg.	Students with pre-connections < avg.
Average of errors in pre-simulation map	0.70	0.86
Average of errors in post-simulation map	0.37	0.48
Error decrease %	(0.7–0.37)/0.7 = 47%	44%
Average number of words in the pre-simulation map	71.0	54.8
Average number of words in the post-simulation map	73.9	63.3
Ratio: errors/number of words (Pre)	0.70/71 = 0.0099	0.0157
Ratio: errors/number of words (Post)	0.37/73.9 = 0.0050	0.0075

Table 3
From empirical data analysis towards theoretical constructs.

Unit of analysis	Examples in empirical data	Data centric theme (1st order)	Theory centric theme (2nd order)	Aggregate dimension
Concepts	The frequency of self-named concepts increased in students' concept maps after the simulation (see Table 1 & Fig. 1)	Acquisition of new business concepts	Addition of beliefs	Mental model complexity (+)
Concepts	The frequency of concepts related to firm's basic processes increased after the simulation (see Table 1 & Fig. 3)	Acquisition of concepts related to firm's basic processes	Addition of beliefs	Mental model complexity (+)
Connections	The number of connections among concepts increased when pre-simulation concept maps were less complex than average (e.g. Fig. 1)	Increased understanding of relationships between concepts	Lack of knowledge Deeper comprehension	Mental model complexity (+) Mental model accuracy (+)
Connections	Increased integration of various business processes in concept maps after the simulation (see Fig. 2)	Increased understanding of relationships between processes	Deeper comprehension	Mental model complexity (+-) Mental model accuracy (+)
Written explanations	Pre-map: No connection & explanation between cash & profit Post-map: "The amount of money in cash affects profit"	New connection added with an erroneous explanation (cash & profit)	Addition of beliefs with misconceptions	Mental model complexity (+) Mental model accuracy (-)
Written explanations	Pre-map: No connection & explanation between loan and profit Post-map: "You can keep the cash balance positive with bank loans, but only the loan interests affect the profit"	New connection added with correct explanation (loan & profit)	Addition of beliefs with correct conceptions	Mental model complexity (+) Mental model accuracy (+)
Written explanations	Pre-map: "Marketing affects profit" Post-map: "Marketing affects sales. Sales affect profit"	Increased understanding of indirect causal connections	Deeper comprehension	Mental model complexity (+-) Mental model accuracy (+)
Written explanations	Pre-map: "Profit comes from customers" Post-map "Sales income comes from customers"	Improved explanations on business concepts and relationships between them	Increased accuracy	Mental model accuracy (+)
Written explanations	Pre-map: "Cash is added to profit" Post-map: "Sales receivables are marked in profit"	Corrected explanations of relationships between cash and profit	Correction of misconceptions	Mental model accuracy (+)

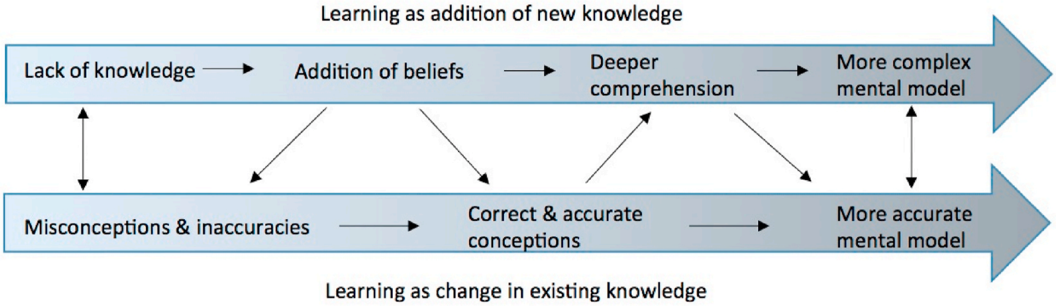

Fig. 4. A model of conceptual change through business simulation.

models were related to connections that were missing in pre-simulation mental models, mental model complexity and accuracy appear to be intertwined. Consequently, we propose that more connections to a concept means a higher probability of correct understanding. In contrast, fewer connections to a concept equals a higher probability of misconceptions. Whether this is a universal phenomenon certainly requires more research to determine.

6. Discussion and conclusions

6.1. Discussion on key findings

The purpose of this research was to examine how students' mental models change during a business simulation course. Overall, our findings indicate two types of change in students' mental models. The first type of change concerns the addition of new knowledge into the mental models. The majority of students marked more concepts and connections in their post-simulation concept maps, indicating increased mental model complexity. Previous management education studies have suggested that increased complexity in students' mental models implies learning (e.g., Nadkarni, 2003; Palmunen et al., 2013; Xu & Yang, 2010). Our findings expand these earlier studies by demonstrating a polarized effect. We discovered that the complexity of a mental model did not increase for those students whose initial business knowledge was higher than average. On the contrary, the students with lower-than-average initial business knowledge produced significantly more complex conceptual maps after the simulation course. This suggests that knowledge-level differences between less and more knowledgeable students decreased during the simulation course, and that the students with a lower level of prior business knowledge benefited more from the simulation course.

However, our findings also indicate a second type of change that concerns the accuracy of students' mental models. In general, our data demonstrated that the lower complexity of a pre-simulation concept map was connected with lower accuracy. Nevertheless, students produced more accurate concept maps after the simulation, regardless of their initial level of knowledge. Hence, when analyzing the accuracy of mental models, the initial differences between more and less knowledgeable students remained the same after the simulation course. This indicates that assessing learning only from the complexity perspective may lead to the neglect of the profound aspect of learning known as *conceptual change.*

Thematically, the conceptual change that occurred during the business simulation course was often related to the transformation of students' conceptions and mental models from a consumer's understanding to that of a business professional. Another common theme of change in students' mental models concerned the indirect causal connections among concepts. Generally, mental models became more comprehensive and better integrated after the simulation course. The overly simple and disintegrated concept maps could be seen as representations of flawed mental models (see Chi, 2013). Hence, their correction can be viewed as conceptual change.

6.2. Contributions to previous research

First, we answered the call for more business simulation studies on how learners make sense of particular problems by analyzing and organizing information (Anderson & Lawton, 2009; Gentry & Burns, 1981). Specifically, we demonstrated that learning in simulations occurs through a combination of knowledge addition and conceptual change processes. Hence, we contribute to the literature on learning from business simulations (e.g. Anderson & Lawton, 2009; Faria, 2001; Hernández-Lara et al., 2019) by showing how both of these intertwined processes are needed to make learners' mental models more complex and accurate.

Second, we apply the conceptual change discussion to the management education literature. By doing so, we answered the call for more conceptual change research in social sciences (e.g., Lundholm, 2018; Murphy & Alexander, 2013). Our results challenge the traditional approach in the management education literature, which regards mental model complexity as an indicator of learning (e.g. Davis & Yi, 2004; Nadkarni, 2003), by highlighting how this approach struggles to explicate students' misconceptions and their persistence.

6.3. Practical implications

The results of the empirical research show that a business simulation course increases students' understanding of the complex nature of relationships among various business concepts. This novel understanding helps them to develop more integrated, complex, and accurate mental models of the phenomena illustrated by the business simulation game. Thus, simulations function as environments for fostering the development of students' conceptions about the dynamics, causes, and effects among different business functions.

The concept map drawing assignment developed for this study offers an excellent model to acquire information about business students' learning needs. According to Salas, Wildman, and Piccolo (2009), the effective implementation of simulation-based training should start by assessing the students' current skill levels and learning needs. Drawing concept maps can be used for revealing both knowledge gaps and misconceptions in students' mental models. These deficiencies may then be explicitly addressed during the course to reach maximal learning outcomes.

Our study brings forth several implications for educators. First, educators who have relied on simulation games to develop students' understanding of business dynamics, can confidently continue to do so. Second, the concept map drawing assignment can serve as a feasible method for assessing students' perceptions on business topics. It has a particular benefit compared to any other assessment method: concept maps elicit students' perceptions on issues that are difficult to cover with methods limited to a fixed set of topics. In addition, concept maps may evoke such learning that the educator may not have anticipated at all. Making this previously hidden learning visible may also give the educator new ideas on how to expand simulation-based education to novel learning topics. Third, the process of drawing a concept map may further contribute to students' learning, as they are urged to clarify to themselves how business cause-effects form.

6.4. Limitations and future research

The connection found between learning as the addition of new knowledge and learning as conceptual change might reflect the business context more than the nature of learning. This is because many business phenomena are complex by nature, and many business decision situations are ill-structured, requiring an understanding of various intervening factors. In other words, our results demonstrate how people learn the complexities of business; but, in other domains, learning might not require a connection between the addition of new knowledge and conceptual change. Thus, it would be interesting to test the methodological approach we developed for this study in other contexts. Furthermore, as this study was among the first to investigate conceptual change in the management education context, we encourage other researchers to consider conceptual change as a meaningful and useful framework for increasing understanding of the nature of business learning and education.

Credit author statement

Lauri-Matti Palmunen: Conceptualization, Validation, Formal analysis, Investigation, Writing - Original Draft, Writing – Review & Editing, Visualization. **Timo Lainema:** Conceptualization, Methodology, Software, Validation, Formal analysis, Writing - Original Draft, Writing – Review & Editing. **Elina Pelto:** Conceptualization, Validation, Formal analysis, Investigation, Writing - Original Draft, Writing – Review & Editing, Visualization.

Declaration of competing interest

None.

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