

Linköping Studies in Science and  
Technology, Thesis No. 1685  
LiU-TEK-LIC 2014:117

# **Towards Pedagogical Content Knowledge in Logistics**

**Björn Oskarsson**



**Linköping University**

2014

Department of Management and Engineering  
Linköping University, SE-581 83 Linköping

© Björn Oskarsson, 2014

Linköping studies in science and technology,  
Thesis No. 1685

LiU-TEK-LIC 2014:117

ISBN: 978-91-7519-198-0  
ISSN: 0280-7971

Printed by: LiU-Tryck, Linköping

Distributed by:

Linköping University  
Department of Management and Engineering  
SE-581 83 Linköping, Sweden  
Tel: +46 13 281000, fax: +46 13 281873

# Abstract

Logistics is regarded as an area of high importance in business, contributing to profitability and competitiveness. Logistics is crucial also from a societal perspective, since logistical activities count for a big proportion of a country's GNP, and since effective logistics systems can help reducing some of the environmental problems we face today. Higher education has an important role to play in order to provide business and society with well-educated logistics personnel. Since not much research is published within higher education in logistics, the purpose of this thesis was defined as:

*To contribute to the knowledge on teaching and learning logistics in higher education.*

More specifically, two research questions were set up:

*RQ1: What knowledge and skills are important for students to learn during higher education in logistics?*

*RQ2: How can students' learning of these skills and knowledge be facilitated?*

A comprehensive literature review serves as a basis for the study. The literature on logistics education gives limited guidance concerning what is to be learned during higher education in logistics, as well as how to facilitate learning within logistics. These findings indicate that the logistics teaching faculty do not base their course designs and teaching practices on solid knowledge on what and how to teach.

Although a major finding of my work is that more research is needed, some more concrete propositions can be made. In order to reach some kind of answers to the research questions, a selection of pedagogical theories was applied on logistics education with help from illustrating examples, partly found in literature, and partly from specific studies performed as part of this thesis.

Concerning the first research question, I propose a tentative model, illustrating how different logistics knowledge and skills can be positioned against each other. A division is made between subject-specific and generic knowledge and skills, and two *core generic skills within logistics* are proposed: Total cost analysis and Structured investigation method.

From pedagogical literature, the concept of *thresholds* was introduced. A threshold refers to something that is troublesome for students to overcome, but once passed leads to a new way of understanding. The identification of the thresholds associated with acquiring important knowledge and skills, is therefore important for teachers. Some thresholds concerning logistics education are discussed in the thesis. For the two core generic skills proposed above, it is suggested that 'case-specific adaptation of total cost models' is a threshold for total cost analysis, and 'investigation planning' is suggested as a threshold for structured investigation method.

The question of *how* something can be learned is dependent on *what* is to be learned. Since there is a lack of clear answers concerning the what, the second research question (focusing the how) is difficult to answer in a concrete manner. On a general level, some findings were found though.

Logistics is a discipline where education has strong emphasis on usefulness for the working-life. *Problem- and practice-based instructional methods* are therefore recommended to create learning situations, where learning is extended from theoretical models as such, to their application in realistic settings. Reflection upon the appropriateness of the models then becomes essential. The use of educational games, simulation, and field-based projects are examples of such methods.

In pedagogical literature, the term *pedagogical content knowledge* addresses the need for teachers to know the subject-matter (the content) in a way that makes it possible for him/her to make it understandable for the students. This kind of knowledge is built up from a number of knowledge components. One of those concerns knowledge about what is troublesome for students, which bridges over to the previously described threshold concepts. Another component is knowledge of students' pre-understanding. An example of a method for capturing such pre-understanding is given in the thesis. Given that a teacher knows the subject-matter, the students pre-understanding, and some other contextual factors, a good knowledge on how to instruct and assess the students is crucial. The instructional methods are to a big extent case-specific, but as indicated above, problem- and practice-based methods are often to recommend within logistics education.

Based on the findings and discussions in this study, a number of *suggestions for future research* are proposed. Among those is the need to identify the thresholds connected to learning core logistical knowledge, and to investigate appropriate instructional methods for helping students to overcome these thresholds.

# Acknowledgements

So now I'm facing the end of the licentiate process, a process which is hard to define since I don't know when it started. Formally, I was accepted as a PhD student just a few months ago, but in practice some years have passed since I took the first stumbling steps on this journey.

There is one person, to whom I would like to express my particular gratitude for supporting me during my work. Maria, from being a colleague, with whom I could discuss my pedagogical thoughts, you transformed into being my supervisor. I can't recall what triggered this transformation, but I sure am glad it happened. Since your supervising efforts haven't been funded, I don't know where you have found energy for this. Anyway, your support has been invaluable; I have experienced a very good balance of support, control and trust from your side. What can I say? 'Thank you' doesn't really live up to my feelings...

All my other colleagues have also contributed to this thesis, by being who you are and doing the things you do. All the engagement you put into your work, not least the education, is impressive, and I'm proud of being part of this professional team. As if this wasn't enough, you seem to have joy and humor embedded in your genetic codes. Thanks to you, it's a pleasure going to work.

To embark a research journey means that you have to climb out of your comfort zone, and accept a certain level of insecurity. Doing this is much easier if you have a solid ground, a base camp to return to. My base camp is my home and my family. Karin, I can imagine that you now and then – especially during the last few weeks – have wondered whether I put work or family first. Don't worry, you're chained to my heart. To my sons, who have developed into at-least-rather-grown-up-beings, not that dependent on their father anymore, I want you to know that I appreciate the moments we have together. It may take the form of a young philosophy student surprisingly coming by a Friday night to spend a weekend with his parents; a youngster leaving his man cave for a cup of tea and a piece of apple pie; or a constantly lagging Skype conversation with a High School student in Indianapolis.

Sometimes, even family isn't enough to disconnect the brain from work. I've got two breathing spaces that over the years have helped me clear my mind. A big thanks therefore to my fellow musicians and to the Oldboys footballers.

# Table of content

<b>1</b>	<b>INTRODUCTION.....</b>	<b>1</b>
1.1	WHY FOCUS LOGISTICS EDUCATION IN THE FIRST PLACE?.....	1
1.1.1	<i>Logistics, today and tomorrow.....</i>	1
1.1.2	<i>It's not self-evident how to teach and learn logistics.....</i>	4
1.2	PURPOSE AND RESEARCH QUESTIONS.....	4
1.3	TEACHERS AND STUDENTS – WHO ARE IN FOCUS?.....	6
1.4	OUTLINE OF THE THESIS.....	7
<b>2</b>	<b>METHODOLOGY.....</b>	<b>9</b>
2.1	RESEARCH DESIGN.....	9
2.1.1	<i>A compilation of the research design and methods used.....</i>	9
2.1.2	<i>Methods used in the papers.....</i>	10
2.1.3	<i>Methods used in the cover text.....</i>	11
2.2	COMMENTS ON THE CREDIBILITY OF THE STUDY.....	12
2.2.1	<i>Internal validity.....</i>	13
2.2.2	<i>External validity.....</i>	15
2.2.3	<i>Reliability.....</i>	15
<b>3</b>	<b>ENTERING THE PEDAGOGICAL WORLD.....</b>	<b>17</b>
3.1	DIDACTICS VS. PEDAGOGY – WHAT'S THE DIFFERENCE?.....	17
3.2	PEDAGOGY - THE SCIENCE OF TEACHING AND LEARNING.....	18
3.2.1	<i>The pedagogical triangle.....</i>	19
3.2.2	<i>Three main pedagogical questions: Why? What? How?.....</i>	20
3.3	CONSTRUCTIVE ALIGNMENT.....	22
3.4	PEDAGOGICAL CONTENT KNOWLEDGE.....	23
3.4.1	<i>PCK components.....</i>	24
3.4.2	<i>How PCK can be acquired.....</i>	28
3.4.3	<i>Evaluation of teachers' PCK.....</i>	30
3.4.4	<i>Areas where PCK is applied.....</i>	31
3.4.5	<i>Some critical voices.....</i>	31
3.4.6	<i>PCK – some concluding words.....</i>	32
3.5	THRESHOLD CONCEPTS.....	32
3.5.1	<i>Characteristics of threshold concepts.....</i>	32
3.5.2	<i>Threshold concepts – some examples.....</i>	34
3.5.3	<i>How threshold concepts can be identified.....</i>	35
3.5.4	<i>Connections between threshold concepts and PCK.....</i>	36
3.5.5	<i>Threshold concepts – some concluding words.....</i>	37
3.6	HIGHER EDUCATION SPECIFICS.....	37
<b>4</b>	<b>WHAT ARE STUDENTS SUPPOSED TO LEARN FOLLOWING A LOGISTICS EDUCATION?.....</b>	<b>39</b>
4.1	LOGISTICS – WHAT DOES IT EMBRACE?.....	39
4.2	RESEARCH CONCERNING IMPORTANT LOGISTICS KNOWLEDGE AND SKILLS.....	40
4.2.1	<i>The working profession perspective.....</i>	40
4.2.2	<i>The educational perspective.....</i>	42
4.3	A TENTATIVE MODEL FOR POSITIONING LOGISTICS KNOWLEDGE.....	44

4.3.1	<i>Knowledge areas and core knowledge</i> .....	44
4.3.2	<i>The example of inventory management</i> .....	46
4.3.3	<i>The example of total cost analysis</i> .....	47
4.3.4	<i>The example of structured investigation method</i> .....	50
4.3.5	<i>A model for visualizing logistics knowledge and skills</i> .....	51
<b>4.4</b>	<b>THRESHOLD CONCEPTS IN LOGISTICS</b> .....	<b>53</b>
4.4.1	<i>The inventory management example</i> .....	54
4.4.2	<i>The total cost analysis example</i> .....	55
4.4.3	<i>The investigation method example</i> .....	56
4.4.4	<i>Threshold concepts in logistics – a concluding discussion</i> .....	56
<b>4.5</b>	<b>CORE KNOWLEDGE AND THRESHOLDS WITHIN LOGISTICS – CONCLUDING THOUGHTS</b> .....	<b>58</b>
<b>5</b>	<b>HOW CAN STUDENTS’ LEARNING ABOUT LOGISTICS BE SUPPORTED?</b> .....	<b>59</b>
<b>5.1</b>	<b>PEDAGOGICAL CONTENT KNOWLEDGE VS. LOGISTICS EDUCATION</b> .....	<b>59</b>
5.1.1	<i>The case of total cost analysis</i> .....	60
5.1.2	<i>PCK components – how case-specific are they?</i> .....	63
<b>5.2</b>	<b>CAPTURING STUDENTS PRE-UNDERSTANDING – AN EXAMPLE</b> .....	<b>65</b>
<b>5.3</b>	<b>METHODS FOR INSTRUCTION AND ASSESSMENT</b> .....	<b>66</b>
5.3.1	<i>Problem- and practice-based methods</i> .....	66
5.3.2	<i>Examples from literature on logistics education</i> .....	67
<b>5.4</b>	<b>ALIGNMENT BETWEEN CONTENT AND EDUCATIONAL METHODS</b> .....	<b>71</b>
5.4.1	<i>Telling whether something has effect</i> .....	72
<b>5.5</b>	<b>SUMMARIZING DISCUSSION</b> .....	<b>74</b>
<b>6</b>	<b>BRINGING IT ALL TOGETHER</b> .....	<b>75</b>
<b>6.1</b>	<b>THE FINDINGS</b> .....	<b>75</b>
6.1.1	<i>What to learn in logistics higher education</i> .....	76
6.1.2	<i>How to facilitate learning in logistics higher education</i> .....	78
6.1.3	<i>Conclusions</i> .....	79
<b>6.2</b>	<b>REFLECTIONS</b> .....	<b>80</b>
6.2.1	<i>What’s so special with logistics?</i> .....	80
6.2.2	<i>Educational research – not an interesting field for logistics faculty?</i> .....	80
<b>6.3</b>	<b>SUGGESTIONS FOR FUTURE RESEARCH</b> .....	<b>81</b>
6.3.1	<i>Identifying core knowledge within logistics</i> .....	81
6.3.2	<i>Identifying threshold concepts within logistics</i> .....	81
6.3.3	<i>Identifying how thresholds could be overcome</i> .....	82
6.3.4	<i>Testing the effects on learning</i> .....	82
6.3.5	<i>Collaboration with educational researchers</i> .....	82
<b>REFERENCES</b>	.....	<b>83</b>

**APPENDIX 1**

**PAPER 1 - A LITERATURE REVIEW OF RESEARCH WITHIN LOGISTICS EDUCATION**

**APPENDIX 2**

**PAPER 2 - INVESTIGATION METHODOLOGY IN LOGISTICS: A FRAMEWORK**

**APPENDIX 3**

**PAPER 3 - DO WE KNOW IF STUDENTS ARE GRASPING WHAT WE WANT TO CONVEY?**





# 1 Introduction

*The road leading to this thesis has been long and winding. Ever since I started my logistics teaching career at Linköping University in 1993, I've been experimenting with different forms and methods for teaching and assessment, as well as different ways of designing courses. I have followed my intuition, and gradually gained experience, but honestly I didn't know much about pedagogical theories and educational research. About ten years ago I became involved in teaching a course in 'university pedagogy', directed towards new teachers at Linköping University, I was then 'forced' to read a book on higher education: "Teaching for quality learning at university" by John Biggs. Having started to read, I was totally captured, finding so much that helped me structure and categorize all my thoughts and experience. This was the starting point for my interest in literature and research within higher education. After some time, I realized that even though much was written about this in general, there seemed to be very little directed towards logistics education. My interest for doing research in the field was born, and I took the first stumbling steps writing a conference paper, and from there I have continued. Due to lack of funding, this thesis is the product of a several-year-process. Logisticians are usually not in favor of long lead times, but sometimes we have to accept exceptions...*

## **1.1 Why focus logistics education in the first place?**

Logistics is an important area in today's society. When consulting the literature, for example Esper et al. (2007), Jahre and Persson (2008), and Christopher (2011), the authors agree upon logistics as an important field, both today and in a foreseeable future. But why is logistics important and what implications does this have for higher education?

### **1.1.1 Logistics, today and tomorrow**

The business perspective

Logistics is often discussed in a business context, where the importance of effective logistics management is emphasized for the companies involved. The basic logistic activities deal with storage, movement and handling of material and goods, but these physical activities are just parts of the full picture. In order to get things to work in a good manner, there are a lot of managerial decisions that must be made on short and long term, for instance: Where to locate warehouses; Which products to keep in stock and in what quantities; Whether transports should be performed in-house or bought from a specialized company; Which customers to give priority in case of limited supply. The planning, control and management of logistical activities is of crucial importance.

Following the CSCMP (2014) definition, logistics management is:

*“...that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flows and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements.”*

The ‘effectiveness’ aspect indicates that logistics should support and produce valuable and useful services (transportation, storage etc.) corresponding to the company’s needs, while the ‘efficiency’ aspect means that this should be done without using more resources than necessary. Connected to logistics activities are human resources, equipment for transports and material handling, as well as buildings like warehouses and terminals. All these contribute to costs and tied-up capital. Customers’ requirements are stressed in the definition, which pinpoints that the logistics activities must be effective, not only from an internal perspective, but from a customer service point of view. Good delivery service is highly valued by many customers. Effective logistics operations may serve as a sales argument, as the reputation of reliable deliveries and good delivery service is something that can attract new customers and serve as order winners. In this way, logistics contributes to a company’s profitability by cutting costs, raising incomes (due to good delivery service) and using capital efficiently (Grant et al., 2006; Oskarsson et al., 2013). The goal of logistics may therefore be described as “to achieve desired levels of delivered service and quality at lowest possible cost” (Christopher, 2011).

Logistics at its best is both cost-cutting and sales-triggering, and therefore an important part of keeping and increasing a company’s competitiveness on the market. Moreover, flexible logistical systems and routines make it easier for companies to expand to other markets, but also to quickly adapt to dropping sales, see e.g. Abrahamsson et al. (2003). Logistics may therefore be seen as a possibility to achieve competitive advantage (Esper et al., 2007). Because of these reasons, effective logistics management is by many companies regarded as a strategically important function (Frankel et al., 2008).

### The societal perspective

However, logistics is not important only in a business context; it is also an urgent matter to society in different ways. Economically, mainly because of the large amount of transportation, logistics activities cover large amounts of money. Depending on how calculations are made, and on how logistics is defined, the figures might differ, but as an example, Murphy and Wood (2010) refer to statistics for a selection of countries around the world, showing that logistics costs account for between 9 and 23 per cent of the respective country’s gross domestic product. Logistics is therefore an important economical ‘engine’ in society. Competitive companies (as described above) open up doors for an increased export, which is positive for a country’s trade balance.

To handle the environmental problems is one of the most important tasks for society today. A negative aspect of transportation is the air pollution and other negative effects on the environment. McKinnon (2010) reports that freight transportation accounts for roughly 8 per cent of the world's energy-related CO<sub>2</sub> emissions. Since the amount of transports is steadily increasing, this figure will most probably increase dramatically if nothing is done. By designing logistical systems in a smart and sustainable way, it is possible to increase fill rates in vehicles, avoid transports at congestion hours etc. and thereby contribute to decreasing the environmental impact (Aronsson and Hüge Brodin, 2006; Allen and Browne, 2010).

Logistics is traditionally connected to flows of material and products. In recent years, mission has been spread to other areas. A good example is the health care sector, where logistics management principles increasingly is being used for improving patient flows, reducing waiting times for patients etc., see for example Aronsson et al. (2011). Since healthcare is an important public service spending large sums of money, in Sweden roughly 9 per cent of GDP (Wiger, 2013), there is a big potential for savings to be done.

### What about the future?

Examples of important trends brought up in literature are:

- Increasing globalization, bringing with it an expanding need for transportation of raw material and finished products (Christopher, 2011; Murphy and Wood, 2010; Langley et al., 2008)
- Greater emphasis on collaboration with supply chain partners (Bowersox et al., 2013; Frankel et al., 2008; Esper et al., 2007)
- Increasing customer demands on logistical performance (Langley et al., 2008; Harrison and van Hoek, 2011; Christopher, 2011; Murphy and Wood, 2010).
- The need for logistics actions to reduce impact on climate and environment. (Piecyk and McKinnon, 2010; Isaksson and Hüge-Brodin, 2013)

The need for efficient and effective logistics management does not seem to decrease in the future. On the contrary, demands and challenges are increasing. Managing material flows and logistics systems in a more global arena, with an increasing collaboration with various partners, serving more and more demanding customers, and still keeping up profitability and long-term competitiveness will surely be challenging. Add to this that we live in an era when 'constant change' has become more or less the rule, requiring a great portion of flexibility to deal with it. Logistics management is a complex task, and will most surely continue to be so. A well-educated work-force is therefore needed, which leads us to the topic about education in logistics.

### **1.1.2 It's not self-evident how to teach and learn logistics**

Logistics is a subject spanning from operational to strategic issues, and education within logistics can be found on different levels in the educational system. In this thesis, focus is on logistics as being strategically important, thus having great impact on organizations' competitiveness. This focus connects logistics education to subjects like business strategy, industrial organization, and operations management. The combination of such subjects is predominantly found in business schools and engineering programs, i.e. within higher education, which therefore is the level of education studied in this thesis.

Higher education is supposed to be well-grounded in existing research. This research connection is primarily established by the fact that teachers in higher education most often are researchers in the fields they are teaching. Hence, the subject is taught by people with a good scientific knowledge in the subject, meaning that the subject-matter taught is based on existing research. But the research connection might also refer to pedagogical aspects. It seems reasonable that the teaching as such and the educational setting should rest on existing research about teaching and learning.

Existing research about logistics education is only to a minor extent based on pedagogical theories and literature (this will be developed further on in the thesis, and the interested reader is specifically referred to paper 1). The knowledge about teaching and learning in logistics is therefore sparse, and this lack of knowledge is what this thesis is addressing.

## **1.2 Purpose and research questions**

Following the discussion in the previous section, the purpose of this thesis was defined:

The purpose of this research is *to contribute to the knowledge on teaching and learning logistics in higher education.*

Three general pedagogical questions, discussed by e.g. Pettersen (2008) and Håkansson and Sundberg (2012), could be applied on logistics education, and serve as a framework for approaching the topic of teaching and learning within logistics.

- *Why* is education within logistics important?
- *What* logistical skills and knowledge is important to learn during the education?
- *How* could we make the students learn those things?

The 'why' question is already covered in the previous section, clearly indicating *that* logistics education is important. The other two questions need to be developed further. Given the high importance of logistics, it could be assumed that educational aspects of logistics are rather well covered in research. A research article by Gravier and Farris

(2008) indicated that this is not the case. Existing research mainly deals with the ‘what’ question, i.e. what is taught at universities, what skills are considered important by employers etc. (Examples of this will be presented later on.) How the students should acquire these skills, or how these skills should be taught, is more scarcely commented. It seems like the ‘how’ question connected to logistics education is more or less ignored in existing research. Hence, there is a lack of research considering teaching and learning of logistics, but is it really necessary to take care of that matter? Could this lack of research exist because it is unnecessary to discuss logistic-specific pedagogical issues? Isn’t it enough with general pedagogical knowledge?

In the pedagogical literature, the matter of teaching specific subjects is discussed. According to Loughran (2013); Zepke (2013); Ramsden (2003) and others, you have to understand how the specific subject should be taught, in order to be a good teacher. You need general pedagogical knowledge as well as factual knowledge about the subject, but in addition you also need to know how to teach that specific subject, which is captured in the term ‘pedagogical content knowledge’ (Shulman, 1986). Given that subject-specific pedagogical knowledge is important, and that this issue more or less is ignored in existing research concerning logistics education, a reasonable research question is:

*How can students’ learning of logistics skills and knowledge be facilitated?*

However, leaning on the notion of pedagogical content knowledge, the ‘how’ question cannot be separated from the ‘what’ question. Teaching and learning activities are tightly connected to what is supposed to be learned. These questions are interdependent and should be treated in an integrative manner. Several researchers, e.g. Zepke (2013), discuss so called ‘threshold concepts’, which are specific aspects that are essential to understand in order to learn a specific topic. Accordingly, identifying central threshold concepts, or more generally the major learning objectives, in a certain field is a necessary step before discussing how these aspects should be taught. As Gravier and Farris (2008) report, a number of studies deal with required skills and knowledge within higher education in logistics. However, some years have passed since they performed their literature review, and new research on this matter might exist. Furthermore, these studies don’t clearly discuss the logistical skills from a pedagogical point of view. For example, there is a lack of discussion about any kind of categorization or prioritization of skills, to point out potential threshold concepts, or in other ways what skills and knowledge to focus in logistics education. There is reason to penetrate this area further, which calls for research considering:

*What knowledge and skills are important for students to learn during higher education in logistics?*

Hence, both the ‘what’ and the ‘how’ questions are considered important to address in this research. Since it is more natural to start with the ‘what’ and continue with the ‘how’, the order of the research questions are as follows:

RQ1: What knowledge and skills are important for students to learn during higher education in logistics?

RQ2: How can students' learning of these skills and knowledge be facilitated?

I don't step into this research thinking there is a straight and simple 'best' method that always is appropriate. Rather, I believe that teaching and learning is multi-faceted, and that easy answers are not to be found. As Loughran (2013) expresses it:

*"... teaching is problematic. There is no one way to teach a subject and no one way that all students learn that subject."* (p. 120).

Given this, I don't consider it possible to deliver a full picture regarding the research questions, but I intend to give a contribution that can serve as a basis for further development.

In an attempt to avoid unambiguity, the next section contains a brief discussion about the role of teachers and students in the subsequent discussion in the thesis.

### 1.3 Teachers and students – who are in focus?

In this thesis, the perspective of students as well as of teachers will be taken. At the right side of Figure 1, there is a student supposed to learn, i.e. to gain knowledge within a certain subject. The teacher's role is to support this learning to happen by applying appropriate instructional methods. Another important task for the teacher is to choose suitable aspects of the subject to be included in a course or a teaching situation, i.e. to make choices concerning content. However, in order to do that in a good manner, the teacher must have deep knowledge about the subject, as well as about for example how learning takes place, and the students' pre-understanding. Hence, teachers must also learn in order to be good teachers.

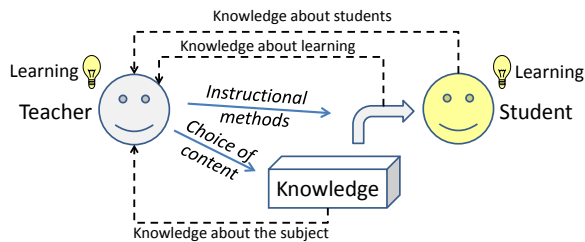


Figure 1: Teachers' and students' learning

Research question 1 focuses what is supposed to be learned, which relates to the appropriate choice of content from the teacher's side, and the student's learning of that content. In research question 2, focus in on how to facilitate this learning. With the student's learning as the aim, the teacher makes instructional choices, which requires an

insight that has to be gained. Hence, the teacher's learning is also important in order to help the student learn. To summarize, the student is primarily in focus in research question 1, while the role of the teacher is considered especially important in research question 2.

## **1.4 Outline of the thesis**

The thesis consists of four parts: three papers and a cover text. How these are connected to the research questions is principally explained in the subsequent text.

### **Paper 1 – An extensive literature study**

A structured literature review was performed in order to capture the state-of-the-art of published research in the intersection between logistics and education. This paper is the one giving the most fundamental contribution to the thesis. It embraces *what* to include in logistics education as well as *how* to design and perform such education, and therefore serves as a base to discuss both research questions. Paper 1 is presented in its entirety in Appendix 1, and some of the findings from this paper are presented in chapter 4 and 5.

### **Paper 2 – Investigation method – an important skill for logisticians**

Many of the articles found in the literature review focus the issue of *what* knowledge and skills that are important. One aspect not covered in these articles is the ability to plan and perform investigations. This area was penetrated in a specific study, where a tentative model for structured investigations is developed. This paper gives an example of *what* to learn, thereby mainly addressing research question 1. The tentative model is presented in chapter 4, and the complete Paper 2 is found in Appendix 2.

### **Paper 3 – The connection between what is taught and what is learned**

Just because something is being taught, this does not mean that the students actually have learned this something. To get an insight in how well students learn what is being taught, some educational activities were studied, whereupon the students' understanding of the taught stuff was examined with help from a questionnaire. This paper focuses both the *what* and the *how* question, thus addressing research questions 1 and 2. Paper 3 is presented in its entirety in Appendix 3, and some of the findings from this paper are presented in chapter 4 and 5.

## Cover text

As already mentioned, Paper 1 provides an important basis for the discussions in this thesis, while Paper 2 and 3 rather serve as illuminating examples. In the cover text, a theoretical base is presented covering relevant aspects within educational research. With help from these theories, together with cases and examples from the papers, the research questions are addressed.

The remaining part of the thesis is structured as follows:

Chapter 2: Research design and methods are presented, together with discussions about the credibility of the study.

Chapter 3: A review of educational research of relevance for this thesis is presented, and selected pedagogical terms and theories are described to give a foundation for discussions in the following chapters.

Chapter 4: The findings from literature are presented concerning what are important knowledge and skills in logistics higher education. Thereafter, a discussion based on theories and cases follows, about *what* to learn in logistics education, thereby addressing RQ1.

Chapter 5: In this part, RQ2 is in focus, i.e. the question on *how* logistics can be taught and learned. As in chapter 4, findings from literature are presented, together with discussions based on theory and cases.

Chapter 6: The research is summarized. Conclusions are drawn, and suggestions for future research are presented.



## 2 Methodology

In this chapter, the research design and methods used are presented, followed by a discussion of quality aspects of the study.

### 2.1 Research design

Since the area of logistics education is a relatively blind spot on the research map, it seemed natural for this thesis to have an exploratory agenda. When knowledge about an area is limited, an exploratory research design is considered suitable (Saunders et al., 2007; Ghauri and Grønhaug, 2005). As Cooper and Schindler (2003) put it:

*“Through exploration, researchers develop concepts more clearly, establish priorities ... and improve the final research design.”* (p. 151)

This quotation indicates that an explorative study is not to be seen as an ending point, rather as a first step, triggering further research. Saunders et al. (2007) explain that focus initially is broad in exploratory research, to be narrowed down when research progresses. Rather than to give clear undisputable answers to the research questions, this exploratory study is more likely to give an increased understanding of logistics education, resulting in ‘sharpened questions’ concerning future research. A better understanding concerning logistics education will therefore be of value for those who want to conduct research in the field.

Information about the unknown can be found in different ways, and a combined approach could therefore give a richer understanding. Several approaches are suggested for exploratory research in the literature (Saunders et al., 2007; Cooper and Schindler, 2003), for example studies of literature and documents, case studies and surveys.

#### 2.1.1 A compilation of the research design and methods used

In this research, a literature review was chosen as the main approach to get information about the state of the art concerning research within logistics education. This review, fully presented in Paper 1, was performed through a structured search in databases. The literature found was categorized by means of a content analysis in order to give structure to the material. The other two papers are based on descriptive case studies, a method regarded suitable when a clear understanding of something is desired (Merriam, 1998; Cohen et al., 2011; Yin, 2009). The case studies in Paper 2 and 3 are in the thesis used to shed light on some specific areas of interest, and to promote the understanding of some theoretical concepts applied to a logistics education context.

Altogether, this thesis is based on a multiple-method design, which is summarized in Figure 2.

	Cover text	Paper 1	Paper 2	Paper 3
<b>Research question</b>	RQ 1+2	RQ 1+2	RQ 1	RQ 1+2
<b>Topic</b>	What to be learned in logistics, and how to facilitate this learning	Review on current research status	Conceptual developm. of a model to describe a logistical skill	Exploration of student learning in a specific educational context
<b>Research design</b>	Literature review (Secondary data) Pattern matching (betw. prim. and sec. data)	Literature review (Secondary data)	Descriptive case (Primary data)	Descriptive case (Primary data)
<b>Data collection method</b>	Database search	Database search	Focus group Questionnaire	Observation Interview Questionnaire
<b>Analysis</b>	Qualitative	Qualitative (+ statistical)	Qualitative (+ statistical)	Qualitative (+ statistical)

Figure 2: Summary of research design and methods used in the thesis

For detailed descriptions of the methods applied in the different studies, the reader is referred to the respective paper (Appendix 1-3). Short descriptions are presented in the subsequent section, followed by a description of methods used specifically connected to the cover text.

### 2.1.2 Methods used in the papers

A brief description of the methods used in the three papers is presented here.

In *Paper 1*, a structured literature review was undertaken. The content in the reviewed articles was categorized based on a qualitative analysis, seeking for common patterns. The presence of pedagogical references in the articles was counted, and consequently presented as quantitative data. Basic statistical analysis was performed to generate comparative statistics concerning the different categories.

The *Paper 2* study started with a qualitative search in the literature for appropriate material with relevance the studied topic (investigation method). Based on this material, a model was developed with help from focus group discussions with teachers. The relevance of the model was tested by use of a survey to students, who answered using a Likert scale. Hence, quantitative data was collected in this stage, statistically processed, and analyzed qualitatively.

The study in *Paper 3* was performed using multiple methods. Lectures were observed, while notes were taken; teachers were interviewed in a semi-structured manner; and students were given a survey. The survey answers were free-form, e.g. qualitative.

However, the answers were categorized, which enabled a basic statistical analysis, followed by a qualitative interpretation.

Hence, although there is an emphasis on qualitative data and analysis in the papers, quantitative data has also been used to some extent, and qualitative analyses have been performed.

### **2.1.3 Methods used in the cover text**

In the cover text, theory from the pedagogical field is presented analyzed, followed by discussions on how these theories can be applied on logistics education. In these discussions, findings from the three papers are used. In the following, the methods applied during this work re described.

#### **Selection and analysis of literature**

Two major topics from the pedagogical theories have been penetrated: Threshold concepts (related to research question 1); and Pedagogical content knowledge (related to research question 2). The reason for selecting these topics is that I did find them interesting and relevant after having repeatedly come across them in the literature during PhD courses, pedagogical development courses, and reading of literature on higher education.

For each of these topics, literature was found using the same methods. First, Google Scholar was used to find articles having the topic in the title. By scanning the abstracts, around 10 relevant and much cited articles in each topic were selected. Some additional papers were found by reading abstracts from the most recent articles (not yet frequently cited, and therefore not on top of Google Scholar's relevance list). Using a snowball strategy, the reading rendered yet some additional articles. All in all, about 35 papers about pedagogical content knowledge were read, and about 25 about threshold concepts.

By reading the articles, categories were gradually developed, which were used for sorting out information on these topics. A simple kind of concept maps was used to give structure to this categorization, as recommended by Veal (2005). The categories had to be revised a couple of times in an iterative manner, before the final categorization was made. All articles were then revisited in order to find all relevant input connected to each chosen category. Such a repeated analysis is recommended be e.g. Merriam (1998) in the process of categorization.

#### **Application of educational theories on logistics education**

The theories on pedagogical content knowledge and threshold concepts were applied on logistics education with help from a number of cases, matching the cases' content with the topic categories (the ones described in the previous section). This procedure is a

kind of pattern matching, which Yin (2009) describes as relating empirically based patterns with a predicted one. Here, the major part of the empiric material was taken from published articles, e.g. cases where I don't have insight in the background material.

The big number of cases was found in the articles reviewed in Paper 1. However, only a small number of these were relevant to match against the topics generated from theory, but these were possible to use as illustrating examples throughout the analyses and discussions in chapter 4 and 5. Paper 2 provided an example of an important logistics skill, discussed in chapter 4, while the case from Paper 3 proved to be a valuable illustration for several of the discussions in both chapter 4 and 5. Being able to use the same case repeatedly helps creating a natural connection between different sections in the thesis.

Concerning the Paper 3 case, more information has been used than is reported in Paper 3. The reason for this is that in the project report (Paper 3), focus is on a certain topic, while focus in the thesis is somewhat different. Since this case concerns the logistics education at my home university, and the teachers involved are my colleagues, I possess more information than is written in the project report. The extra information was added to give richer illustrations of the case, and has the character of background facts and information, i.e. not being controversial or questionable as such.

In addition, another case where I have participated has been used as a source of information. It is presented in a conference paper, referred to in the text, but not included as a separate paper in the thesis. The reason for this is that due to the iterative and explorative process of connecting the theory with logistics education, it wasn't until late in the process that I discovered the usefulness of this specific case.

In the discussion about core knowledge (section 4.3) and threshold concepts in logistics (section 4.4) I have chosen to add some of my personal experience of teaching logistics. This was done in order to add more illustrations to the discussion, and the personal experience is not to be seen as 'evidence'. Throughout the text, it is clearly stated what is my personal experience.

## **2.2 Comments on the credibility of the study**

In this section, the credibility, or trustworthiness, of the study is commented upon. Several authors, e.g. Bryman and Bell (2007), Merriam (1998), and Yin (2009), agree that the traditional measures of validity and reliability cannot directly be applied on qualitative studies. Since quality seldom is easily measurable in qualitative studies, these authors stress the need for the researcher to clearly describe the research process, choices made, standpoints taken etc. in order to give the reader the possibility to evaluate. Some alternative quality measures have been suggested, see e.g. Bryman and Bell (2007), and different interpretations of validity and reliability have been made to

make them better match qualitative studies (Merriam, 1998; Cohen et al., 2011; Yin, 2009). In this section, the traditional measures are used as a framework for discussions, following the categorization by Merriam (1998) in Internal validity; External validity; and Reliability.

### **2.2.1 Internal validity**

Internal validity basically refers to whether the results reflect reality. A general problem in qualitative research is that it is (close to) impossible to make exact representations of reality. The researcher has to interpret reality to gain understanding, and to make sense out of the data collected (Ghauri and Grønhaug, 2005; Merriam, 1998). Interpretations may therefore obscure the internal validity. Another important aspect is the matter of the researcher's objectivity. Bryman and Bell (2007) mention personal values and theoretical standpoints as examples of aspects that may (but should not) color an investigation. Researcher bias is brought up by e.g. Cohen et al. (2011), who for example address the risk of 'illusory confirmation', which is the tendency of finding relationships even if they don't exist. This could be the case if the researcher is not able to take an objective stance, but let the desired outcome affect what is discovered. Another aspect on internal validity mentioned by Cohen et al. (2011) is 'reactivity', which addresses the possibility that the researcher affects the case studied. For example, the pure presence of the researcher may affect the behavior of the persons studied. In the following, some comments are made regarding the internal validity in this thesis.

#### **Interpretation**

All data used in this thesis has one way or another been interpreted by me. That goes for observations and interviews in Paper 3, and for survey data in Paper 2 and 3. It also concerns all literature I've read connected to the thesis. Of special concern is the literature about logistics education in Paper 1. These articles are predominantly reports on surveys and case studies. Since all research, according to the discussion above, in some way is afflicted with interpretation, the authors of these articles have made interpretations. When reading these articles, I add another layer of interpretation, which means that there is an inevitable risk of some misunderstandings being built-in the categorization of articles in Paper 1, and the matching of articles to theoretical topics in the analysis in chapters 4 and 5. The use of literature, with its embedded interpretations, is however a standard source of information in research, and not unique to this study.

#### **Illusory confirmation - finding what you would like to find**

As Yin (2009) stresses, the researcher may see explanations and patterns even where evidence is weak. One measure that can be taken to avoid this is to document each case carefully before starting the analysis. Applied on this study, the literature review in Paper 1 was made with a general purpose of investigating the status of research about

logistics education. Each article included was documented with short descriptions on topic, findings etc. When revisited for the purpose of seeking for papers matching the theoretical categorization, these descriptions were used to select articles for closer examination. Since the articles were read and documented before the categorization took place, the risk for an all too positive interpretation of the articles was decreased. The same applies also to the cases from Paper 2 and 3, since these were also documented before the theoretical categorization was made. However, as I added complementary knowledge from the Paper 3-project, which was not reported in Paper 3, I might in that phase have been colored by pre-conceptions of expected findings.

### About researching one's own world

In the studies reported in Paper 2 and 3, the cases studied belong to the logistics education at Linköping University, which means that I have good insight in the cases, and therefore a high level of pre-understanding. This has advantages, since it makes it possible to gain access to more information than would otherwise have been possible. On the other hand, as e.g. Merriam (1998) discusses, being too familiar with a case, there is a risk for bias, in that the researcher can't keep up the objectivity. Especially in Paper 3, there was a risk for bias, since I possessed rather good knowledge of the studied teachers, their teaching styles, teaching material etc. before entering the study. This might have colored my impression during observations and interviews, even though I tried to keep an objective view.

### Reactivity - affecting the 'objects of study'

In the Paper 3 study, there is also a risk that I may have affected the teachers' behavior. When being observed, people might change the way they behave, causing the observed sequence to deviate from 'normality'. In this case, I had a triple role. Besides being an observing researcher, and a colleague, I was also in the position of Director of studies, and thereby being their superior<sup>1</sup>. Although this might have had effect on the teacher's behavior during the lectures, I don't consider this to have affected the result much. While my primary analysis considered to what extent the students did understand what was communicated during the lecture, this should not be affected by possible deviations from the teachers' 'normal behavior'.

---

<sup>1</sup> My position was not superior in a formal meaning, including staff liability, but in a practical sense, I had influential power concerning their job assignments etc.

### **2.2.2 External validity**

External validity refers to the possibility to generalize the results from the study to other contexts and situations. When qualitative research is concerned, generalizability in a traditional sense, meaning that a result is valid and true in other contexts is most often not applicable. However, results from specific cases can to some extent be transferrable to other cases. Transferability is the term used by Bryman and Bell (2007) to describe the usefulness of the results in other contexts. They recommend authors to include so called 'thick descriptions' describing the context well enough to make it possible for the reader to make their own evaluations of the transferability to their specific contexts.

The aim of this thesis is not to generate conclusions that are generally true for logistics higher education. The intention is to give suggestions that are based in theory and existing cases that may serve as an inspiration for further research, and for development of logistics education. The methods used, however, may well be able to transfer to other cases. Concerning the literature review in Paper 1, the categorization of articles is not logistics-specific, and therefore generically applicable to principally any subject. The student survey in Paper 2, concerning their understanding of the components in the tentative framework, is possible to use in any student group having been involved with investigations of a similar kind as the one described in the paper. Finally, the observation, interview and survey used in Paper 3 can be applied to any course where total cost analysis is covered.

### **2.2.3 Reliability**

A distinction is made between two kinds of reliability. External reliability refers to the possibility to replicate a study, while internal reliability addresses whether the different researchers involved agree upon interpretations etc. (LeCompte and Goetz, 1982).

Replication of a study is relevant regarding literature search procedures, which is addressed in the method descriptions in Paper 1. As discussed in the previous section, several of the methods in Paper 2 and 3 are also possible to use in the same manner in other contexts. An exact replication of the study is not possible though, because the same pre-conditions regarding students and teachers can never be re-created.

What is still to be mentioned concerns the internal reliability. Kitchenham and Charters (2007) and Denyer and Tranfield (2009) recommend that literature reviews are conducted by a team of researchers, in order to enable discussions concerning interpretation of content, categorization etc. As I was the single researcher of this study, such inter-rater comparisons were not possible. However, Kitchenham and Charters (2007), state that in 'mapping studies', where the aim is to get a first understanding of an area, a single researcher study is acceptable. Since my purpose was to explore the field of literature about logistics education, my study falls rather into the mapping study category.





## 3 Entering the pedagogical world

The purpose of this thesis is to contribute to the knowledge on teaching and learning logistics in higher education. To be able to discuss logistics education, it is essential to be acquainted with a number of relevant terms and aspects related to teaching and learning. In this chapter, a theoretical basis is established, which will support the discussions in the subsequent parts of the thesis.

After an introductory terminological discussion, *main pedagogical questions* are presented, together with the basic *pedagogical triangle* model. Since education embraces the interrelation between teaching and learning, theories about *alignment between teaching and learning* are presented.

The research questions are directed towards investigating what logistics knowledge and skills that are important to learn, and how students' learning of these skills can be supported. Two important themes in pedagogical literature with strong connection to these questions are threshold concepts and pedagogical content knowledge. In the theory of *pedagogical content knowledge*, the content, or subject-matter, is viewed from a pedagogical perspective. Thereafter, *threshold concepts* are discussed, referring to those specific aspects that are crucial for learning the essentials of a subject.

In general, the content presented in these sections is applicable in different contexts, but some notations with specific bearing on higher education are made. In the concluding section in this chapter, pedagogical issues of specific interest for higher education are discussed.

### 3.1 Didactics vs. pedagogy – what's the difference?

Terminology within the pedagogical field is not an open-and-shut case. Rather, there is room for interpretation. This chapter aims to give a short background and declare the terminological standpoint in this thesis.

The terms pedagogy and didactics both have their origins in the ancient Greek culture, where it was a strong distinction between the two. The task of pedagogues was to accompany boys through their childhood and give them a proper moral upbringing, helping them to become men, while didactics was associated with teaching specific subjects (Smith, 2012).

Didactics has over the years developed in more than one direction. Håkansson and Sundberg (2012) discuss a dividing line between the 'Continental' tradition (dominated by Germany and the Scandinavian countries) and the 'Anglo-Saxon' (dominated by Great Britain and the U.S.). In the continental tradition, didactics embraces a rather

broad spectrum of aspects concerning how to organise and perform education in order to bring about an optimal learning situation. The Anglo-Saxon use of didactics is narrower, focusing instructional methods used in teaching (Kansanen, 2009; Håkansson and Sundberg, 2012).

Pedagogy is often regarded as a rather broad field, with the suggested definition:

*“how individuals, groups, organizations and society is formed and developed, in other words how learning comes about”* (Bränberg et al., 2013) (p. 23, my translation).

This broad definition covers both upbringing of children, from infants to teenagers, as well as different aspects of teaching and learning in educational settings. However, Kansanen (2009) reports that in the Anglo-Saxon countries, the term pedagogy often refers to teaching and learning more specifically, which puts the Anglo-Saxon ‘pedagogy’ rather close to the continental ‘didactics’. Loughran (2013) on the other hand, states that in the Anglo-Saxon world, pedagogy is sometimes used more narrowly as a synonym for teaching. In the French-speaking world, didactics and pedagogy are used almost interchangeably, according to Bertrand and Houssaye (1999), but by different groups of researchers, where ‘didacticians’ and ‘pedagogists’ don’t want to be confused with each other.

The only thing that seems clear is the impossibility to use terminology in an undisputable way. The terms didactics and pedagogy may both be interpreted in different ways, partly depending on the tradition in which you are formed. In order to avoid confusion, in this thesis I have chosen to stick to one of the terms, and my choice has fallen on ‘pedagogy’. What I refer to when talking about pedagogy is teaching and learning issues for educational purposes.

## **3.2 Pedagogy - the science of teaching and learning**

Pedagogy was for a long time mostly associated with teaching. Knowledge was supposed to be transmitted to the students, and pedagogical questions circled around suitable ways for teachers to instruct the students. In the 1970s, pedagogical research interest arose concerning how students learn (Entwistle, 2009). The student, or learner, was put in the spotlight. The ‘discovery’ of the importance of learning has ever since had a great influence on pedagogical research and literature. Barr and Tagg (1995) writes about a paradigm shift from colleges as “...*institutions that exists to produce instruction*” to “...*institutions that exists to produce learning*”. The focus on learning does not mean that teaching should be seen as unimportant. Teaching and learning are interrelated, or as Loughran (2013) puts it: “*teaching influences learning and learning influences teaching*” (p. 122). Ramsden (2003) argues that there is a myth that teaching is not very important in higher education since the major part of the learning takes place

apart from formal classes. This stems from the conception that teaching is about instruction, rather than creating learning opportunities.

### 3.2.1 The pedagogical triangle

A commonly used model, showing how teaching, learning and subject-matter are inter-related, is the pedagogical (or didactical) triangle (Bertrand, 1994; Bränberg et al., 2013; Håkansson and Sundberg, 2012). Although some alternative denotations of the corners exist, the triangle basically shows that the subject-matter (or knowledge) is connected to the teacher (who possesses knowledge) and the student/learner (who is supposed to learn), and that there also is a direct relation between teacher and student. Momanu (2012) describes how Houssaye<sup>2</sup> connects the three corners with the terms teaching, learning and training. To further stress the interrelatedness between the three components, Bertrand and Houssaye (1999) added ‘pedagogical interactions’ in the midst of the triangle, as displayed in Figure 3. Other labels of this mid-space are ‘communication system’ (Bertrand, 1994), showing the importance of communication to learning, and ‘teaching resources’ (Tiberghien et al., 2009), highlighting the need for appropriate tools and vehicles for facilitating learning. Such resources are by Rezat and Sträßer (2012) called ‘artifacts’, and in their view not placed in the midst, but forming a fourth corner in a three-dimensional model.

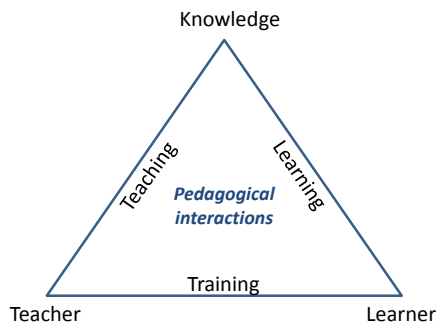


Figure 3: The pedagogical triangle (synthesis from Momanu (2012) and Bertrand and Houssaye (1999))

---

<sup>2</sup> Unfortunately written in French, which prevents me from using the original source. Those wishing to read it, are referred to Houssaye, J. (1993), “Le triangle pédagogique ou comment comprendre la situation pédagogique”, in *La pédagogie: une encyclopédie pour aujourd’hui*, E.S.F., Paris.

### 3.2.2 Three main pedagogical questions: Why? What? How?

Pettersen (2008), Bränberg et al. (2013), and others point out three main pedagogical questions as being generally relevant for educators: *why?* *what?* and *how?*

#### Why

The *why* question refers to the purpose of the education, asking why a subject or topic is important to learn. According to Pettersen (2008) there must be rational and articulated reasons for why the expected learning is considered important. These reasons can be directed towards fulfilling societal needs, as well as with individual development in focus (Ramsden, 2003). Higher education in Sweden is for example, according to Regeringskansliet (2014), supposed to contribute to e.g. the country's growth and welfare (societal perspective), and the students' critical thinking and problem solving ability (individual perspective).

#### What

The *what* question serves to specify what is to be learned in forms of explicit learning targets, thereby making the goal more concrete for teachers as well as students. What kind of competence that is to be learned can be expressed as subject-matter knowledge, as well as skills and abilities. Bränberg et al. (2013) divide the expected learning outcomes in three categories, describing what students are supposed to know, do, and be. They clarify this with help from the following examples (translation from pp. 28-29, my underlining):

*Know:* “After passing the course, the student shall know how filters, amplifiers and oscillators are constructed.”

*Do:* “After passing the course, the student shall be able to use knowledge gained in the course to specify, construct and realize electronic constructions...”

*Be:* “After passing the course, the student shall be able to perform a group-based development- and construction project under consideration of a creative and critical approach.”

The ‘do’ category represents what Ramsden (2003) refers to as a “less complex view of what learning consists of”, while the ‘be’ category implies a more “relativistic, complex and systematic view of knowledge”.

#### How

The *how* question deals with pedagogical strategies and methods, with the aim to arrange and conduct the education in a way that enables the students to achieve the expected learning objectives (Pettersen, 2008). Included here is not only the teaching

and instruction, but also the matter of how to assess students learning. The distinction between strategies and methods is not clearly articulated, neither by him or by Ramsden (2003), and these terms are therefore used interchangeably in this thesis. Methods and strategies can be of a general character (e.g. using problem-based learning, PBL, as a basic educational principle) as well as more specific (e.g. choosing suitable ‘vignettes’<sup>3</sup> to address a certain learning target in a PBL setting).

In an example borrowed from Ramsden (2003), two science teachers’ are applying different ways of teaching the same topic, using the same textbook chapter. While Ms. Lane tries to cover all parts of the text in her questions to the pupils, Ms. Ramsey focuses a limited number, what she considers to be the key aspects. Ms. Ramsey’s strategy is according to Ramsden (2003) probably a better one, if a deeper understanding by the pupils is desirable. Entwistle (2009) gives examples of teaching that encourages students’ thinking and understanding. Such teaching includes e.g.: to exemplify ways of thinking; to emphasize critical features; and to encourage discussions.

### Interrelations between them

The why question is hard to separate from the what question. A certain amount of pre-understanding of the subject is needed to be able to express why this is to be learned (Bränberg et al., 2013). On a higher level, what to learn is therefore known before the purpose (the why) can be articulated. Or at least, the ‘why’ and the ‘high-level what’ are concurrently developed. Thereafter, what to be learned can be specified, as described above.

The what and the how questions are tightly interrelated. There are many ways of organizing learning situations, conducting teaching, evaluating student performance etc. Although many of these methods and strategies can be discussed on a general level, the choice of appropriate methods is context-dependent. First when you know what is to be learned (together with other contextual factors) the question on ‘how’ becomes concrete.

The relation between these questions, and the interaction between teaching and learning, has been addressed in the literature. Some theories of such alignment will now be described.

---

<sup>3</sup> A vignette is a short introduction, describing a specific case or situation, and pointing out the specific problem(s) and question(s) the students are about to tackle, see e.g. Schoenberg and Ravidal (2000).

### 3.3 Constructive alignment

Based on the pedagogical triangle, Pettersen (2008) discusses some relational aspects that explains the important interplay between the actors and the content. In Figure 4, these relational aspects are included in the triangle model. The teacher applies certain strategies and methods to teach the subject, in order to make the desired knowledge learnable for the students. The students apply working methods and use learning strategies in their attempts to learn what they consider to be the important knowledge. By the assessment, the teacher is examining to what extent students have gained the desired knowledge. Pettersen (2008) argues that teaching methods cannot be chosen independent from what learning strategies students apply. Teaching styles can have effect on learning styles, and the other way around. Likewise, forms of assessment tend to affect how students take on learning, as well as they should be mirrored in the teaching. What is embedded here is a kind of alignment between teaching, learning and assessment activities.

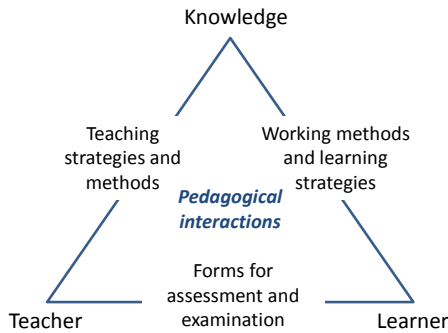


Figure 4: Pedagogical interactions - a relational model. Inspired by Pettersen (2008)

The close connection between teaching and learning is highlighted also by Biggs (2003). He introduces the term ‘constructive alignment’, where he describes the importance of tight bounds between the expected learning outcomes, the teaching and learning activities, and the assessment, as shown in Figure 5.

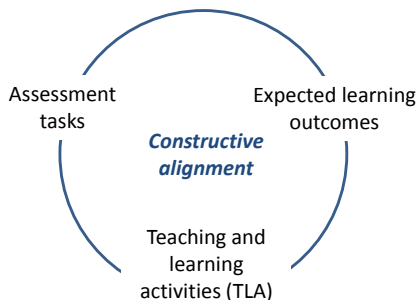


Figure 5: Constructive alignment

Biggs (2003) stresses that the expected learning outcomes must be carefully formulated, and that assessment and teaching should be based upon the expected learning outcomes. He further claims that students are very sensitive to the assessment forms applied. They choose learning approaches in order to live up to what is being asked for in the examinations. Therefore, the assessment must clearly ask students to show such understanding that is articulated in the expected learning outcomes. The assessment thereby directs the students into suitable learning approaches, which opens up for the use of corresponding teaching strategies.

These two models are rather similar, with a slightly different focus. The ‘expected learning outcomes’ in Biggs’ model, is an articulation of ‘Knowledge’ in Pettersen’s model. Biggs has chosen to treat teaching and learning as an integrated element instead of two separate ones, and consider pedagogical interactions to be central in the constructive alignment between the three elements in his model. Behind these different labeling, I find Biggs (2003) and Pettersen (2008) to have a united view on the principal ideas.

The intimate relation between teaching and learning, and between the main pedagogical questions, predominantly the what and the how, leads us in to the next session, which deals with pedagogical content knowledge.

### **3.4 Pedagogical content knowledge**

In a reaction to what he considered to be a lack of focus on subject-matter knowledge in teacher education, Shulman (1986) introduced the concept of pedagogical content knowledge. He argued that a teacher must have something more than just factual knowledge about a subject. To be able to teach the subject, he or she must also possess a specific content knowledge, enabling him/her to explain it to others. As Shulman (1986) expresses it:

*“... the ways of representing and formulating the subject that make it comprehensible to others.”* (p. 9)

This specific knowledge, labelled pedagogical content knowledge, PCK, relies on a thorough understanding of the subject-matter (content), but it also requires a certain amount of general pedagogic knowledge. PCK can therefore be seen as an intersection of content knowledge and pedagogical knowledge, as displayed in Figure 6.

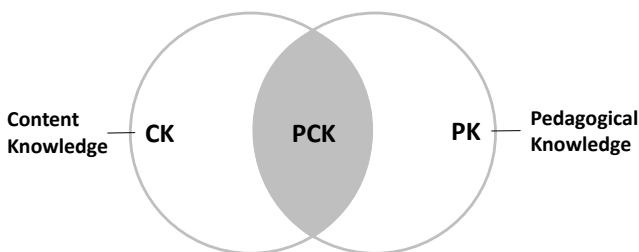


Figure 6: Pedagogical Content Knowledge, PCK

Veal and MaKinster (1999) argue that there are different levels of PCK, ranging from generic aspects for a whole discipline, to specific ones connected to certain topics, see Figure 7.

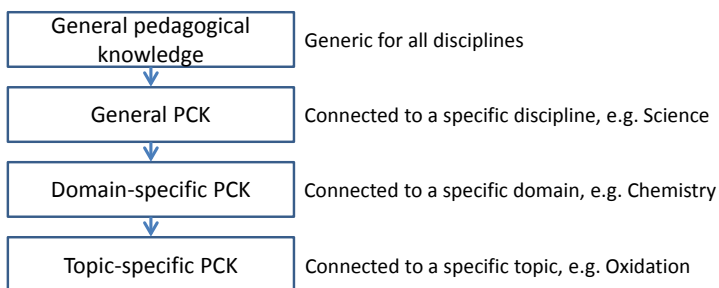


Figure 7: Levels of Pedagogical Content Knowledge

In the following sections, different components of PCK are described, followed by some thoughts about how PCK could be acquired and evaluated. Finally, critique against PCK is presented together with an account of in which disciplines PCK is discussed.

### 3.4.1 PCK components

In his subsequent work, Shulman (1987) specified what he considered to be the components PCK is composed of. Several authors, for example Fernandez-Balboa and Stiehl (1995), and Veal and MaKinster (1999) have over the years suggested additional components as well as debated whether specific components should be seen as belonging to or complementing PCK. The list of PCK components can therefore be more or less exhaustive. The components described in the following are a selection made to reflect the ones dominating the discussion in literature.

#### Content / subject-matter knowledge

Knowledge of the subject-matter is indisputably necessary. Shulman (1986) argues that a teacher must not only understand something as such, but also why this something is this way, why certain topics are central and others peripheral. This kind of under-



standing is central for the teacher's possibility to find ways for making knowledge accessible to the students. University teachers interviewed by Fernandez-Balboa and Stiehl (1995) highlighted that subject-matter is not static, but constantly evolving. This indicates that as time moves on, teachers must refresh and reconsider their subject-matter knowledge.

### Knowledge about instructional strategies

Instructional strategies comprise different methods, principles and strategies for facilitating learning. Included here are more directly instructional aspects, e.g. various delivery strategies, like lectures, tutoring etc. (Fernandez-Balboa and Stiehl, 1995) and classroom management (Shulman, 1987), as well as broader aspects, like motivational activities, creation of a learning environment, and organization of learning activities (Fernandez-Balboa and Stiehl, 1995). Connecting to something students can refer to is considered important. Alonzo et al. (2012) suggest the use of real-life examples, stressing that not only a variety in the examples as such are essential, but also a variety in the explanations of the examples. In line with the more general illustration of PCK levels by Veal and MaKinster (1999) in Figure 7, Goodnough (2006) and Park and Oliver (2008) say that instructional strategies can range from discipline-generic to topic-specific. They also, as does Shulman (1986), highlight that it is important for a teacher to have knowledge about instructional material, e.g. texts, software and laboratory demonstrations<sup>4</sup>.

### Knowledge about assessment

Goodnough (2006) and Park and Oliver (2008) argue that knowledge of assessment is an important component of PCK. Included here is knowledge about which aspects of students' learning that are important to assess, as well as which methods (instruments, activities etc.) that are appropriate to use to assess the learning outcomes.

### Curricular knowledge

Knowledge about the curricular context is needed for the teacher to make informed instructional choices, and relate the content of a given course to topics and issues handled in other courses. This refers to the 'vertical' curriculum (preceding and subsequent courses in the same subject area) as well as the 'horizontal' curriculum (courses that students are following in parallel). (Shulman, 1986; Goodnough, 2006; Park and Oliver, 2008).

---

<sup>4</sup> Instructional material is by these authors for some reason positioned under 'curricular knowledge'. I find it more appropriate, though, to connect it to the 'instructional strategies' component.

## Knowledge about students' understanding

Teaching should preferably be influenced by the student group. Depending on their characteristics and the kind of understanding the students bring into the learning situation, instructional strategies are to be accordingly adapted. Among the aspects to consider are their study motivation and interest for the subject (Park and Oliver, 2008; Fernandez-Balboa and Stiehl, 1995), their maturity and pre-knowledge in the subject (Goodnough, 2006; Fernandez-Balboa and Stiehl, 1995), and their general skills and abilities (Goodnough, 2006; Park and Oliver, 2008). Another aspect brought to the front by Goodnough (2006) and Park and Oliver (2008) is the learning styles or learning approaches students apply. Alonzo et al. (2012) stresses the importance of finding out what the students consider to be difficult, a notion they share with Fernandez-Balboa and Stiehl (1995) and Park and Oliver (2008).

In a study conducted by Fernandez-Balboa and Stiehl (1995), successful university teachers give voice for the value of spending time early in the course to get to know the students well. Among the activities they use are: asking students to write introduction letters; having them to fill in background sheets about themselves; and inviting each student for short conversations. They mean that this might be time-consuming, but still worthwhile in the end.

## Knowledge about the learning context

The students' background and understanding discussed above is a kind of contextual factor, but there are also other factors included in the learning context. Shulman (1987) mentions e.g. differences between cultures and communities, governance structures and funding of the education. These factors have influence on class sizes, resources to use on instructional material, and the amount on time that can be spent on different educational activities (Fernandez-Balboa and Stiehl, 1995). These authors also discuss that the amount of support from peers and administrators may differ. Another thing brought forward by them, which is specific for higher education, is that teachers' willingness to put effort in teaching is reduced by the fact that promotion largely depend on research merits.

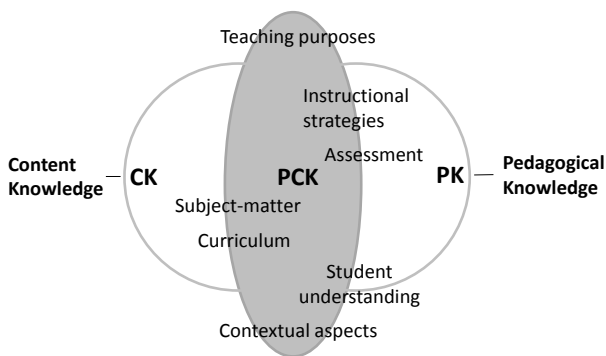
## Knowledge about one's teaching orientation and purposes

Teachers' orientation towards teaching is discussed by Park and Oliver (2008) and Goodnough (2006). They argue that the teachers' beliefs about their teaching purposes and goals are guiding their choice of instructional strategies and materials, and thereby influencing their PCK. Fernandez-Balboa and Stiehl (1995) report on university teachers who see a double purpose with their teaching. On the one hand, presenting the subject-matter in a way the students find relevant, meaningful and applicable, on the other, enhancing the well-being of their students. These teachers, who had received high

appreciation for their teaching efforts, considered the ‘bettering of their students’ lives’ to be equally, or even more important than the subject-matter itself.

### Putting the components together

The different kinds of knowledge presented above are considered to contribute to teachers’ pedagogical content knowledge, PCK. In the beginning of this section, PCK was described as an intersection between Content knowledge (CK) and Pedagogical knowledge (PK), see Figure 6. Some of the knowledge types described fits well in under the CK or the PK umbrella. Subject-matter knowledge is at the heart of CK, where curricular knowledge also seems to have an appropriate position. Knowledge about instructional strategies and assessment has its foundation in pedagogy, why these are regarded as parts of PK. Knowledge about students’ understanding includes aspects as learning styles, closely connected to PK, but also more contextual factors, like their prior knowledge and level of maturity, aspects that neither fit into the CK nor the PK area. The general knowledge about contextual aspects, as well as the knowledge about one’s teaching purposes, are also components not directly related to neither CK nor PK. In Figure 8 below, the different knowledge components have been given suggested positions in relation to content and pedagogical knowledge. The PCK area has been extended to illustrate that PCK includes aspects stemming from outside the CK and PK spheres.



*Figure 8: Components of Pedagogical Content Knowledge*

The discussion above shows that PCK is multi-faceted, which indicates that it takes time to develop PCK. The next session deals with the question of how teachers can acquire PCK.

### 3.4.2 How PCK can be acquired

Alonzo et al. (2012) support the idea that teachers may develop PCK starting either from a strong content knowledge base or from a strong pedagogical knowledge base. They claim that the mechanisms for how PCK is developed are not clear. In the literature, different aspects are suggested that contribute to the acquisition of PCK.

A proper knowledge of the subject-matter is by many authors, e.g. Kind (2009), seemed as a necessary prerequisite. Shulman (1987) talks about a '*scholarship in the subject*', by which he means a scientifically based knowledge. Such a scholarship is the standard starting point for most teachers in higher education, since their teaching career often depends on a research degree in the subject.

Another way to acquire PCK is via '*formal educational scholarship*' (Shulman, 1987). Unless occupied with teacher education, a pedagogical exam or research experience in the pedagogical field is not so common for teachers in higher education. A way for higher education institutions to deal with this is to arrange courses for developing teachers' pedagogical skills. Lindberg-Sand and Sonesson (2008) report on an increase of such courses in Europe, sometimes based on a strong national agenda, e.g. in Sweden and the UK, where academics are obliged to attend at least one pedagogical course (Lindberg-Sand and Sonesson, 2008; Kinchin and Miller, 2012).

Jang (2011) reports on a case where novice university teachers participated in so called 'PCK workshops', where they among other things were introduced to some theoretical PCK foundations, and did get support from an experienced teacher. Another example of strong institutional support is given by Major and Palmer (2006). They report on a major implementation of Problem-Based Learning, PBL, at a university in the US, requiring a change in pedagogical perspective from many of the teachers. The university offered specific courses for the teachers, as well as plenty of time to get acquainted with the new pedagogical form.

Loughran (2013) suggests that teachers are encouraged to work with '*CoRes*' and '*PaP-eRs*' to improve their thinking about teaching. A '*CoRe*' (Content Representation) is supposed to open up teachers' understandings of the particular subject by relating to questions such as 'Why is it important for students to know this?' or 'How does your knowledge about students' thinking influence your teaching about this?'. Kind (2009) argues that:

*"Training novice teachers in writing CoRes would prove valuable in helping develop their ability to reflect on practice and consider the 'real world' of a professional science teacher."* (p. 199)

A 'PaP-eR' (Pedagogical and Professional-experience Repertoire) is according to Loughran (2013):

*“...designed to purposefully unpack a teacher’s thinking about a particular aspect of PCK in that given content ... intended to represent the teacher’s reasoning; that is, the thinking and actions of a successful science teacher in teaching specific aspects of science content.”* (p. 128)

Although these authors exemplify with the teaching of science, nothing in their reasoning indicates that the concept of CoRes and PaP-eRs isn’t generally applicable on other disciplines.

Kind (2009) stresses the importance of classroom experience, and refers to studies showing significant changes in teachers PCK during the early parts of their careers. When being exposed to real teaching situations, teachers learn to take the students’ needs into account. The impact of students on the PCK development is discussed also by Park and Oliver (2008). They state that challenging questions from students are deepening and broadening teachers’ subject-matter knowledge. Another thing they highlight is that students’ responses (enjoyment, how they show learning, verbal and non-verbal signs etc.) affect how teachers decide to validate, modify and replace their instructional strategies. All these aspects can be summarized in what Shulman (1987) labels ‘*wisdom of practice*’.

If student responses are important to notice, so are also their non-responses. Fernandez-Balboa and Stiehl (1995) and Park and Oliver (2008) highlight that it’s essential to *learn from misunderstandings* that are preventing students from further understanding. If teachers discover such misconceptions they can search for ways to enlighten the students, and apply a proper sequencing of instructional activities (Alonzo et al., 2012). This is also addressed by Entwistle (2009):

*“... the teacher has to imagine what it is like not to understand, and then consider what steps are needed to help students achieve their own understanding.”* (p. 183)

The different aspects discussed above, contributing to a development of a teacher’s PCK, indicate that teachers both *receive* knowledge by learning from others, and *produce* new knowledge, in that they reflect upon the received knowledge in the light of their teaching practice and educational context. This reflection can take two forms, according to Park and Oliver (2008): reflection-in-action, where teachers unexpectedly encounter challenging teaching situations and have to respond to them immediately; and reflection-on-action, which is undertaken after completed teaching sessions. Both these kinds of reflection help teachers to produce a kind of pedagogical content knowledge relevant for their specific context.

Different ways for teachers' development of PCK has been described in this section. That development is possible is one thing, whether it really happens is another. Since PCK is considered an important kind of teacher competence, ways of evaluating their current state of PCK is needed, in order to identify needs for further development. This leads us to the next section, focusing methods for evaluation of teachers' PCK.

### **3.4.3 Evaluation of teachers' PCK**

The literature gives several examples of how to evaluate or measure teachers' PCK. In this section, some of them are presented in short.

Viiri (2003) reports on a study where first-year mechanics students at a Finnish university were given a number of questions. In their answers they were supposed to describe their reasoning behind the answer. Their engineering teachers were asked to describe their expectations on the students' answers, as well as their beliefs about the students' reasoning. When comparing the students' answers and the teachers' expectations, it turned out that the teachers could predict the students' answers quite well. When it comes to the students' reasoning, however, it was clear that the teachers generally were unaware of the reasoning patterns of their students. To connect to the previous sections, they were missing some knowledge about student misconceptions. The method described by Viiri (2003) brought these misconceptions to the front, and made possible for the teachers to improve their understanding of the content from a pedagogical perspective.

In a study at secondary school level in Germany, Alonzo et al. (2012) were shooting videos of Physics classes. The teachers' use of content in interaction with the students was analyzed and categorized. The differences between the teachers' classes could then be compared in the light of the study results of the students in the respective class. As the study was rather small, the result as such should be taken with caution, but the method of video analysis might well be valuable for evaluating teachers' PCK.

By letting students fill in a questionnaire, Jang (2011) captured college students' perceptions on their teachers' performance. By analyzing the answers statistically (Likert-scale questions) and qualitatively (open-ended questions), Jang (2011) could form an opinion on the teachers' PCK. The questionnaire was built on four categories, namely: Subject-matter knowledge (whether the subject-matter is comprehensively demonstrated); Instructional representation and strategies (the use of analogies, metaphors, examples etc.); Instructional objects and context (teacher attitudes, curricular knowledge, classroom management etc.); and Knowledge of students' understanding (to what extent this is evaluated by the teacher). It can be noted that many of the PCK components described in section 3.4.1 are included in these four categories.

In their study on math teachers' PCK, Buschang et al. (2012) used several evaluation tools. Two kinds of 'concept maps' were applied to evaluate certain aspects of PCK; a

multiple-choice test was used to check other PCK aspects, and a ‘student response analysis’ task for some other aspects. The authors conclude that since PCK is such a complex kind of knowledge, single evaluation tools cannot capture enough information. They recommend the use of a battery of well-developed tests.

To conclude the PCK section, some short notes are given on areas where PCK is being used, followed by a discussion of some critique towards the PCK concept.

#### **3.4.4 Areas where PCK is applied**

The literature on pedagogical content knowledge reveals that this concept is predominantly discussed related to primary and secondary school teaching. Specific studies have been made directed to certain school subjects, for example in mathematics (Groth et al., 2009; Buschang et al., 2012; Niess, 2013) and science (Goodnough, 2006; Alonzo et al., 2012; Settlage, 2013). Other studies address teacher education more generally, e.g. Fransson and Holmberg (2012).

When teaching in higher education in general is concerned (not directed to teacher education), the literature is more limited. Science seems to be the dominating subject here, see e.g. Jang (2011), but studies are found also in other areas, for example mechanical engineering (Viiri, 2003) and industrial design (Phillips et al., 2009).

#### **3.4.5 Some critical voices**

Even though PCK is an influential field in the pedagogic literature, some critical words have been raised towards the PCK concept. Kind (2009) writes, with reference to a number of authors, that the distinction between PCK and CK (content knowledge) is unclear. My own impression is that this critique is fair. PCK is by most authors regarded as built upon CK and PK (pedagogical knowledge), i.e. CK is *influencing* PCK. On the other hand, CK is often mentioned as being *a component of* PCK. Segall (2004) argues that is doubtful to say that PCK is in the intersection between CK and PK, since CK in itself already has pedagogical attributes embedded, which have to be addressed.

A number of critical aspects are risen by Settlage (2013), among them the unclear relationship between CK and PCK. He also claims that PCK suffers from a proper underpinning in research. Moreover, he argues, within the PCK framework, learning is regarded as ‘transmission and absorption of information’.

According to Kansanen (2009), PCK is nothing new. When Shulman introduced the concept in 1986, these aspects were already dealt with in the ‘Continental tradition’ (as opposed to the Anglo-Saxon), under the label ‘subject-specific didactics’. Kansanen (2009) finds it surprising that PCK has gained so much interest, without acknowledging the existence of the European research in this closely related field.

### **3.4.6 PCK – some concluding words**

In the previous sections, PCK and its components have been described, followed by notes on how to develop and evaluate teachers' PCK. A high level of PCK gives teachers better possibilities to create educational settings that facilitate students' learning. This means that PCK is strongly connected to the second research question (how to support students' learning). But an important part of PCK is the emphasis on knowing the subject-matter (as such, and from a pedagogical perspective), which creates a link between PCK and the first research question (what is important for students to learn). A central point in PCK is to keep students' understanding in focus. An aspect of this is to identify what students consider as being difficult to learn. Closely connected to this are so called threshold concepts, which is the topic of the next section.

## **3.5 Threshold concepts**

The term 'threshold concept' was introduced about a decade ago by Meyer and Land (2003), who give the following description:

*“A threshold concept can be considered as akin to a portal, opening up a new and previously inaccessible way of thinking about something. It represents a transformed way of understanding, or interpreting, or viewing something without which the learner cannot progress. ... This transformation may be sudden or it may be protracted over a considerable period of time, with the transition to understanding proving troublesome.” (p. 1)*

A central issue connected to threshold concepts, is the notion of 'liminality', a term that Meyer and Land (2005) explain stems from the Latin 'limen', meaning 'boundary or threshold'. In the threshold theory, liminality is used as described by Sandri (2013) as 'the process of transformation through engagement with a threshold concept'. This transformation is often considered troublesome. Cousin (2010) claims that learning involves 'the occupation of a liminal space during the process of mastery of a threshold concept' and compares it with the process of growing up:

*“It is an unstable space in which the learner may oscillate between old and emergent understandings, just as adolescents often move between adult-like and child-like responses to their transitional status.” (p. 3)*

After this introduction, the characteristics of threshold concepts will be further explained.

### **3.5.1 Characteristics of threshold concepts**

Meyer and Land (2003) distinguish between threshold concepts and so called 'core concepts'. They see a core concept as a 'building block' contributing to progressed



learning, which also applies for a threshold concept. However, while a core concept not necessarily leads to a qualitatively different view of a subject matter, this kind of transformative understanding is an essential characteristic of a threshold concept. Meyer and Land (2003) suggest five aspects that are characteristic for threshold concepts.

*Transformative* - As described above, passing a threshold leads to a significant shift in how a subject matter is viewed. A previously inaccessible way of thinking now becomes possible.

*Irreversible* – The change of perspective is unlikely to be forgotten. Once understood, the concept cannot become ‘not-understood’.

*Integrative* – A threshold concept exposes interrelations that were previously hidden. Aspects within the subject which up until now has been regarded as disparate are now seen in a new light, revealing the integrative connections between them.

*Bounded* – Threshold concepts may, but don’t have to, serve to define the border between different areas or disciplines. They are then bounded to specific disciplinary areas.

*Troublesome* – Students often have difficulties in overcoming the thresholds, because they are difficult, challenging and sometimes counter-initiative. They may even be regarded as absurd. Meyer and Land (2003) give an example from Mathematics, where understanding of ‘complex numbers’ are essential for conceptualization and solution of many types of problems. For a novice, though, complex numbers may be seen as absurd, since they include an abstract ‘imaginary part’ which cannot be represented in traditional mathematical ways.

The threshold concept framework has been developed over the years, and Baillie et al. (2013) report on three additional characteristics.

*Liminality* – as previously described, this refers to the unstable phase of acquiring a threshold concept. The liminality is thereby tightly related to the already described aspect of troublesomeness.

*Reconstitution* – This implies adopting a new way of understanding the world. Baillie et al. (2013) describe this as ‘a shift in learner subjectivity, a transfiguration of self, of identity’.

*Discourse* – A new way of thinking will often incorporate an enhanced use of language (natural, symbolic and artificial), reflecting the way things are thought about and articulated in the specific disciplinary discourse.

To make thresholds concepts a bit more tangible, some examples of such thresholds in different disciplines will now be presented.

### **3.5.2 Threshold concepts – some examples**

Meyer and Land (2003) give an example from Mathematics, which concerns the concept of ‘limit’, meaning that a value may come infinitely close to this limit, but never reach the limit. The concept of ‘limit’ is seen as a gateway, or threshold, for understanding for example differential calculus.

In Economics, Meyer and Land (2003) claim, ‘opportunity cost’ (‘the evaluation placed on the most highly valued of the rejected alternatives or opportunities’) is fundamental for understanding how to handle situations of choice between alternatives.

Tucker et al. (2014) present a compilation of threshold concepts reported in literature. Among the more concrete ones are: Market equilibrium (in the discipline of Economics); Atomic structure (Physics); Energy transfer (Biology), and Integrals (Mathematics).

While the examples mentioned so far are regarded as transformative, troublesome etc., according to the characteristics described in the previous section, they are rather limited in scope, focusing specific content knowledge aspects of a subject, like integrals in mathematics, or opportunity cost in economics. However, thresholds can be wider in scope, rather focusing more abstract skills, as the following examples will show.

Within sustainability education, learners are asked to engage with complex problems concerning e.g. climate change and social inequality. Such problems are often considered as seemingly unsolvable by students. According to Sandri (2013), applying a systems perspective is helpful for viewing sustainability problems in a more ‘solvable’ way. Systems thinking represents a different way of viewing the world, and works as a threshold for understanding complex sustainability issues.

Humphrey and Simpson (2012) describe that doctoral students often find it difficult to write academic texts, especially when these include qualitative analyses. It seems like the writing process in itself is a barrier, and that the students have to pass the threshold of ‘how to write about qualitative data’ in order to gain enough confidence to produce good academic texts.

During the last decades, there has been a general shift from teacher-centered to more learner-centered education, supported by a rather strong consensus in research. However, Kinchin and Miller (2012) report that many university teachers still have not adapted educational methods in line with student-centered education. Kinchin and Miller (2012) claim that a new way of thinking about education is needed, and that the process of adapting this new way of thinking is a threshold concept for the teachers’ possibility to change their concrete educational activities.

Some thresholds reported in literature regards development of personal skills rather than connected to a specific subject. Osmond et al. (2009) suggest that ‘the confidence to

challenge conventions' is a threshold for design students. Another example comes from healthcare education, where Tsang (2011) claims 'thinking as a healthcare professional' to be a threshold for achieving professionalism.

The descriptions above illustrate different kinds of thresholds. Some of them are rather narrow, focusing specific subject-matter knowledge, while others are broader, dealing with important subject-related skills, and yet others refer to personal skills. Most examples refer to threshold for students. The case describing a threshold for teachers might be considered a little 'out-of-bounds' in this context. However, this example highlights 'adoption of a new way of thinking' as a possible threshold, something that most likely might be a threshold also for students.

One might raise critical questions when considering some of the threshold concepts illustrated above. If we for example agree that systems thinking is important for understanding sustainability issues, it seems reasonable to ask what is needed to understand systems thinking. Could systems thinking in itself require the passing of a threshold? Likewise, are there thresholds to overcome in order to acquire a 'confidence to challenge'? The answer to these questions is that threshold concepts can exist on different levels. Meyer and Land (2005) point out that within a certain curriculum it might be necessary to pass through a series of threshold concepts to gain a proper understanding. Passing one threshold then opens up new landscapes, where new thresholds are to be found. Moreover, Entwistle (2009) explains that there are different kinds of thresholds. He distinguishes between basic, disciplinary and procedural thresholds. In early stages of a course or an educational program, students meet *basic* concepts, clarifying their thinking. Later on, *disciplinary* concepts are encountered, integrating several basic ones, thereby affecting the students' way of thinking. The *procedural* thresholds are bringing knowledge and thinking together, facilitating ways of practicing.

Having seen a number of examples of threshold concepts in various disciplines, one might wonder how these thresholds were defined or decided upon. It's now time to look at some methods that can be used to identify threshold concepts.

### **3.5.3 How threshold concepts can be identified**

Different methods are reported in literature on how to identify threshold concepts. Smith (2013) describes a case where thresholds in design education were identified. Students in the final stage of their education were interviewed regarding their experiences. The questions asked were rather broad, in order to encourage students' narratives about aspects that had facilitated as well as hindered their learning. The interviews were recorded and transcribed, and during the analysis, patterns and categories were formed in a structured manner. As an outcome of this process, some barriers for students' learning were identified, and classified as threshold concepts.

Entwistle (2009) suggests the use of ‘concept maps’, where individuals write down their conception on how different things are interrelated. He provides examples from economics and history to illustrate how these may look. Asking students to do this can provide insight in how they perceive a subject, which topics are seen as essential, difficult etc.

Since identification of threshold concepts is a complex task, Knight et al. (2014) argue that multiple methods should be used. They report on a case where thresholds in an undergraduate hydraulics course were investigated. Multiple methods and information sources were used. First, teachers were asked to construct concept maps, showing the interrelation between different course topics. The teachers then discussed their different ways of representing and conceptualizing the subject-matter, leading to a common identification of the major threshold concept (A) in the course. Second, students were asked to answer open-ended reflective questions regarding their learning behaviors and their conceptual understanding connected to their progress within the course. The analysis of the answers indicated that A was seen as troublesome by the students, but that students found another aspect (B) even more difficult. Third, a workshop was held with a number of students. Through concept mapping and discussions, B was still considered difficult and important, however not a threshold, since it was dependent on knowing A. Fourth, student examinations were analyzed. Multiple-regression analysis was performed to test correlations between the overall result on the exam, and specific concepts (among them A and B) asked for in specific short-answer questions. The analysis showed that the mastering of A was the most influential concept on the total result, and that A had much stronger influence than B. Only relying on one method, Knight et al. (2014) claim, may lead to a false view on what really is a threshold concept. In this case, using the students’ reflective answers only, B might have wrongly been identified as a threshold concept.

#### **3.5.4 Connections between threshold concepts and PCK**

To conclude the section on threshold concepts, let us return to the connection between threshold concepts and pedagogical content knowledge, PCK.

A central characteristic of threshold concepts is that they are considered troublesome and difficult to grasp. In one of the PCK components, ‘knowledge about students’ understanding’, the importance for teachers to understand what students find difficult is being stressed. Finding out the troublesome parts of a subject-matter, of which some might qualify as threshold concepts, is therefore essential for teachers. This might be done in several ways, e.g. in classrooms situations, or by structured inquiries, like the ones suggested above by Knight et al. (2014)

Using the illustration of PCK as being in the intersection between content knowledge and pedagogical knowledge, Zepke (2013) lifts up threshold concepts as an important

aspect on the ‘content side’. On the ‘pedagogical side’, he points out student engagement as a factor of major importance. He argues that:

*“PCK springs from a partnership of accessible and transforming content, engaging teaching and active learners”* (p. 104)

‘Transforming content’ implies threshold concepts, and making these ‘accessible’ certainly may be a challenging task for teachers. Getting the students ‘engaged’, Zepke (2013) means, will improve the possibilities of dealing with the kind of troublesome knowledge that thresholds concepts are.

### **3.5.5 Threshold concepts – some concluding words**

As described in this section, threshold concepts can take different forms, concrete or abstract, knowledge-oriented or skill-oriented. There are a number of aspects characterizing thresholds, where the basis is that a threshold is difficult to overcome, but once passed, opens up new ways of understanding. To identify which the threshold concepts are related to a certain subject is according to the literature not an easy task, though. Leaving the thresholds behind, a section on higher education will conclude this chapter.

## **3.6 Higher education specifics**

Much of what has been written in this chapter is generally valid, although some examples have been given from higher education. This last section will point out some aspects of certain relevance for higher education, the area in focus in this thesis.

Compared to lower stages of education, the *class sizes* may differ considerably. Fernandez-Balboa and Stiehl (1995) address that classes can be very small, reaching down to five students in specialized courses, and also very big, with over 100 students at the time. According to Biggs (2003), class sizes are generally increasing in higher education, much due to economic pressure. The size of classes may put some limitations on which instructional methods that are possible to use. For example, big classes may necessitate that a major part is done through lecturing, but especially when having big classes, lecturing poses challenges on the teacher to catch and keep students’ interest (Entwistle, 2009).

As higher education is voluntary, it is reasonable to expect that *students*, being there of free choice, are highly motivated and willing to learn. Moreover, they are grown-ups, and have gained a certain level of maturity (Fernandez-Balboa and Stiehl, 1995). However, Biggs (2003) notices that even if this generally is true, the variance of student maturity and ability has grown, in pace with a higher proportion of students entering higher education. This increases the importance for university teachers to understand various learning strategies, and be able to adopt a multitude of teaching strategies.

When *teachers in higher education* are concerned, it has already been mentioned in previous sections that they in most cases lack pedagogical education beyond those introductory courses compulsory at some higher education institutions. Biggs (2003) means that this is an institutional problem, because as long as teachers are promoted based on their research achievements, with very little regard to their teaching efforts, teachers are not likely to engage in pedagogical development.

## 4 What are students supposed to learn following a logistics education?

Addressing the first research question, this chapter will deal with the matter of what the important things to learn are, when studying logistics in higher education. According to the previous chapter, there are subject- or discipline-specific threshold concepts that students have to pass in order to grasp the important knowledge and skills in the subject or discipline. When it comes to logistics, which are the important knowledge and skills, and which are the threshold concepts? It can be revealed from the start that these questions do not have simple answers, since these matters have not really been penetrated in existing research. In this chapter, findings from a literature review will be presented, showing which logistics skills and knowledge are asked for in industry, which aspects logistics educational programs include, and which logistics skills and knowledge that are focused in research about logistics higher education. To see how the literature review was conducted, together with a more extensive presentation of the results, the reader is referred to Appendix 1, where Paper 1 - the literature review, is included in its entirety. When the findings from literature have been presented, a discussion will follow about how core knowledge and threshold concepts can be viewed within logistics education. First, however, since logistics is a rather broad subject with different interpretations, the chapter will start with declaring what is included in logistics in this thesis.

### 4.1 Logistics – what does it embrace?

As addressed in section 1.1.1, logistics is regarded as an important discipline from a business perspective as well as a societal. Logistics may be defined in different ways, which makes it appropriate to discuss what logistics is, how it refers to related disciplines, and how logistics is viewed in this thesis.

Jahre and Persson (2008) and Frankel et al. (2008) describe how logistics has developed over the years, from a cost focus to creation of competitive advantage; from being focused on functional areas within the company to the management of flows in external supply chains. Essentially, logistics concerns material flows and other activities supporting these flows. This is reflected in the frequently cited definition by the Council of Supply Chain Management Professionals, CSCMP:

*“Logistics management is that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flows and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements.”* (CSCMP, 2014)

Many of the major logistics textbooks agree with the CSCMP definition, e.g. Bowersox et al. (2013), Langley et al. (2008), and Grant et al. (2006). In this definition, the term logistics *management* is used, to stress that it's not the operational activities (e.g. truck driving, order picking, or order placement) that are in focus, but the planning, controlling and management of activities to make the logistics system function. It is also stated in the CSCMP definition that logistics is a part of supply chain management, SCM. That logistics encompasses supply chain activities is addressed by many researchers, e.g. Frankel et al. (2008) and Gligor and Holcomb (2012). Many logistics textbooks have chosen to include both logistics and SCM in the title, e.g. Bowersox et al. (2013), Mangan et al. (2012), Langley et al. (2008), and Jonsson (2008). Hence, logistics is closely related to SCM.

There are close connections between logistics and other related areas too. Frankel et al. (2008) relate logistics to operations management, marketing, and purchasing. Logistics is connected to operations management by e.g. issues like inventory control, materials planning, and supply of material to work stations. Connections to marketing are e.g. distribution of goods to customers, stock availability, and delivery precision. Regarding purchasing, important issues are inventory control and delivery service. On a more strategic level, logistics capabilities are important when selecting suppliers (Kumar and Kopitzke, 2008), and they may help creating competitive advantages towards customers (Esper et al., 2007).

In this thesis, the term logistics is used in accordance with the CSCMP definition of logistics management. Logistics activities may well be in the interface with other disciplines, such as purchasing, SCM or operations management, but these disciplines as such are not regarded as belonging to logistics.

## **4.2 Research concerning important logistics knowledge and skills**

In the research articles about higher education in logistics, the importance of logistics topics are shown in different ways. In this section, a division has been made between, on the one hand: skills and knowledge being expressed as important to have when entering logistics working positions at different levels; and on the other: skills and knowledge being focused in logistics education.

### **4.2.1 *The working profession perspective***

A number of investigations have been done concerning what kind of knowledge and skills that are desired in industry. For example, Parker et al. (2001) highlight the need for knowledge about specific statistical methods for analyzing logistics data; Canen and Canen (2001) point out that intercultural competence is important in international logistics settings; and skills for humanitarian logisticians are penetrated by Kovacs et al.



(2012). Although these are examples of studies focusing a specific knowledge or skill, the dominating kind of studies are of a broader kind, covering a number of skills and knowledge. This kind of studies are focused in the following.

An early study often referred to was performed by Murphy and Poist (1991). They formed the so called BLM framework, dividing skills and knowledge important for logisticians into three categories, Business, Logistics and Management (BLM). They repeated their study (Murphy and Poist, 2007) with slight modifications in the framework, and other researchers have since then used and modified the BLM framework (Thai, 2012; Thai et al., 2012) or used it as an influence for studies on the same matter (Rahman and Qing, 2014). The studies using the BLM framework conclude that general management skills and general business skills are higher ranked than logistics skills. Murphy and Poist (2007) conclude that:

*“The contemporary logistician should be a manager first, and a logistician second.”* (p. 430)

However, these studies have focused on knowledge and skills for logisticians in *managing* positions. For managers, skills and knowledge outside their immediate subject area can be expected to be of high importance, why the results are not so strange. But what about graduates coming from higher education? Unfortunately, there are few studies concerning desired knowledge and skills for logistics graduates entering the working life. It sounds reasonable though, that many of those having a logistics-focused higher education degree, in a few years will reach a management position at some level. General business and management skills may therefore be relevant to include in a logistics degree program. In this thesis, however, focus is on knowledge and skills more specifically related to *logistics*, why the general business and management skills are left aside from now on.

The different studies mentioned above have used slightly different methods. All of them have been using questionnaires for data collection, but Murphy and Poist (1991); (2007) directed their questions towards placement firms in the U.S., Thai (2012) and Thai et al. (2012) towards logistics managers in Australia and Singapore, and Rahman and Qing (2014) targeted students with working experience within logistics and at managing positions<sup>5</sup>. Despite these differences, a comparison between the top-ranked logistics knowledge and skills gives an indication of which knowledge and skills that are most important. In the comparison, displayed in Table 1, two more studies are included, since these are not limited to managerial job positions. Bourlakis et al. (2013) have examined jobs ads for logistics and supply chain management positions requiring a higher education degree in the UK, in order to see which knowledge and skills that was

---

<sup>5</sup> The students came from two universities. It is not clearly described in which countries, but according to the authors' affiliations, Australia and China are regarded.

considered most important. A similar study was performed in the U.S. by Sodhi et al. (2008).

Table 1: Logistics knowledge and skills considered important

Rank	Murphy and Poist (1991)	Murphy and Poist (2007)	Thai et al. (2012)	Thai (2012)	Rahman and Qing (2014)	Sodhi et al. (2008)	Bourlakis et al. (2013)
1	Customer service	Customer service	Customer service	Customer service	Inventory management	Inventory management	Transportation
2	Transportat. management	Inventory management	Logistics info. management	Contract management	Supply chain costing	Forecasting	Supplier management
3	Inventory control	Transport. management	Inventory management	Transport regulations	Distribution planning	Customer service	Inventory and forecasting
4	Warehousing	Logistics info. management	Integrated logistics	Transport management	Demand forecasting	Performance metrics	Global issues
5	Distribution	Warehousing management	Warehousing management	Logistics terminology	Warehousing	Transportation	Service & after sales support

As this compilation shows, customer service is top-ranked in four of the seven studies. Inventory management, transportation management, and warehousing management, are other frequent items on the top-five lists. What is common for most of the items in this list is that they are ‘high level’ aspects, pointing out *knowledge areas*, rather than specific knowledge and skills. With exception from Bourlakis et al. (2013), all studies used questionnaires to collect data, and all these questionnaires had pre-determined categories for the respondents to evaluate. Since these categories pointed out areas rather than specific topics, these studies could not deliver a picture of desired knowledge and skills on a more detailed level.

As mentioned previously, there is a certain overlap between logistics and supply chain management, SCM. There are many logistics issues that can, and sometimes should, be viewed from a supply chain perspective. Knowledge in SCM and/or supply chain thinking, is also something being mentioned as important by several authors, e.g. Murphy and Poist (2007); Sodhi et al. (2008), and Thai et al. (2012), however by most referred to as a general business knowledge, rather than a logistic-specific one.

The next section will discuss whether these areas of importance are reflected in logistics education.

#### 4.2.2 The educational perspective

One way to get a picture of what skills and knowledge that is included in logistics education is to study program and course content, and thereby get an overview of the most frequent topics. The frequency might be an indicator of the importance. Another way is to look at reports on specific educational cases. The topics covered there can be supposed to be considered important ones, since effort is laid down on reporting on them. Using the papers found in the literature review, both these ways have been used.

## Program content

During the last 10 years, there are a handful of studies providing an overview of the content in logistic-focused programs in higher education. Except from courses labelled ‘logistics’ or ‘supply chain management’ (which does not reveal the real content in focus), the most frequently reported logistics courses are within inventory management, transportation, customer service and warehousing (Sodhi et al., 2008; Bourlakis et al., 2013; Lutz and Birou, 2013). This corresponds well to the most desired knowledge and skills as reported in section 4.2.1 above. Since the studies reported are based on content analysis of program descriptions on websites or in curricular documents, the findings are on a rather general level.

Sauber et al. (2008) describe a case where a supply chain management program was designed on basis of more detailed intended learning outcomes. Among those learning outcomes listed, some more specific logistics-related knowledge ones are displayed in Table 2.

*Table 2: Examples of expected learning outcomes within logistics in an SCM program. Extract from Sauber et al. (2008), p. 384-385.*

<i>Inventory management</i>	“Know the differences between various inventory systems for independent and dependent demand items, and learn how to use them for managing inventory.”
<i>Transportation</i>	“Can identify the transportation needs for different goods and services.” “Understand the causes of uncertainty and variability in the transportation industry.”
<i>Warehousing</i>	“Be familiar with different types of material handling equipment.”
<i>Cross-topical</i>	“Understand the strategic and operational issues pertaining to location, warehouses, inventory, and transportation decisions.” “Learn how to use optimization models for warehousing and transportation.”

As the table shows, these learning outcomes reflect knowledge and skills on a more detailed level. Looking at more specific teaching cases, even more detailed information is sometimes provided, as will be seen in the next section.

## Teaching cases

More than 70 articles were found in the literature, addressing teaching and learning activities. Several areas and topics within logistics are covered in these articles, but the dominating topic is *logistics in a supply chain context*, dealt with in 30 of the articles. A number of different supply chain aspects are covered, and among those, ‘dynamics in supply chains’ is the most common, discussed by e.g. Kumar and Kropp (2006), Siddiqui et al. (2008), and Zeng and Johnson (2009). These dynamics are illustrated by the ‘bullwhip effect’, by e.g. Lee et al. (1997) described with help from a distribution channel with several actors, with a minimum of communication between them. The market demand is stable; each actor is keeping stock, and putting orders to the previous actor in the chain. When the market demand is changed, this will affect every actor in

the chain. Even small changes in demand will cause excess inventory levels as well as stock-outs, and the size of these problems will increase dramatically the further away from the market you are. The understanding of such ‘supply chain dynamics’ and how to counteract its negative effects, is considered important.

*Inventory management and control* is another topic frequently covered (12 articles), some from an overall perspective, others focusing some specific issue. Meyer and Bishop (2011), for example, specify a number of general aspects they consider important for the students to understand, for example: tradeoffs between holding costs and ordering costs; the effect of order quantity on these costs; ABC analysis connected to the value of stocked items. Weltman and Prater (2012) focus specifically on how re-order points can be calculated in the case of long lead-times.

*Transportation* is in focus in 5 articles, e.g. Zhu et al. (2011) and Cheong et al. (2012), and several other topics are covered, e.g. IT tools (Zhong and Huang, 2014), sustainability (Grantham and Cudney, 2011), and lean issues (Ozelkan et al., 2007). However, two of the areas identified above as being important skills in industry, customer service and warehousing, are not in focus in any of the articles about teaching and learning activities within higher education in logistics.

From the descriptions in this section, I conclude that there is a rather high correspondence between what is regarded as desired knowledge and skills at logistics working positions, what is covered in courses on logistics-focused programs in higher education, and what is in focus in teaching cases reported in research articles. However, the teaching cases are to a large extent very case-specific, without proper discussions provided concerning their general validity. When the program descriptions and job skills are concerned, these are on a very general level, not really specifying important logistics knowledge. Hence, research does not really point out what is to be considered as important logistics knowledge. In the following section in this chapter, a model will be suggested for how to position logistics knowledge and skills.

### **4.3 A tentative model for positioning logistics knowledge**

In this section, I discuss how logistics knowledge and skills can be divided into core and non-core, and suggest a model to support the structure of such a division. The model is formed with help from some examples, preceded by an introductory discussion.

#### **4.3.1 Knowledge areas and core knowledge**

Knowledge and skills can be regarded as more or less important, as well as be viewed on different hierarchical levels, from general to specific. Knowledge is hierarchical in the sense that knowledge on one level may contain knowledge on a lower level, a sub-level. In a language discipline for example, a high-level knowledge might be grammar,

which is built up from sub-level knowledge like e.g. ‘sentence construction’ and ‘plural form’. When the importance is concerned, Meyer and Land (2003) describe a ‘core concept’ as important knowledge within a field, contributing to progressed learning. If some knowledge qualifies as being core, there must also be some ‘non-core’ knowledge<sup>6</sup>. As pointed out in the previous section, many research articles on logistics education rather deal with more general ‘knowledge areas’. In Figure 9, the relation between knowledge areas, core and non-core knowledge is schematically displayed. A knowledge area contains different elements of knowledge on different levels. On each level, there might be core as well as non-core knowledge elements. Each of those elements (core as well as non-core) may have subordinated knowledge elements. Simplified this figure might be, it may serve as a starting point for discussing these aspects of knowledge and skills within logistics.

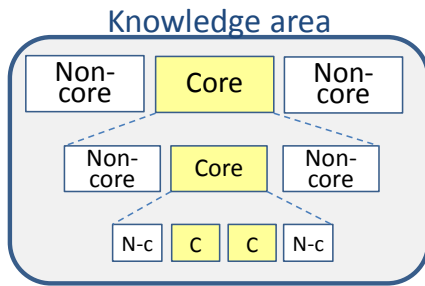


Figure 9: The relation between knowledge area, core knowledge and non-core knowledge.

Based on literature, as discussed in the previous sections, the knowledge areas within logistics may be: customer service, inventory management, transportation management, warehousing management, and supply chain logistics. Concerning core and non-core knowledge within logistics, it becomes more difficult. Some logistics topics that are highlighted in the teaching-oriented articles might be regarded as being core knowledge, while others rather would fit in the non-core category. The level of importance is however not discussed by the authors.

To proceed in the discussions about positioning logistics knowledge, we will now consider three examples. To start with, one of the proposed knowledge areas will be penetrated, namely inventory management.

---

<sup>6</sup> For practical reasons, I use ‘knowledge’ as the general label here. Implicitly, however, I also include skills under this label.

### 4.3.2 The example of inventory management

An important part of logistics management is to manage and control the inventory levels of raw material, components, finished goods etc. in different parts of the material flow. One of the central issues within inventory management concerns how much to order, see e.g. Waters (2003), Webster (2008) and Langley et al. (2008). There are other issues embraced by inventory management (e.g. which products to keep in stock, when to put orders, and how to protect against uncertainty), but the one highlighted above is sufficient for the discussion here.

Decisions about suitable order quantities require knowledge of different methods, and in which situations these methods are appropriate to use. The choice of method is dependent on various context-specific circumstances. Some methods are for example more suitable than others when the demand is unstable. The knowledge about such methods could therefore be seen as core knowledge within inventory management. But what is needed in order to understand these methods? An underlying concept in most (if not all) order quantity methods is total cost analysis. Different costs are affected by the order quantity, and to make a good decision, a trade-off has to be done between these costs in order to find the most economical solution. As an example, the widespread basic EOQ (Economic Order Quantity) formula produces an order quantity that minimizes the total of ordering costs and inventory carrying costs. Penetrating the inventory carrying cost, this reflects the cost of keeping products in stock. To facilitate the calculations for individual products, inventory carrying cost is represented by an inventory rate of interest, expressed as a percentage of the product value. Considering a case with steady demand and a fixed order quantity, the quantity stored will follow a saw tooth structure, as shown in Figure 10, together with the formula for calculating the inventory carrying cost connected to the order quantity.

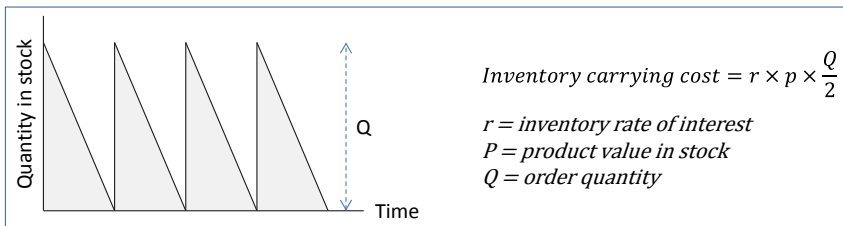


Figure 10: Inventory carrying cost under stable demand

The inventory rate of interest is basically built on two factors, the cost of tied-up capital, and the cost for risks associated to the storage. The risks concerned here are e.g. obsolescence, handling damages, theft, and fire. The risk factor is calculated by comparing a company's total yearly risk-related costs with the total average inventory level. The cost of tied-up capital is represented by the lost possibility of investing the money, hence a kind of opportunity cost.

Figure 11 displays the different ‘levels’ of knowledge connected to deciding an order quantity, as discussed above. Starting from the bottom, understanding the principle of *opportunity cost* could be seen as a prerequisite for understanding how the *inventory rate of interest* is constructed. Deciding the level of this rate of interest is necessary for calculating *inventory carrying costs*, which in turn is an essential factor in *total cost decisions* used in *methods for deciding appropriate order quantities*. All the knowledge elements mentioned here is important for understanding inventory management, so they might be considered as core knowledge. In the figure, some other knowledge elements, core and non-core, are symbolically displayed, illustrating that there are more elements included in inventory management than the ones discussed here.

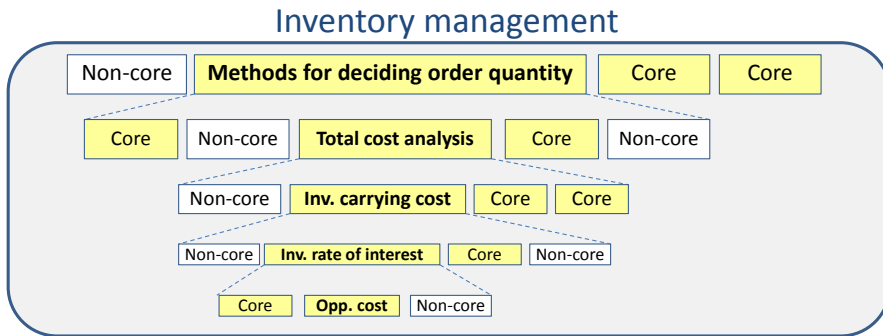


Figure 11: Examples of important knowledge in inventory management

As explained above, order quantity methods are based on total cost analysis, and therefore understanding of such analyses is essential. However, the use of total cost analysis is not restricted to inventory management. It is important in many other logistics applications too, which means that it is a kind of knowledge that doesn’t really fit in the hierarchical level suggested so far. Therefore, the next example will focus on total cost analysis.

### 4.3.3 The example of total cost analysis

Cost aspects are important in almost any logistical decision, e.g. when deciding upon an appropriate mode of transport; choosing location of a distribution center; or evaluating offers from transportation companies. An understanding of total cost analysis is therefore essential for a logistician. In most logistics textbooks, total cost analysis is described one way or another. One of the most cited total cost models was developed by Lambert (1975), pointing out five logistical cost categories, describing trade-offs between the different costs, and between the costs and customer service. Models in contemporary logistics textbooks are often based upon Lamberts model, however with some modifications. According to Oskarsson et al. (2013) it is important to adapt the cost model to the specific context, e.g. concerning which cost categories to include. Since it often is hard to acquire sufficient input data, calculations might be a bit shaky.

Therefore, these authors also recommend that the result is supplemented with some kind of sensitivity analysis.

In the literature review, no articles were found with total cost analysis explicitly in focus. There is however a number of teaching cases, where total cost analysis is being used as a part of an exercise. Tyworth and Grenoble (1991) describe a case where students are using Excel modules to practice total cost analysis. In the case by Merkurjev et al. (2011), total logistics costs for companies in a supply chain are considered, when changing the ordering routines between the companies. Ashenbaum (2008) describes an exercise where the students apply total cost calculations to decide which new market to penetrate with their products. Even though total cost analysis is treated in these cases, the importance of it is not penetrated, nor is the difficulties in making such analyses. However, since many logistics decisions depend on proper cost analyses being made, it is worthwhile examining total cost analysis from an educational perspective.

## Two teaching cases

In a recent project considering how much students are grasping of what is covered in lectures, a study was performed, focusing two lectures about total cost analysis, TCA. The project report, Paper 3, is included in this thesis, and can be found in Appendix 3. Some of the findings will briefly be presented in this section.

Two lectures on TCA were studied, given for two different groups of students by two different experienced teachers at Linköping University. In case 1, third-year students on the Business and Economics Program were taking a basic course in logistics, where TCA was covered as part of the introductory lecture. The lecturer didn't fully follow his intentions concerning the content of the lecture, as all important aspects were not mentioned as planned. The students were invited to active participation, by suggesting relevant cost categories. Some of these, but not all, were then commented upon by the teacher. Case 2 refers to a basic logistics course given to fourth-year students on the programs Industrial Engineering and Mechanical Engineering. In this case, the lecture was the third one in the course and dedicated to total cost analysis. The lecturer followed his intentions and covered all aspects as planned.

The two lectures were observed, and the teachers' intentions with the lectures were captured with help from interviews directly after each lecture. Immediately after the lecture, a questionnaire was handed out to the students, who answered a number of questions focusing their perception of TCA. Their answers were then analyzed concerning which essential parts of TCA they included in their answers, and how well these were described. There were some differences between the lectures, in how clearly the principles of TCA were presented. Not surprisingly, the students having attended the somewhat more 'loosely structured' lecture (case 1) showed a poorer understanding of the concept. However, even in case 2, where TCA was very clearly described, the



students' understanding was found to be rather low. For example, suggested cost components were well described by the majority, while only a minority described the underlying reasons for performing TCA, or pointed out the importance of adapting the model to different contexts<sup>7</sup>. In Figure 12, students' understanding of TCA is displayed for the two cases.

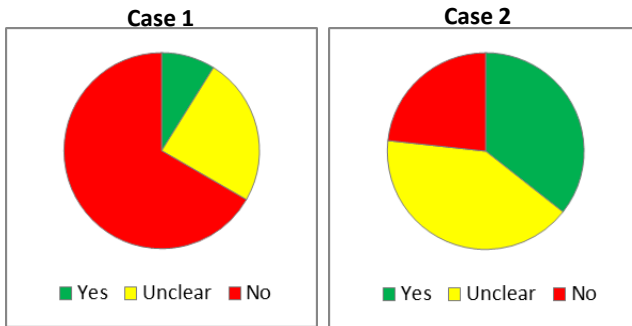


Figure 12: Students understanding of Total cost analysis in the two cases

Even though this was a small study, not aimed at providing statistical evidence, the results confirm that TCA is somewhat problematic to understand.

### Total cost analysis – a generic kind of logistics knowledge and skill

I argue that total cost analysis should be considered a core knowledge and skill within logistics, because of its importance in various kinds of logistics decision-making. *Knowledge* about how total cost analysis principally is performed, and about common cost factors is an important base. The ability to apply total cost analysis in different contexts, to adapt the model to varying preconditions, and to evaluate the reliability of the calculations, is an important *skill* needed to make practical use of total cost analysis. Since it cuts through a number of different knowledge areas of logistics, as shown in Figure 13, it can be considered to be a *generic* skill for the logistics discipline.

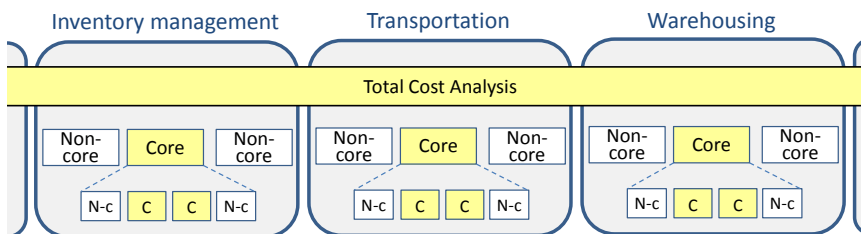


Figure 13: Total cost analysis - a generic core knowledge and skill within logistics.

<sup>7</sup> In the project report (appendix 3), possible reasons for this limited understanding are discussed.

Total cost analysis is an example of a generic kind of knowledge and skill within logistics. Another such generic kind of knowledge/skill is described in the next section.

#### **4.3.4 The example of structured investigation method**

Organizations are more or less constantly seeking to improve their performance. As mentioned in chapter 1, ‘constant change’ is more role than exception. Working with improvement and change projects is therefore an essential task for logisticians. Decisions about changing logistics processes, procedures, routines etc. should be based on proper investigations and evaluations. In Paper 2 (found in its entirety in Appendix 2), a conceptual framework for describing investigation methodology is proposed, which will be briefly discussed here.

##### A proposed framework

The framework consists of a number of components, schematically displayed in Table 3, together with short descriptions of the respective components.

*Table 3: Proposed framework for investigation methodology*

<b>Component</b>	<b>Description</b>
<i>Formulating the problem</i>	<ul style="list-style-type: none"> <li>– Discuss the problem</li> <li>– Decide purpose and investigation questions</li> <li>– Make delimitations, define what to be studied</li> </ul>
<i>Obtaining knowledge</i>	<ul style="list-style-type: none"> <li>– Use existing knowledge.</li> <li>– Search for information in a structured and thought-through manner</li> <li>– Make a good selection of available information</li> </ul>
<i>Proposing alternatives</i>	<ul style="list-style-type: none"> <li>– Generate alternative solutions/actions, well-grounded and possible to evaluate</li> </ul>
<i>Collecting data</i>	<ul style="list-style-type: none"> <li>– Collect needed data and information</li> <li>– Choose appropriate methods to do this</li> <li>– Document collected data</li> </ul>
<i>Analysing</i>	<ul style="list-style-type: none"> <li>– Evaluate the alternatives - compare them towards each other and the present situation</li> <li>– Illuminate consequences of the alternatives from different angles</li> </ul>
<i>Reviewing</i>	<ul style="list-style-type: none"> <li>– Critically evaluate the quality of the investigation</li> <li>– Review chosen working methods, data used, delimitations made etc.</li> </ul>
<i>Reporting</i>	<ul style="list-style-type: none"> <li>– Present - adapted to different audiences</li> <li>– Make possible for the audience to evaluate the investigation</li> <li>– Written reports and oral presentations</li> </ul>
<i>Overall planning</i>	<ul style="list-style-type: none"> <li>– Plan the investigation</li> <li>– Combine the other components in a way that suits the specific situation</li> </ul>

Two things should be noted here. First, ‘Overall planning’ differs from the other components, since it considers the totality of the framework, and regards how all the other components should be combined when planning and performing an investigation. Second, the order in which the first seven components are presented, is suggested to be logical, however not strict. The intention with the framework is not that they should be performed in this exact sequence. The components might overlap each other, and some might be repeated several times during an investigation.

### Structured investigation method – a generic logistics skill

The matter of conducting investigations in order to produce decision support is not brought up in any of the studies focusing desired skills for logisticians or logistics managers, neither as a specific logistics skill, nor as a general management or business skill. This does not necessarily mean that investigations lack importance. In the questionnaire studies reported in section 4.2.1, there were no categories covering ‘investigation method’ (or something with the same meaning). The respondents were therefore unable to give an opinion concerning the importance of this aspect.

From my own experience, in supervising over a hundred master level student projects aimed at providing decision support for improvement of the logistical processes in various organizations, I consider it very important that these investigations are performed in a structured manner. A thorough planning is a key to successful projects. Therefore, it qualifies as a core skill for logisticians. As in the case of total cost analysis, investigation method is not connected to any specific knowledge area within logistics. Rather it is a generic logistics skill.

### ***4.3.5 A model for visualizing logistics knowledge and skills***

In this chapter, knowledge and skills within logistics have been viewed in different ways. From the literature, general areas of desired knowledge and skills are identified. Inventory management, transportation management, warehousing management, customer service, and supply chain logistics, are pointed out as being the most important knowledge and skills.

When it comes to more specifically pointing out what should be regarded as core knowledge within logistics, the guidance from literature is weak. Surveys directed to logistics managers, placement firms etc. have not been designed to capture opinions on this level. This indicates a lack in existing research.

Three examples were used for discussing possible knowledge and skills within logistics. First, within the area of inventory management, ‘methods for deciding an appropriate order quantity’ was proposed as core knowledge. As subsets to this, ‘inventory carrying cost’, ‘inventory rate of interest’ and ‘opportunity cost’ were discussed as being core knowledge on different ‘levels’. Second, understanding of ‘total cost analysis’ was

considered to be core within logistics, however a generic one, not connected to any specific knowledge area. Third, ‘investigation method’ was suggested to be a core logistics skill, like total cost analysis generic, spanning over the whole spectrum of logistics knowledge areas. The last two examples are of specific importance in higher education where students are supposed to e.g. apply a critical view, and be able to choose appropriate methods in a conscious and independent manner.

Some aspects, like ‘inventory rate of interest’ and ‘opportunity cost’, have the character of subject-specific knowledge, and are closely related to what Bränberg et al. (2013) call the ‘know’-kind of learning outcomes. Others, like ‘total cost analysis’ and ‘investigation method’, can in line with the discussions above be considered as more generic subject-related skills, connected to the ‘do’- and ‘be’-kinds of learning outcomes (see section 3.2.2).

Since the suggestions here only scratch the surface, there is room for further research about what is to be considered as core knowledge and skills within logistics. The schematic picture in Figure 14 shows the aspects discussed here, together with indications of what is yet to be discovered. There might be other subject-generic skills than total cost analysis and investigation method. Most probably, there are some knowledge and skills that spans over more than one knowledge area, and there certainly are a number of knowledge and skills to be found within each specific knowledge area. Moreover, there are more knowledge areas to consider within logistics, than then the ones highest ranked in the studies referred to above.

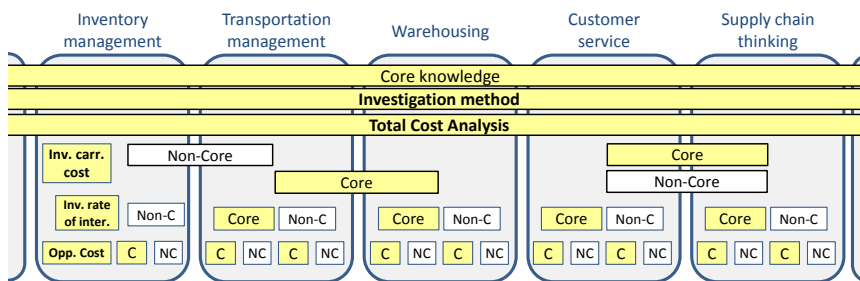


Figure 14: Core and non-core knowledge within logistics - a tentative model

As this figure indicates, there are a lot of ‘white spaces’ concerning which logistics knowledge and skills that are to be regarded as core (thereby important to cover in higher education), as well as non-core (which also may be relevant to include in the education). Research is needed on identifying important logistics skills and knowledge.

To identify core logistics knowledge and skills is an important task in order to form a good content in logistics education. Another thing that also should be identified is which the so called threshold concepts are, serving as major keys to understanding core knowledge and skills. Therefore, the next section will deal with threshold concepts within logistics.

## 4.4 Threshold concepts in logistics

In section 3.5.1, a distinction was made by Meyer and Land (2003) between core concepts and threshold concepts. Core concepts and threshold concepts are seen as important knowledge within a field, contributing to progressed learning. In addition, a threshold concept is transformative, representing knowledge that leads to a qualitatively different view of the subject-matter in focus. The different characteristics of threshold concepts were described in section 3.5.1, and are briefly presented in Table 4 below.

*Table 4: Threshold characteristics*

<b>Characteristic</b>	<b>Brief description</b>
<i>Transformative</i>	Leads to a significant shift in how a subject matter is viewed.
<i>Irreversible</i>	The change of perspective is unlikely to be forgotten.
<i>Integrative</i>	Revealing integrative connections between aspects within a subject.
<i>Bounded</i>	Defines the border between different areas or disciplines.
<i>Troublesome</i>	Difficult, challenging and sometimes counter-intuitive.
<i>Liminality</i>	Instability during the acquisition of a threshold concept.
<i>Reconstitution</i>	A new way of understanding the world, changing ones self-identity.
<i>Discourse</i>	Enhanced use of language, reflecting the specific disciplinary discourse

In the studied literature about logistics education, threshold concepts are never mentioned. It could of course be that ‘threshold-alike’ things are discussed in the articles, although the authors don’t use this expression<sup>8</sup>, but I don’t consider this to be the case. Threshold concepts within logistics are not discussed, neither explicitly, nor implicitly. To start a discussion about what could be considered as thresholds within logistics, the same examples as in the previous section (4.3) will be used, combined with my personal teaching experiences.

As the study by Knight et al. (2014) shows (see section 3.5.3), identifying threshold concepts is not an easy task. The ambition in the following is to come up with examples of aspects that qualify as possible thresholds within logistics. Since the examples below aren’t grounded in extensive data collection, there is not enough material to make an exhaustive analysis, taking all threshold characteristics into account. Focus will in the coming discussions will be on those characteristics that are more easily accessible for discussion, where ‘transformative’ and ‘troublesome’ are in the forefront, as they represent essential parts of the concept of thresholds.

---

<sup>8</sup> Since pedagogical references only to a very low degree are being used in the articles, threshold concepts may be an unknown term for many of the authors.

#### 4.4.1 The inventory management example

In section 4.3.2, some core knowledge and skills in inventory management were listed with focus on methods for deciding order quantity, see Figure 15.

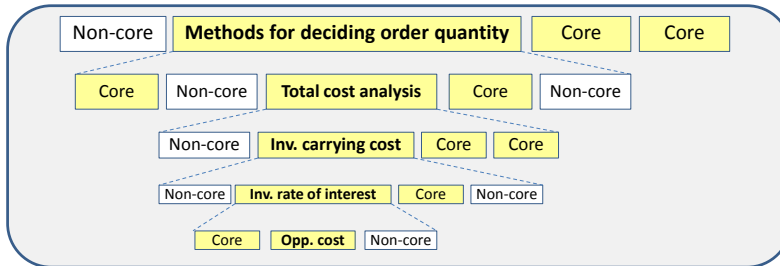


Figure 15: Examples of core knowledge within inventory management

As described in section 3.5.2, threshold concepts might be sequential, in that passing one threshold leads to another one (Meyer and Land, 2005). Hence, there is no formal obstacle against classing all of these knowledge elements as thresholds. Each one of the core elements will now be discussed from a threshold perspective.

#### Opportunity cost

Opportunity cost can be described as "the loss of potential gain from other alternatives when one alternative is chosen" (Wikipedia, 2014). As reported by Meyer and Land (2003), opportunity cost is found troublesome, and even regarded as a threshold concept for students within economics. While hard to see why it should differ between students in different disciplines, this reasonably applies also to logistics education.

#### Inventory rate of interest

Given that opportunity cost is understood, there are still some difficulties in grasping how the inventory rate of interest is constructed, and how a fair rate should be calculated. The opportunity cost reflects the cost of capital for keeping stock. The other major component in the inventory rate of interest is risk cost. The risk part of the inventory rate of interest is principally calculated by relating a company's actual risk costs with the total average inventory level. For the product(s) under investigation, this rate is then used to calculate the estimated yearly risk cost. I have noticed that this principle of using the (historical) risk costs to calculate the (predicted) risk costs does not really make sense for some students. They see it as a kind of cyclic reasoning, using A to calculate A. It seems like the distinction between actual/historical costs and estimated/predicted costs is not being self-evident.

The inventory rate of interest can be *troublesome* to understand. In a sense, it may lead to an *integration* of cost of capital/opportunity cost on the one hand, and more tangible risk costs on the other. Whether the understanding is *transformative*, significantly changing the learner's views, is however not clear. While transformation is central for a threshold, without further investigation it can't be concluded that the inventory rate of interest should be regarded as a threshold.

### Inventory carrying cost

When the previous aspects are understood, the calculation of inventory carrying costs is normally not a problem, but when applying this cost in a total cost perspective, a deeper understanding is necessary. As the cost of capital is an opportunity cost, it is an estimation of what interest we could have received on the capital, not having it tied up in stock. When presenting a reduced inventory carrying cost at a certain level as an effect of decreased inventory levels, this amount is a *potential* cost reduction, assumed that the released money will be used in a certain way, corresponding to the rate of interest used in the calculations. However, in an actual situation where inventory levels are decreased, tied-up capital will be available for investments, but not always actually used for this purpose. The real savings in inventory carrying costs is therefore dependent on how we choose to use the capital released. The 'looseness' in this cost post makes it more difficult to understand than most other costs involved in logistics decision-making, e.g. transportation cost and warehousing cost.

Because of this 'abstractness' of inventory carrying cost it is regarded as *troublesome*. It might be *transformative*, *integrative* etc., thereby qualifying as a threshold, but so far there is too little knowledge available to know whether this is the case.

### Total cost analysis

Total cost analysis is considered an important part when making inventory management decisions. It is important also in other logistics situations, and the next example is dedicated to total cost analysis.

#### **4.4.2 The total cost analysis example**

Total cost analysis, as described previously, is about taking all relevant cost factors in account, when making a logistics decision. Oskarsson et al. (2013) suggest a number of steps involved in a total cost analysis: identify the case-specific cost elements; estimate which of those that will have strongest impact on total cost; decide specific calculation methods and required input; collect necessary input data; conduct calculations.

Even though the principle of taking all relevant cost elements into account is rather easy to grasp, some of the steps involved can be difficult to conduct. However, this does not make the concept as such troublesome. Many times, though, I have faced students

having a hard time to understand that a total cost analysis must be adapted to the context, to the specific case. Students are often stuck in a belief that the textbook model, with its suggested cost elements, should be applied in a specific situation exactly as it is. They then feel frustrated when it's hard to fill some of the cost elements with something usable (which is not strange, because these cost elements should not have been included in the first place). It seems like one of the basic ideas with total cost analysis, the principle of case-specific adaptation, is *troublesome* to understand. I have also noticed students struggle with the understanding of this principle, when confronted with challenging questions from me as teacher or supervisor. This state might be compared to the notion of *liminality*, described by Cousin (2010) as "...an unstable space in which the learner may oscillate between old and emergent understandings..." (p. 3). Once having understood this, however, it seems to be self-evident for them to construct case-specific cost models when confronting a new decision situation. Their thinking seems to have *transformed*, and probably in an *irreversible* way, since it is unlikely that they should fall back to the old 'follow the textbook model' way of doing it.

The discussion above indicates that although total cost analysis in its entirety is not a threshold, the principle of case-specific adaptation of the total cost model might qualify as a threshold.

#### **4.4.3 The investigation method example**

As described in section 4.3.4, there are a number of important activities connected to performing logistics investigations in a structured manner. A thorough planning is regarded as a key activity for successful investigations.

Over the years, I have discovered that students have a hard time understanding how to plan and conduct an investigation in a proper way. When trying to grasp how this *troublesome* activity should be done, they are often ambiguous and feel frustration while struggling over how to proceed. This could be regarded as a state of *liminality*. Once they have grasped the idea, they tend to look back critically on what they have done previously. This is a sign of a *transformation*, indicating that a threshold has been passed, and might not be crossed again in the other direction (*irreversible*). The planning of investigations therefore qualifies as a possible threshold.

#### **4.4.4 Threshold concepts in logistics – a concluding discussion**

Some examples of core logistics knowledge have been examined considering their possible qualification of being thresholds. In addition to these examples, it is relevant here to address a threshold mentioned in literature in connection to education in another discipline. Within sustainability education, Sandri (2013) reports that 'systems thinking' is suggested as being a threshold concept. Systems thinking refers to the notion that different matters or components together form more complex systems. To understand



the system from a holistic perspective is important, in order to get a more complete view. The systems thinking perspective is regarded important also within logistics (Lindskog, 2012). The understanding of this kind of thinking is reasonably as difficult for logistics students as for those studying sustainability, why systems thinking most probably is a threshold within logistics.

In several of the teaching cases found in literature, understanding of dynamic effects in supply chains was highlighted as important. Even though this kind of understanding is not treated as a threshold concept in these articles, it might well qualify as one. There are several examples in literature showing that supply chain dynamics is *troublesome*, see e.g. Senge (2006). Whether fulfilling other threshold characteristics, such as the notion of *transformative*, is still to be investigated.

Linking to the notion in section 3.5.2 by Entwistle (2009), there are different types of threshold concepts: *basic* (clarifying students' ways of thinking), *disciplinary* (integrating basic thresholds, affecting the way of thinking), and *procedural* ones (bringing knowledge and thinking together, facilitating ways of practicing). As the previous sections show, there is unambiguity whether the different knowledge elements discussed are to be regarded as being logistics thresholds. Based on the discussions, notions on the 'threshold qualification' for the knowledge elements are displayed in Table 5, together with a positioning against the three threshold types suggested by Entwistle (2009).

Table 5: Threshold positioning of the knowledge elements

Knowledge element	Threshold qualification	Type of threshold
<i>Opportunity cost</i>	Strong, since being regarded a threshold in other disciplines	Basic, since it does not integrate underlying thresholds
<i>Inventory rate of interest</i>	Not so strong, while transformative aspects are not indicated	Basic, since it is clarifying, rather than affecting the way of thinking
<i>Case-specific adaptation of total cost model</i>	Strong, based on indications on transformative and irreversible	Disciplinary, while integrating several important aspects, and cutting through a number of different logistics knowledge areas
<i>Investigation planning</i>	Strong, based on indications on transformative and irreversible	Procedural, while it affects the way of practicing
<i>Systems thinking</i>	Strong, since being regarded a threshold in other disciplines	Disciplinary, while integrating several important aspects. Maybe even procedural, while affecting practicing
<i>Understanding supply chain dynamics</i>	Rather strong, but so far transformative not indicated	Disciplinary, while integrating several important aspects.

Since these findings are based on rather free discussions, they are to be seen as preliminary indications, serving as a basis for further discussion and investigation.

## **4.5 Core knowledge and thresholds within logistics – concluding thoughts**

Although there is research pointing out important general knowledge areas within logistics, existing research is vague about which specific knowledge and skills that is important to learn in higher logistics education, and non-existing concerning the thresholds for acquiring important logistics knowledge and skills. With help from a number of examples, as well as some years of experience from teaching logistics at university level, logistics knowledge has been discussed. As a result of this, some suggestions are given on what can be regarded as core knowledge, skills and thresholds within logistics, together with an illustrative model on how different knowledge can be positioned against each other on different levels. This is just a start though, and further studies are needed to gain better knowledge concerning these issues.

Some of the knowledge elements discussed have been argued to be logistics-generic, not limited to a specific knowledge area within logistics. In finishing this chapter, it feels appropriate to raise one's sight a bit further, and relate logistics to other disciplines. Systems thinking, as well as opportunity costs, are examples of knowledge elements reported as being thresholds in other disciplines. They are also relevant within logistics, as discussed in this chapter. This corresponds to Veal and MaKinster (1999) description of different levels of knowledge, ranging from topic-specific to general for all disciplines. While 'inventory rate of interest' and 'inventory carrying cost' can be considered as specific logistics knowledge, 'total cost analysis' and 'investigation planning', are applicable in a number of other disciplines. Some input to the discussions on core knowledge and thresholds within logistics might therefore be gained from studying other disciplines, while others are to be found by specifically focusing the logistics field.

After having focused the first research question, concerning 'what' to learn in higher education in logistics, the next chapter will address the 'how' to learn, i.e. the second research question.

# 5 How can students' learning about logistics be supported?

The second research question addresses the learning: 'How can students' learning of the important logistics skills and knowledge be supported'. The findings in the previous chapter reveal that it is not clear what is regarded as the important knowledge and skills to learn in logistics education. If the 'what' is not known, it is in a sense impossible to define the 'how', since the choice of instructional arrangements, teaching methods, assessment forms etc. is interrelated with the subject-matter about to be learned. Therefore, in this chapter an attempt is made to find some answers that can be of general use when planning logistics education. First, the concept of pedagogical content knowledge is revisited, and applied on a logistics educational case. Some interesting examples will then be presented of teaching cases reported in the literature on logistics education, leading to a discussion on appropriate instructional methods.

## 5.1 Pedagogical content knowledge vs. logistics education

The concept of *pedagogical content knowledge*, PCK, was presented in section 3.4. In short it refers to knowledge in the intersection between subject-matter knowledge and pedagogical knowledge. According to the PCK theory, introduced by Shulman (1986), a teacher must possess PCK that enables him or her to explain the subject-matter to the learners in an effective way. PCK is composed of seven knowledge components, displayed in Figure 16. The components are described in detail in section 3.4.1, and a brief description of the respective component included will be presented in the next section.

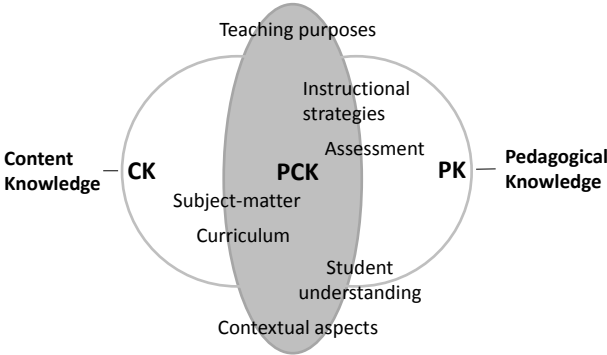


Figure 16: Components of pedagogical content knowledge

PCK is not mentioned in any of the articles studied in the literature review (Paper 1), which indicates that it is a non-familiar concept to a majority of logistics higher education teachers. Aspects of PCK are implicitly touched upon in several of these articles, though, and this will be addressed in the coming sections. First, however, we will return to the example previously described of two lectures on total cost analysis.

### **5.1.1 The case of total cost analysis**

To refresh the memory, two lectures covering total cost analysis were studied. They were given by two different teachers to two different groups of students. For more details, please visit Appendix 3 (Paper 3) for the full description, or go back to section 4.3.3 for a summary. In the following, references will be made to the two cases. Case 1 refers to the lecture for Business and Economics students, and case 2 to the one given to Engineering students. The teachers will accordingly be referred to as teacher 1 and teacher 2. The structure of the presentation is according to the different PCK components. A short description of the component will precede the discussion in each section.

#### **Subject-matter knowledge**

*A teacher must not only understand something as such, but also why this something is this way, why certain topics are central and others peripheral, and what aspects that in general are considered difficult by the students.*

The subject-matter in focus was the same in both cases. Both teachers have a deep knowledge about total cost analysis, TCA, and have been involved in many discussions about teaching the subject. Teacher 1 is also the co-writer of a textbook in logistics, in which TCA is an important theme, and where a chapter is dedicated to TCA. Teacher 2 has developed a teaching case with focus on TCA and its relation to customer service. I regard them both to have knowledge going beyond the subject ‘as such’, having a deeper understanding required according to PCK theory.

#### **Knowledge about instructional strategies**

*Methods, principles and strategies for facilitating learning. This includes more directly instructional aspects, like lectures, tutoring etc., as well as broader aspects, like motivational activities and organization of learning activities.*

Both teachers have long teaching experience. Teacher 1 has been teaching for about 30 years, with approximately 20 of them in higher education in logistics, while teacher 2 has some 10 years of experience in teaching logistics in higher education. They have both been involved in a lot of different kinds of instructional activities. Due to his longer experience and a teacher exam from university, teacher 1 has an even broader experience than teacher 2, and he has also acted as course planner and examiner for a

large number of courses, of different size, to different student groups, and with different focus regarding the content. Teacher 1 is therefore considered to have an even deeper knowledge about instructional strategies than teacher 2.

### Knowledge about assessment

*Which aspects of students' learning that are important to assess, as well as which methods that are appropriate to use to assess the learning outcomes.*

Assessment was not in focus in these lectures at the beginning of each course. However, both teachers were also examiners for the respective courses, and therefore with good insight in how TCA was about to be assessed. Since TCA was considered an important part of both courses, it was to be examined in group work during the courses as well as in the final written individual examinations. Both teachers are regarded to have good assessment knowledge.

### Curricular knowledge

*About preceding and subsequent courses in the subject area, as well as the different courses that students are following in parallel.*

In case 1, the course is given full-time, so the students don't take any courses in parallel. There are very few elective courses preceding this course. After this course, the students choose different major tracks, where no one is focused on logistics. Teacher 1 has only limited knowledge of the curriculum, and how other courses connect to this course.

Case 2 is different. The students belong to two different programs, Industrial engineering, and Mechanical engineering. Both groups have mostly faced compulsory courses so far, with a varying degree of logistics-related courses (i.e. within business economy and management). A majority of the students, but not all, will continue taking a number of logistics courses after this one. The engineering programs are organized in a way that students follow two other courses in parallel with this one. Some of these are compulsory, others elective; some are management-oriented, others technically focused; some are common for both programs, others not. This diverse picture makes it almost impossible to have a good grip of the curriculum. As a former student on one of the programs, teacher 2 has good insight in the preceding courses for this program, but a more limited for the other. Considering the subsequent and parallel courses, he has very good insight regarding the logistics courses, but limited or no insight into other courses.

## Knowledge about students' understanding

*Depending on their characteristics and the kind of understanding they bring into the learning situation, instructional strategies are to be accordingly adapted to the student characteristics, e.g. their study motivation, interest for the subject, maturity, pre-knowledge in the subject, and their general skills and abilities.*

This knowledge has connections to the previous one, since the curriculum affects the students' pre-understanding. In case 1, the student group is very homogeneous. Since the students follow two different programs in case 2, there are two homogeneous sub-groups with slight differences between them. Following from the curricular insights the teachers have, their knowledge on students' understanding on a collective level is somewhat limited.

When it comes to the individual students, the differences are probably even bigger. Both lectures were given at an early stage of the course. The teachers had not performed any kind of activity or test in order to get more information about the individuals. The knowledge about the students' understanding on an individual level is therefore non-existing for both teachers.

## Knowledge about the learning context

*Includes e.g. class sizes, resources to use on instructional material, amount on time that can be spent on different educational activities, and amount of support from peers and administrators.*

Class sizes and available resources are known by both teachers. The same goes for the possibilities for support, since they work in the same teaching group and thereby share both colleagues and administrator.

Two things differ contextually between the cases, though. First, the resources per student are significantly lower in case 1, due to policy decisions regarding funding of education in different scientific areas. This means that less contact hours between teacher and student is possible in case 1 compared to case 2, and that the course must be arranged so that a bigger proportion of the learning activities are made by the students themselves. Second, since the students in case 1 only follow one course at the time, the pace in the course has to be higher than in case 2. Teacher 1 is fully aware of this, after some years' experience from running this course. He sees both positive and negative aspects with this situation. On the one hand, the students are concentrated on one subject, and can focus 100 per cent on their logistics studies. On the other hand, since the course is compressed, it can be hard for students to find time for reflection. In summary, the concentrated schedule and the low level of funding puts big pressure on the teacher, in arranging for full-time work, without the possibility to put down that many teacher hours for support, coaching and continuous assessment.

## Knowledge about one's teaching orientation and purposes

*Teachers' beliefs about their teaching purposes and goals. Balance between focusing the subject-matter and on enhancing the students' well-being.*

This is the most abstract of the knowledge components, and therefore also the one hardest to examine. It regards the teachers' beliefs and ambitions, more or less independent of the courses they are teaching. I would say that both teachers have reflected rather much on their teaching, and what they want to achieve. While teacher 1 is somewhat clearer than teacher 2 in expressing his care for the students, teacher 2 articulates his subject-matter ambitions more clearly than teacher 1.

## Concluding remarks to the case

As the descriptions above show, even if there are some differences between the cases concerning student groups, curricula etc., there is a high level of similarity in the two teachers' 'knowledge level' within the different knowledge components. While being colleagues, belonging to the same educational environment, this is not that strange. The main point here is however not to value the two teachers against each other, but to try and describe these cases using the PCK terminology as a basis for the next section, where it will be discussed to what extent the PCK components are case-specific, and whether there are some aspects of PCK that can be of a more general interest for logistics education.

### **5.1.2 PCK components – how case-specific are they?**

In the previous section, the PCK components were discussed connected to a specific case. If some recommendations are to be given in the long run concerning logistics higher education in general, it has to be investigated to what extent these components are of a case-specific nature. In this section, the matter of 'case-specificity' of the PCK components will be discussed.

The *knowledge about one's teaching orientation and purposes* is something which does not depend on the specific case. This knowledge component rather refers to teachers' teaching orientation and purposes more generally. However, this PCK component differs from the others, since it concerns teachers' self-perception and personal attitudes. Focusing such issues is beyond the scope of this thesis, why it is left aside in the remaining discussions.

Knowledge about preceding, parallel and subsequent courses is important for decisions on content and instructional methods in a specific course. However, the curriculum is specific for each situation, why *curricular knowledge* is considered to be totally case-specific. The same goes for *knowledge about the learning context*, since class sizes, available resources etc. are specifically related to the specific situation.

*Knowledge about students' understanding* is related the specific students in the specific case (which partly depends on the preceding courses in the curriculum). What could be of general interest is whether there are methods for capturing information about the students. As previously reported (section 3.4.1), there are examples when university teachers in the beginning of a course let the students write introduction letters or fill in background sheets, and when the teachers have informal conversations with each student. Such activities could be used also within logistics education. The knowledge of different formats of background sheets, conversations etc. and their appropriateness in different educational settings might be valuable knowledge. An example of such a method with relevance for logistics will therefore be presented in section 5.2.

Which logistics aspects that are to be covered in a certain course, or a certain lecture, is of course dependent on the specific case, and in a sense *subject-matter knowledge* therefore is case-specific. However, an important part of subject-matter knowledge is to know which aspects of the subject that is important to learn, and therefore desirable to include in courses. This connects to the matter of core knowledge within logistics, which was discussed in section 4.3. Another essential part of subject-matter knowledge is the teacher's ability to make the subject-matter understandable for the student. This requires that the teacher understands what the students regard as difficult and problematic. Included in this is to be aware of the thresholds the students have to pass to acquire certain understanding, and how to act in order to facilitate the passing of these thresholds. Logistics-related thresholds were discussed in section 4.4. Hence, there are aspects of subject-matter knowledge of general interest for logistics teachers, concerning core logistics knowledge, and thresholds within logistics, aspects that have already been addressed in previous sections.

The two remaining PCK components, *knowledge about instructional strategies*, and *knowledge about assessment*, are of a more general kind. The methods for instruction and assessment that are applied should be well-suited to the specific case, but in order to choose appropriate methods, the teacher must possess knowledge about different methods. This will be penetrated more closely in section 5.3.

In this section, the seven PCK components have been discussed. Some are regarded to be case-specific, others of a more generic character, and yet others fit in both categories. Those PCK components that are of a generic character are of special interest here, since they support a general discussion on how to facilitate learning within logistics education. In Table 6, the discussion is summarized by commenting if the different components are regarded as case-specific or generic. References are given to the sections in the thesis where chosen components are addressed more specifically. Comments are included to clarify some of the marks. Note that a 'no' in the column 'case specific' does not mean that the component is irrelevant in a certain case. All components are influential when *applied* to a specific case the summary concerns, but the knowledge as such is not necessarily case-specific.



Table 6: PCK components being case-specific or generic

PCK Component	Case-specific	Generic	Section where this component is focused
<i>Knowledge about one's teaching orientation and purposes</i>	No	Yes, on a personal level	--
<i>Curricular knowledge</i>	Yes	No	--
<i>Knowledge about the learning context</i>	Yes	No	--
<i>Knowledge about students' understanding</i>	Yes	Yes, when considering ways of getting to know their previous understanding	5.2
<i>Subject-matter knowledge</i>	Yes	Yes, concerning core knowledge within the subject, as well as thresholds for acquiring core knowledge	4.3; 4.4
<i>Knowledge about instructional strategies</i>	No	Yes	5.3
<i>Knowledge about assessment</i>	No	Yes	5.3

In the next section, an example is given about a method for capturing knowledge about students pre-understanding of a topic. Thereafter, in section 5.3, methods for instruction and assessment will be discussed with help from some examples from the logistics education literature.

## 5.2 Capturing students pre-understanding – an example

In section 4.4.4, 'systems thinking' was identified as a knowledge/skill relevant for logistics. An example from systems thinking may therefore serve as an illustration of a 'skill-specific' test of students' understanding.

Booth Sweeney and Sterman (2000) developed the 'Systems Thinking Inventory', STI, which is a test consisting of a set of tasks designed to test individuals' understanding of some fundamental concepts of dynamics in a system: stock and flow structures, delays, and feedbacks. Although the test is not developed specifically for the purpose of logistics systems, these fundamental concepts are relevant also when studying logistics systems.

The applicability of the STI on logistics education was tested by Oskarsson and Lindskog (2010), who let a group of students on a Master level university course complete an STI test before playing the Beer Game, a well-known game illustrating dynamic behavior in a supply chain, manifested by the so called bullwhip effect (see e.g. Senge (2006) or Riemer (2010) for a description). After the Beer Game session, the students were asked to complete a reflection assignment, explaining the causes for the dynamic effects occurring during the game. Since for example Senge (2006) believes

that an understanding of such dynamic effects relies on a certain level of systems thinking, the students' scores on the STI test were compared with their explanations in the reflection assignment. The result showed a positive correlation between high STI results and high scores on the reflection assignment, thus indicating that the level of systems thinking has influence on the possibility to understand dynamic behavior in a logistics system.

To some extent, the STI scores predicted the students' level of understanding about supply chain dynamics. Knowledge about such pre-understanding is an aspect of PCK, which can be useful for teachers when planning teaching and learning activities in a course. Thus, the STI test might be a useful diagnostic testing tool for teachers to find out if there are students with a lower level of systems thinking, who then possibly need more support during the course.

Although being just an example, this illustrates that it's possible to test students' pre-understanding in a logistics educational setting, and thereby increasing the level of knowledge about students' understanding. Next, the remaining PCK components, connected to instruction and assessment, will be focused.

### **5.3 Methods for instruction and assessment**

There are numerous different methods available for instructing and assessing students. These can be arranged as belonging to different categories of teaching and learning methods that are presented in literature. Although traditional methods, like e.g. lectures, are appropriate in many situations, focus will here be directed towards methods that emphasize connections to realistic problems that can be met in practical working-life. The literature on logistics higher education clearly reveals that logistics is a discipline where education has strong emphasis on usefulness for the working-life. For example, as already reported in this thesis, several survey studies have addressed companies' desired knowledge and skills compared to existing logistics education. This section will start with a discussion about problem- and practice-based methods. Thereafter, some examples from the logistics education literature will be given to illustrate problem- and practice-based teaching and learning within logistics.

#### **5.3.1 Problem- and practice-based methods**

Pettersen (2008) discusses learning in connection to how the memory works. He argues that theoretical knowledge ('knowing what') is stored in the semantic memory and practical knowledge ('knowing how') in the episodic memory. If learning situations are created that stimulates both kinds of memory, the probability increases that theoretical knowledge is activated when later being confronted with similar practical situations. From Pettersen's thoughts it can be concluded that if education is aimed at providing knowledge and skills that are applicable in coming professional situations, the learning

situations are to be designed to reflect real-life situations. Pettersen (2008) uses the term ‘problem- and practice-based methods’ as a collective term for instructional methods suitable for creating this connection between education and real life. Within this umbrella term he includes case-based learning, project-based learning, and problem-based learning. The bearing point here is that students are supposed to be active, and that their activities and learning should be centered on exercises, problems and situations that reflect the practice where the knowledge and skills are used for real. Under the label ‘action learning’, Marsick and O’Neil (1999) highlight two important features. First, that students work on real problems where there is no one right answer; and second, that students engage in discussing their problems and progress during the learning process. There are a number of other labels to be found in literature on student-active and practice-based learning. For example, Ozelkan et al. (2007) talk about interactive learning, Thomchick (1997) uses the term collaborative learning, Neumann and Gerecke (2005) refer to active learning, while Sweeney et al. (2010) address experiential learning, and Zhong and Huang (2014) discuss learning-by-doing. While there are some differences between these different approaches, for the purpose of the discussion here, these distinctions are not crucial. No matter the specific labels used by the different authors, the cases presented below are examples of teaching and learning activities that fit under the umbrella label ‘problem- and practice-based methods’.

### **5.3.2 Examples from literature on logistics education**

In the literature review on logistics education (see Paper 1, Appendix 1), the biggest category of articles, 74 out of 163, is focusing teaching and learning activities, while only a small number, 5 articles, focus on assessment. In these 79 articles, various kinds of educational activities are described. Some topics covered in the literature are presented here as illustrations of methods of general interest for logistics teachers.

#### **Simulation / visualization tools**

The use of simulation and visualization provides learning opportunities about complex things in a simulated manner. Such tools can be used by students connected to various assignments, but also by teachers as demonstration tools. In the studied articles, several examples of education using such tools are described. A few of those will be briefly presented here.

A web-based tool for basic inventory control was developed by Meyer and Bishop (2011), to make some inventory concepts more tangible for students not yet familiar with inventory control. As a preparation for an introductory lecture about inventory control, the students are asked to run the simulation, which concerns placing replenishment orders for three different stock items, with the goal of minimizing the total cost for inventory carrying, ordering and lost sales. Days are passing by with a certain pace, revealing each days demand, and the students have to decide when and

how much to order. During the session, diagrams are displaying progression of inventory level (a saw tooth curve) and total costs. Coming to the lecture, the students have an experience-based pre-understanding, which makes it easier for them to grasp discussions about the saw tooth model; trade-off between costs; how the order quantity affects the costs etc.

Cheong et al. (2012) report on a simulation tool for transport routing. The tool is based on Google Maps, because of its embedded visualization features. A number of addresses representing stores and customers are displayed on the map. The task is to schedule transports for distribution of goods from the stores to their customers, in order to keep transport time and distance down. Students can elaborate with manually choosing suitable routes, and then compare their solutions with optimal solutions calculated by the program. The tool is by the authors regarded to be an effective way of showing the strength of transport scheduling programs. As a reflection to the increased effectiveness, the time released can be used by students for reflection to gain a deeper understanding.

An example where software is combined with physical simulation is provided by Zhong and Huang (2014). In order to facilitate learning about Internet of Things in a logistics context, a physical lab has been built with 'rooms' representing a factory, a distribution center, and a retailer. In these rooms, production, materials handling, storage etc. is performed. Products are tagged with RFID, and in all parts of the process, RFID devices are used to capture information. On a course website, students chose different exercises connected to their curriculum. After learning what to do, and making required preparations, they perform some operations in the physical lab. After the lab session, they return to the software, to view the outcome of their operations. They are supposed to make an on-line test, showing what they have learned during the session. According to Zhong and Huang (2014), students' learning is facilitated by them having hands-on experience with materials handling equipment, RFID scanners etc. The combination with preparation exercises available for the students on-line is also regarded as an effective way of achieving the expected learning, saving time for both students and tutors.

These examples illustrate that simulation and visualization can be used for highlighting various aspects of logistics by use of practice-based problems. Most often, this is done in a software environment, but as the last example shows, physical simulation is also an opportunity. Some simulation exercises can take form of a game. To use games in logistics education is the next topic dealt with.

## Games

The kind of educational method most frequently reported in the studied articles are games in different forms. Physical games (e.g. board games) as well as software-based games are both commonly referred to. The popularity of games is according to Ngai et

al. (2012) due to that students are engaged by the ‘competition’ in the game setting, and that learning takes place in an interactive way.

The majority of games described in the logistics education literature relate to issues concerning dynamics in supply chains. A much referred game is the ‘Beer Game’. In its basic version, four players represent different actors in a distribution channel: producer, distributor, wholesaler and retailer. Each party keeps stock and is supposed to minimize the inventory cost and backlog cost, by keeping down the stock levels, without getting shortages. No communication is allowed between the parties except for information about placed orders and delivered amounts. Starting from a stable state, small changes in market demand will inevitably result in an unstable system, with big shortages and fluctuations in stock level at every stage of the supply chain. (See e.g. Senge (2006) for a closer description.) These effects are a good starting point for discussions about the causes for these dynamic effects, and possible ways of what can be changed in order to decrease these negative consequences.

The Beer Game has been around for decades, but is still much in use. Being traditionally a board game, several software models have been developed, which is described by e.g. Pupavac (2006) and Riemer (2010). Several variants and extensions of the Beer Game have been developed over the years. For example, Fetter and Shockley (2014) report on a variant with increased complexity, including several actors at each stage of the channel, and several products to be managed at the same time. Others, like Reyes (2007), combine the Beer Game with other games (in Reyes’ case, a Lego block building exercise) to put the Beer Game in a wider context.

There are other games than Beer Game applications. For example, Gumus and Love (2013) describe a game where students are acting as either retailers or wholesalers, where wholesalers deliver products to retailers. Retailers and wholesalers are negotiating with each other to agree upon terms of contracts. The retailers are to secure supply to meet the end-customers demand, and the aim for both wholesalers and retailers are to make a higher profit than their competitors. Dhumal et al. (2008) report on a game used for teaching students how to deal with inventory control issues under fluctuating demand.

As seen in the examples, games are often based on practice-based problems. Since there are many games available, it might be hard for teachers to know whether they are suitable in a specific educational situation. In an attempt to help logistics teachers to navigate among the different games available, Cvetić et al. (2013) present a tool to support the decision of selecting appropriate games. By entering data about the desired logistics topic, the tool makes recommendations of games from a data base of 55 games within logistics and supply chain management.

## Field-based projects

Projects and group assignments of various kinds are presented in many articles. A specific kind of projects is field-based projects, by some authors addressed consultancy projects, where students are being assigned the task to help a company solving a live logistical problem. Davis et al. (2004) report that expert evaluations show that field-based projects are generally of higher quality than on-campus projects. Ziarati et al. (1995), Handfield et al. (2011), and Bak and Boulocher-Passet (2013) agree upon the appropriateness of using field-based projects in logistics education.

Ziarati et al. (1995) provide an example of a project, where the supply to the assembly at a major car manufacturer was changed from using a push system to applying pull principles. Another example is given by Kopczak and Fransoo (2000), where a group of students developed a reverse logistics concept. This concept was then offered by the client as an additional logistics service to its customers.

Bak and Boulocher-Passet (2013) point out challenges with field-based projects, e.g. to find client companies that offer suitable projects and good support to the students; that running these projects is time-demanding from a teacher as well as a student perspective; and that students often are frustrated because of the discomfort in working with real-life projects. However, as described above, there are positive learning experiences connected to field-based projects. Handfield et al. (2011) reports on alumni witnessing that they have good use of their project experiences when entering their work positions.

Working with field-based projects may thus be challenging as well as rewarding for the students. From a learning perspective, field-based projects forces students to apply knowledge learned in classroom conformity to “ill-defined, real-world business problems”, working with problem definition, data collection, and problem analysis, in order to recommend action plans (Handfield et al., 2011). The activities mentioned by Handfield et al. are well in line with ‘structured investigation method’, suggested in section 4.3.4 as being core logistics knowledge.

### The ‘no-solution’ approach

Working with field-based projects means that there is no accurate solution or answer prepared by the teachers, which the students are to be judged against. Rather, there are many possible solutions, and the students are supposed to in a structured manner work their way to find a reasonably good one.

Even in classroom situations, open-ended exercises can be used. Tipi (2009) discusses the teaching of mathematical modelling within forecasting, inventory control, and other logistics-related areas. She concludes that students often ask for the ‘right solution’, in a sort of belief that such right answers always exist. To counteract this behavior, she suggests that exercises are constructed, requiring the students to use appropriate

arguments to the solutions they find. Students often feel frustration when not used to this, but Tipi (2009) means that since the right answer very much depends on the context, the underlying discussion and argumentation is much more important to learn than what happens to be the best in a specific situation.

Working-life is not shaped in order to fit into theoretical models or textbook framings. Exposing students to exercises and examples where discussions are promoted about what good solutions are, is therefore a good way of introducing students to real-life reasoning. Practice-based examples can be used to make such exercises more authentic.

## Assessment

Considering the importance assessment generally is given in literature (Ramsden, 2003; Bergendahl and Tibell, 2005), it is a bit surprising that only five articles were found that address this area within logistics education. Moreover, even in most of these articles, the assessment procedures are not described in detail. Different forms of assessment are reported: students' in-class presentations (Carravilla and Fernando, 2004; Tipi, 2009); home examinations (Alvarstein and Johannesen, 2001); and written essays (Romanovs et al., 2010). Carravilla and Fernando (2004) also describe a written exam, where all questions are based on the presentation slides the students have provided at an earlier stage in the course.

Naslund (2005) describes an on-line assessment system. Beyond multiple-choice questions, which is rather common in on-line settings, this system also contains questions that require the students to use a template in MS Excel to solve some problems and hand in the files via the on-line system. The teachers save a lot of time on exam correction. They also get better insight in how the students have solved the exercises, since they can follow the solutions step-by-step in the Excel files. This improved insight in the solving procedure makes the grading more fair, which is appreciated by the students.

After these examples of teaching and assessment activities, the notion of alignment will be revisited.

## 5.4 Alignment between content and educational methods

As highlighted previously in this thesis, there is strong connection between teaching and learning. Teaching must be arranged in a way that supports students' learning. Returning to Biggs (2003) model of constructive alignment (presented in section 0), expected learning outcomes, teaching and learning activities, and assessment should be closely aligned to each other. Biggs (2003) states that students are highly sensitive to the form and content of the assessment. If the expected learning outcomes are not tested in the assessment, proper teaching activities won't help much. The students will direct their learning towards the assessment, and what is demanded there.

Since the literature about logistics education does not contain much concerning assessment, it is not possible to dwell into discussions about the status of alignment in higher logistics education. However, a few examples are possible to give. Tipi (2009) describes an ‘open book’ assessment, where students are allowed to bring with them all material they need. Her motive is that she wants to the students to apply problem solving skills on the exam, rather than reproducing facts. During the course, the ‘no solution’ approach (described in the previous section) is used, where focus is put on approaching problems in a methodical way, and not searching for ‘the correct’ answer. Hence, in this example, there is an alignment between the way of teaching the subject, and how it is assessed.

Alvarstein and Johannesen (2001) describe a course on logistics and transportation, where problem-based learning is applied. In the course, six major problem areas are covered, each with specific expected learning outcomes. Students work in groups and receive a scenario connected to each problem area. The groups are responsible for specifying which information they need, collecting this information, making necessary analyses etc., and finally making a presentation for their course fellows on their scenario. They are assessed on their presentations. The learning activities in this case are built upon the learning objectives and directed towards the presentation, which is part of the assessment. Hence, there is alignment between the three.

In the cases reported in paper 3, both teachers plan their teaching about total cost analysis with the examination in mind. One of the expected learning outcomes in both these courses is that: “the student shall be able to compare and evaluate several given alternatives with regard to changes in a specific logistics system, and to recommend and justify one or several of these options”. An important part of such an evaluation regards the total costs connected to the different alternatives. The examination in the courses includes an individual written exam, where a major part is a case exercise, aimed at testing exactly what is stated in this learning outcome. During the course, students are working in groups with a case where such analyses are trained. An important part of this case is to determine which cost factors that are relevant to include in the total cost analysis. This is one thing highlighted by the teachers, in the lectures, seminars and tutoring sessions during the course. This way, learning outcomes, teaching and learning activities, and assessment are aligned.

If there is a good alignment as described by Biggs (2003), one could assume that the probability increases for learning really to take place. Next, the issue of learning effects will be addressed.

#### **5.4.1 *Telling whether something has effect***

In educational research in general, a common type of research question concerns whether certain teaching methods and activities are effective, in the sense that they contribute to learning. This can be made by some kind of effect studies, where students’



understanding is tested before and after a specific intervention. In another kind of studies, different groups of students get different education, whereupon their understanding can be tested and compared (Cohen et.al., 2011).

In the studied articles about higher education in logistics, the matter of actual learning in relation to the educational activities is close to neglected. The teaching cases reported are often interesting and inspiring, but the real effects of the course designs, teaching and assessment are not investigated, which makes it hard to draw general conclusions concerning their appropriateness. There are some exceptions, though, where these issues are discussed.

One example is provided by Zeng and Johnson (2009), who report on a lab session where a supply chain is simulated by letting the students take on different roles (suppliers, warehouse manager, production manager, assemblers, customer etc.) in a supply chain. At the end of the course, students' understanding was tested concerning relevant stages in supply chains, and suitable supply chain performance measures. As similar courses were given, and this specific lab session was included only in some of them, it was possible to see that participation in the lab session made a positive difference in understanding regarding the supply chain topics tested.

Pre- and post-tests were used also by Zhu et al. (2011), in order to test the effectiveness of using a specific software to learn transportation planning. Two different groups of students were included in the study, taking the course different semesters. One of them was a 'control group', performing the transportation planning exercises in the traditional way, using paper and pen. The students answered surveys before and after the transportation planning classes, to catch the progression in learning. It turned out that the group using the software showed a higher increase in understanding than the control group. However, it was the students' self-reported understanding that was analyzed, not the actual learning. As Paper 3 reveals, there can be a rather big discrepancy between self-rated and actual understanding, while results based on self-reported understanding might be treated with some caution.

Wu and Huang (2013) describe an online self-learning module that was constructed for college students to a logistics certification. Tests were performed on students before and after their interaction with the web-based learning environment system to compare their understanding. The results on the post-test proved to be significantly higher than on the pre-test, indicating that the self-learning module is effective.

As stated above, reports of evaluation of the effects of specific teaching interventions are rare in the studied literature. The examples given in this section are a few exceptions.

## **5.5 Summarizing discussion**

In this chapter, the PCK components have been discussed, and it was concluded that some of them are case-specific, while others are of a general interest for logistics teachers: knowledge about subject-matter, instructional strategies, assessment, and methods for capturing students' understanding. Specific attention was given to methods for instruction, and it was argued that problem- and practice based methods are well suited for logistics education. It was then stated that constructive alignment between learning outcomes, teaching methods and assessment is not clearly addressed in a majority of the examined articles on logistics education. Finally, only in a few of these articles, the learning effects are evaluated.

Having discussed the question of what logistics knowledge that is important, and the issue on how logistics knowledge can be learned, time has come to try and summarize the findings in this thesis, and look towards the future.

## 6 Bringing it all together

In this concluding chapter, the findings are summarized, reflected upon, and connected to the purpose and the research questions. Moreover, suggestions for future research are given. To refresh the mind of the reader, the purpose and research questions are first revisited.

*Purpose:* To contribute to the knowledge on teaching and learning logistics in higher education

*RQ1:* What knowledge and skills are important for students to learn during higher education in logistics?

*RQ2:* How can students' learning of these skills and knowledge be facilitated?

### 6.1 The findings

The literature on logistics education gives limited guidance concerning what is to be learned during higher education in logistics, as well as how to facilitate learning within logistics. Concerning appropriate logistics knowledge to learn, a number of studies have pointed out important knowledge areas, e.g. 'transportation management' and 'inventory management'. What to focus within these high-level knowledge areas is however not revealed in the literature related to logistics education. Regarding methods for teaching and assessment, a lot of cases are described, where different methods are used. In most cases, though, it's hard to make general conclusions concerning the appropriateness of these methods, since there is a lack of evaluation about their learning effectiveness. This means that knowledge is scarce concerning how or why students actually acquire certain logistics knowledge and skills.

These findings are somewhat discouraging, since it indicates that the logistics teaching faculty does not base their course design and teaching practices on solid knowledge on what and how to teach. In order to reach some kind of answers to the research questions, a selection of pedagogical theories were applied on logistics education with help from illustrating examples from the articles found in the literature review (Paper 1), together with findings from studies presented in Paper 2 and 3.

### 6.1.1 What to learn in logistics higher education

Concerning the first research question, ‘What knowledge and skills are important for students to learn during higher education in logistics?’, the following was found:

- A tentative model is presented, aimed as a tool for categorizing logistics knowledge and skills.
- Two specific skills are highlighted as core generic skills within logistics education: total cost analysis, and structured investigation method.
- Some examples of thresholds in logistics education are suggested.

These findings are in the coming sections examined a bit closer.

#### A tentative model for categorizing logistics knowledge

Since there is so much that might be of interest within a subject, some kind of division must be made concerning the importance of different topics and areas. Some knowledge aspects are more central than others, and in this thesis the terms ‘core’ and ‘non-core’ knowledge have been used as a rough categorization. Moreover, knowledge can be seen as belonging to different hierarchical levels. A model was developed for schematically illustrating how different knowledge aspects relate to each other, see Figure 17, and some aspects of knowledge were discussed more in detail. In the figure, five general knowledge areas are displayed, as being the ones highlighted in the studied literature. These five areas do not cover the complete logistics discipline, which is illustrated by the glimpse of additional knowledge areas to the far left and far right in the figure. One of the knowledge areas, inventory management, was used as an example to discuss what kind of knowledge aspects that exist on different levels, and whether they are to be regarded as core or non-core knowledge. As shown in the figure, some knowledge aspects span over more than one knowledge area. This symbolizes that knowledge can be of a more generic character, not related only to one specific area.

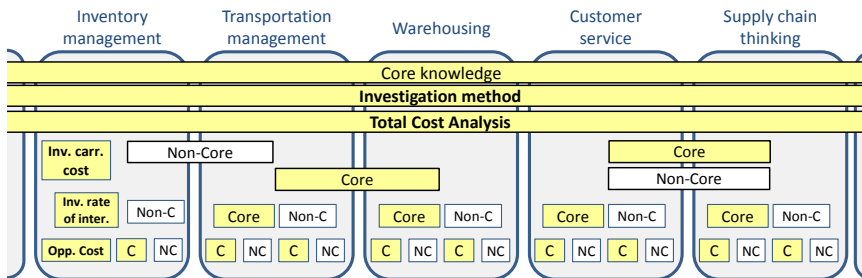


Figure 17: Principal model showing how knowledge areas, core and non-core knowledge aspects relate to each other.

In the figure and the accompanying text, the word *knowledge* has been used as an overarching term. However, it is more appropriate to talk about *knowledge and skills*, where knowledge symbolizes more factual understanding, ‘knowing that’, while skills refer to the ability to do and perform, ‘knowing how’. Logistics is an applied discipline, since it to a large extent is directed towards the usefulness in industry and society. Therefore, both knowledge and skills are essential, since the factual knowledge must be put into practice in order to be valuable.

### Suggested core knowledge and skills in logistics

As indicated in Figure 17, inventory carrying cost, inventory rate of interest and opportunity cost were regarded as being core knowledge within the area of inventory management. However, these are not claimed to be more than examples, since no attempt was made to make a full investigation of core knowledge within this area. More important, two knowledge aspects of a more generic character have been particularly focused in this thesis: total cost analysis; and investigation method.

To perform total cost analyses in a good way is regarded as a skill, although reliant on certain knowledge of more factual character. Since logistics decisions most often is based upon costs (among other things), total cost analysis is regarded as a core skill. Moreover, total cost analysis is important independent of different knowledge areas, which means that it is a generic skill. Hence, *total cost analysis is suggested as a generic core logistics skill.*

In order to make proper logistical decisions, different alternatives must be investigated and analyzed properly. Performing such investigations in a structured manner is therefore of great importance, and being able to do that is seen as a core skill. This is another example of a skill that spans over the knowledge areas, being relevant for every kind of logistics decision. Hence, to perform *structured investigations is suggested as a generic core logistics skill.*

### Thresholds in logistics

A threshold concept refers to something which is troublesome to overcome, but once it is passed leads to a new way of understanding things. Thresholds can be of a basic, disciplinary, or procedural character. According to the theory, every subject has its thresholds. Identifying which the thresholds are for acquiring core knowledge and skills is central, if education should be able to aid students in overcoming them.

In the literature on logistics education, threshold concepts are never mentioned, and neither are they treated implicitly. The theories on threshold concepts were applied to the core logistics knowledge and skills discussed, which resulted in some suggested examples of thresholds in logistics education, see Table 7.

Table 7: Suggested examples of thresholds within logistics education

Knowledge element	Type of threshold
<i>Opportunity cost</i>	Basic, since it does not integrate underlying thresholds
<i>Inventory rate of interest</i>	Basic, since it is clarifying, rather than affecting the way of thinking
<i>Case-specific adaptation of total cost model</i>	Disciplinary, while integrating several important aspects, and cutting through a number of different logistics knowledge areas
<i>Investigation planning</i>	Procedural, while it affects the way of practicing
<i>Systems thinking</i>	Disciplinary, while integrating several important aspects. Maybe even procedural, while affecting practicing
<i>Understanding supply chain dynamics</i>	Disciplinary, while integrating several important aspects.

### 6.1.2 How to facilitate learning in logistics higher education

The second research question ‘How can students’ learning of these skills and knowledge be supported?’ is focused. How to facilitate learning, by e.g. choosing methods for instruction and assessment, is closely connected to what is to be learned. Since knowledge is limited on what to learn in logistics higher education, answering the how question in a sense becomes a ‘mission impossible’. Literature on logistics education provides many interesting teaching and learning examples, but not much guidance on which methods really have effect on logistics learning. However, some things of general interest were found, that will be addressed more closely in the next sections:

- Problem- and practice-based instructional methods are recommended.
- To acquire pedagogical content knowledge, some aspects are important for logistics teachers to learn about, e.g.:
  - Methods for capturing students’ pre-understanding
  - Thresholds that students are facing, and how these can be overcome

#### Problem- and practice-based methods

The literature on logistics higher education clearly reveals that logistics is a discipline where education has strong emphasis on usefulness for the working-life. Educational methods are therefore recommended that help students gain an understanding that is useful when entering working positions. There are a number of different labels on instructional methods and concepts highlighting the positive effects of student-active learning based on real-life problems. Problem- and practice-based learning was chosen as a collective term to embrace these different methods. While higher logistics education is aimed at providing knowledge and skills that are applicable in coming professional situations, the learning situations are to be designed to reflect real-life situations. Although traditional teaching methods still will be valuable, it is therefore suggested that logistics higher education takes advantage of problem- and practice-based learning.

## Pedagogical content knowledge – what is the teacher supposed to know?

It is claimed in theory that it's not enough for a teacher to possess pedagogical knowledge and knowledge about the content to be taught. These have to be merged into something called pedagogical content knowledge, PCK, which in essence means that a teacher must have extended knowledge about the subject-matter in order to know how to best make that specific subject-matter understandable for the specific group of students. Since for example the subject-matter differs from situation to situation, there is a portion of case-specificity connected to PCK. However, PCK is built up from a number of components. These were discussed by using an example from logistics education, to sort out which of these components that are of general interest for logistics teachers. In Table 8, those components are displayed.

Table 8: *Generic aspects of PCK components*

<b>PCK Component</b>	<b>Generic aspect of the component</b>
<i>Knowledge about students' understanding</i>	Methods for capturing students' pre-understanding
<i>Subject-matter knowledge</i>	Identifying core knowledge and the thresholds for acquiring that knowledge
<i>Knowledge about instructional strategies</i>	General knowledge concerning problem- and practice-based instructional methods Specific knowledge about how to make students pass the thresholds
<i>Knowledge about assessment</i>	General knowledge concerning assessment methods. Constructive alignment with learning outcomes and teaching/learning activities

### 6.1.3 Conclusions

The aim of this thesis is *to contribute to the knowledge on teaching and learning logistics in higher education*. The state of the art regarding research on logistics education is rather weak, which affects what is possible to achieve on a short term. This thesis is therefore to be seen as point of departure, rather than a destination.

Although there is need for further investigation in this area, the findings presented in the preceding sections gives a contribution to the knowledge on teaching and learning logistics in higher education. The findings are valuable for logistics teachers, partly by giving some concrete advice, but even more as inspiration to continue developing logistics education based on a solid pedagogical ground. Moreover, the findings are of interest for those wanting to conduct research within logistics education, while it highlights areas in need for more research. This will be discussed more closely in section 6.3.

## **6.2 Reflections**

In this section, some reflecting comments to the study are presented.

### **6.2.1 *What's so special with logistics?***

As discussed in the previous chapters, there are some aspects that are case-specific, while others are of a more generic character. For example, the inventory rate of interest is a kind of knowledge relevant in the case of inventory management, while total cost analysis is highly relevant within logistics in general. However, as commented on previously, total cost analysis is relevant also in other disciplines, where decisions are to be made based on costs. Even though the discussions in this thesis have been made with help from logistics examples, many of the findings are most probably applicable also in other disciplines, not least management-related ones, which have a lot in common with logistics. If pedagogical aspects on logistics are applicable on other related disciplines, this should also be true the other way around. Interesting input to logistics education might therefore be found in studying literature on education in logistics-related disciplines, like marketing, operations management, industrial organization etc.

### **6.2.2 *Educational research – not an interesting field for logistics faculty?***

Andersson (1995) used the term 'professional amateurs' to describe university teachers having a solid knowledge base in their subject content, but being illiterate when it comes to knowledge about education and pedagogy. Based on the articles studied in the literature review (Paper 1), the label 'professional amateurs' is valid for logistics teachers. This somewhat harsh statement is based on the fact that pedagogical literature is used to a very small extent in the articles. Even in those articles focusing on teaching and assessment (where a lot of educational inspiration is to be found), the median article only refers to two pedagogically relevant sources. A number of the articles are to be characterized as 'interesting case descriptions with a scientific touch' rather than scientific research. However, many articles, even those with a weaker pedagogical basis, appear to be written by committed teachers, eager to share their educational experiences. There seems to be a lot of logistics teachers out there, dedicated to teaching. Most of them (so I suppose at least) act as researchers in parallel with their teaching. But how come only a minority of them put down some research effort in connection to their teaching? And why is educational research literature not used, by those who actually do some research within logistics education?

Some possible explanations are found in literature. Many teachers share their time between research and teaching. It probably gains more credibility for the academic career, focusing research within the traditional discipline, than stepping into a side-area, making a cross-over research with pedagogy. Biggs (2003) supports this, stating that



many universities pay lip service to good teaching, but that “everyone knows that research productivity is what brings prestige and money to the university” (p 274).

On the road to becoming a skilled researcher, you get a lot of training, take courses in research methodology etc., but how about the teaching part of the career? Even if many universities today offer pedagogical courses to their personnel, pedagogical education is very limited for many teachers. Ramsden (2003) means that teachers don't get pedagogical vocabulary, methods and knowledge enough to feel confident in taking a research approach on their education.

### **6.3 Suggestions for future research**

Based on the findings and discussions in this study, a number of suggestions for future research will follow as a concluding section.

#### ***6.3.1 Identifying core knowledge within logistics***

A number of survey studies have been performed aimed at identifying important topics to cover in logistics higher education. Logistics managers, headhunting companies, alumni etc. have been targeted to give their opinion on what knowledge is needed in working life. Focus in these studies has been on high-level knowledge areas, while it is still unclear what knowledge and skills that is regarded important on a more specific level. Further research is therefore called upon in order to capture opinions on what is considered as core logistics knowledge and skills. The kind of respondents mentioned above may well be used also in coming studies. What is important is that more specific knowledge and skills are investigated, both considering basic ones, and more generic ones.

#### ***6.3.2 Identifying threshold concepts within logistics***

One of the most important topics discussed in this thesis is the one about threshold concepts, i.e. those key concepts that are necessary for students' progressed understanding, but are problematic for students to grasp. Threshold concepts have until now not been explicitly discussed in logistics, and consequently there is a lack of knowledge concerning thresholds in logistics education. Research is needed to identify logistics thresholds, preferably connected to knowledge and skills that are regarded as core. Some inspiration on how to identify thresholds can be found in Knight et al. (2014).

### **6.3.3 *Identifying how thresholds could be overcome***

When thresholds are identified, the next step is to try and find ways of arranging and conducting educational activities in a way that facilitates students' overcoming these thresholds. A possible method for doing this could be using a multiple case-study, where a number of higher education institutions, facing the same logistical threshold concept, are investigated. By examining how the different institutions address this threshold, and evaluate students' learning, the 'good educational solutions' might be identified.

### **6.3.4 *Testing the effects on learning***

To be able to tell whether a certain method for teaching or assessment is successful, the effect on students' learning must be investigated some way. Such evaluations are rare in the logistics education literature. This indicates that logistics education in most cases is performed without any evidence concerning the effectiveness of the methods used. Research is therefore called upon, that focuses the learning effect of certain instructional and assessment methods in logistics education. Different methods for experimental research in education, including pre- and post-tests, the use of control groups etc., are described by e.g. Cohen et al. (2011).

### **6.3.5 *Collaboration with educational researchers***

As indicated above, in section 6.2.2, some of the shortcomings in the research within higher education logistics, are probably partly because many logistics educators lack a pedagogical vocabulary, as well as knowledge concerning educational research. A way to overcome this would be to engage educational researchers for collaborative research projects. Using pedagogical expertise this way can give several advantages. First, it would increase the quality of the research in logistics education; second, logistics faculty would gain educational knowledge within the collaboration; and third, the probability will increase of getting the logistics educational research published, thereby giving the logistics teachers more 'credit that counts' for their efforts.

## References

- Abrahamsson, M., Aldin, N. & Stahre, F. (2003), "Logistics platforms for improved strategic flexibility", *International Journal of Logistics: Research & Applications*, Vol. 6, No. 3, pp. 85-106.
- Allen, J. & Browne, M. (2010), "Sustainability Strategies for City Logistics". in Mckinnon, A., Cullinane, S., Browne, M. & Whiteing, A. (Eds.) *Green Logistics - Improving the Environmental Sustainability of Logistics*. Kogan Page.
- Alonzo, A. C., Kobarg, M. & Seidel, T. (2012), "Pedagogical content knowledge as reflected in teacher–student interactions: Analysis of two video cases", *Journal of Research in Science Teaching*, Vol. 49, No. 10, pp. 1211-1239.
- Alvarstein, V. & Johannesen, L. K. (2001), "Problem-based learning approach in teaching lower level logistics and transportation", *International Journal of Physical Distribution & Logistics Management*, Vol. 31, No. 7/8, pp. 557.
- Andersson, P. (1995) Den professionelle amatören: Universitetslärares syn på lärande, kunskap och sin egen uppgift. in Falklöf, L. (Ed.) *Kvalitetsarbete vid Linköpings universitet*. Linköpings universitet.
- Aronsson, H., Abrahamsson, M. & Spens, K. (2011), "Developing lean and agile health care supply chains", *Supply Chain Management*, Vol. 16, No. 3, pp. 176-183.
- Aronsson, H. & Hüge Brodin, M. (2006), "The environmental impact of changing logistics structures", *International Journal of Logistics Management*, Vol. 17, No. 3, pp. 394-415.
- Ashenbaum, B. (2008), "The Global Sourcing and Logistics Exercise: A Group Exercise to Demonstrate Basic Global Supply Chain Principles", *Decision Sciences Journal of Innovative Education*, Vol. 6, No. 2, pp. 355-364.
- Baillie, C., Bowden, J. & Meyer, J. (2013), "Threshold capabilities: threshold concepts and knowledge capability linked through variation theory", *Higher Education*, Vol. 65, No. 2, pp. 227-246.
- Bak, O. & Boulocher-Passet, V. (2013), "Connecting industry and supply chain management education: exploring challenges faced in a SCM consultancy module", *Supply Chain Management-an International Journal*, Vol. 18, No. 4, pp. 468-479.
- Barr, R. B. & Tagg, J. (1995) From Teaching to Learning: A New Paradigm for Undergraduate Education. *Change*. Heldref Publications.
- Bergendahl, C. & Tibell, L. (2005), "Boosting complex learning by strategic assessment and course design", *Journal of Chemical Education*, Vol. 82, No. 4, pp. 645-651.

- Bertrand, Y. (1994) The Bermuda Triangle of Education. *Annual Meeting of the American Educational Research Association*. New Orleans.
- Bertrand, Y. & Houssaye, J. (1999), "Pédagogie and didactique: An incestuous relationship", *Instructional Science*, Vol. 27, No. 1/2, pp. 33-51.
- Biggs, J. B. (2003), "*Teaching for quality learning at university : what the student does*", 2 ed., the Society for Research into Higher Education, London.
- Booth Sweeney, L. & Sterman, J. D. (2000), "Bathtub dynamics: initial results of a systems thinking inventory", *System Dynamics Review*, Vol. 16, No. 4, pp. 249-286.
- Bourlakis, M., Sodhi, M. S. & Son, B. G. (2013), "The relative emphasis on supply-chain/logistics topics by UK industry in hiring postgraduates and by UK universities in teaching and research", *International Journal of Logistics-Research and Applications*, Vol. 16, No. 6, pp. 506-521.
- Bowersox, D. J., Closs, D. J., Cooper, M. B. & Bowersox, J. C. (2013), "*Supply chain logistics management*", 4 ed., McGraw-Hill, New York, NY.
- Bryman, A. & Bell, E. (2007), "*Business research methods*", 2 ed., Oxford University Press, Oxford.
- Bränberg, A., Gulliksson, H. & Holmgren, U. (2013), "*Didaktik för ingenjörslärare: Konsten och glädjen med att utbilda ingenjörer*", 1 ed., Studentlitteratur.
- Buschang, R. E., Chung, G. K. W. K., Delacruz, G. C. & Baker, E. L. (2012), "Validating Measures of Algebra Teacher Subject Matter Knowledge and Pedagogical Content Knowledge", *Educational Assessment*, Vol. 17, No. 1, pp. 1-21.
- Canen, A. G. & Canen, A. (2001), "Looking at Multiculturalism in International Logistics: An Experiment in a Higher Education Institution", *International Journal of Educational Management*, Vol. 15, No. 3, pp. 145-152.
- Carravilla, M. A. & Fernando, O., Jos (2004), "Teaching logistics without formal classes: a case study", *European Journal of Engineering Education*, Vol. 29, No. 4, pp. 571-580.
- Cheong, F., Cheong, C. & Jie, F. (2012), "Re-Purposing Google Maps Visualisation for Teaching Logistics Systems", *Journal of Information Technology Education: Innovations in Practice*, Vol. 11, pp. 159-177.
- Christopher, M. (2011), "*Logistics & supply chain management*", 4 ed., Financial Times Prentice Hall, Harlow.
- Cohen, L., Manion, L. & Morrison, K. (2011), "*Research methods in education*", 7 ed., Routledge, Milton Park.

- Cooper, D. R. & Schindler, P. S. (2003), "*Business research methods*", 8 ed., McGraw-Hill, Boston.
- Cousin, G. (2010), "Neither teacher-centred nor student-centred: threshold concepts and research partnerships", *Journal of Learning Development in Higher Education*, Vol. 2, pp. 1-9.
- CSCMP (2014), "Supply Chain Management Definitions", available at: <http://cscmp.org/about-us/supply-chain-management-definitions>,(accessed 2014-06-25).
- Cvetić, B., Vasiljević, D. & Mijatović, I. (2013), "Design and application of a decision support tool for the selection of logistics and supply chain management games", *International Journal of Engineering Education*, Vol. 29, No. 6, pp. 1527-1536.
- Davis, P. W., DiBiasio, D., Durgin, W. W., Schachterle, L. E. & Vaz, R. F. (2004) Acheiving Learning Outcomes Through Project-Based Education. *International Conference on Engineering Education*. Gainesville, Florida, US.
- Denyer, D. & Tranfield, D. (2009), "Producing a systematic review". in Buchanan, D. A. & Bryman, A. (Eds.) *The Sage handbook of organizational research methods.*, Sage Publications Ltd, Thousand Oaks, CA.
- Dhumal, P., Sundararaghavan, P. S. & Nandkeolyar, U. (2008), " 'Cola-Game': An Innovative Approach to Teaching Inventory Management in a Supply Chain", *Decision Sciences Journal of Innovative Education*, Vol. 6, No. 2, pp. 265-285.
- Entwistle, N. (2009), "*Teaching for Understanding at University: Deep Approaches and Distinctive Ways of Thinking*", Palgrave Macmillan.
- Esper, T. L., Fugate, B. S. & Davis-Sramek, B. (2007), "Logistics learning capability: sustaining the competitive advantage gained through logistics leverage", *Journal of Business Logistics*, Vol. 28, No. 2, pp. 57-81.
- Fernandez-Balboa, J.-M. & Stiehl, J. (1995), "The Generic Nature of Pedagogical Content Knowledge among College Professors", *Teaching and Teacher Education*, Vol. 11, No. 3, pp. 293-306.
- Fetter, G. & Shockley, J. (2014), "Developing Students' Understanding of Co-opetition and Multilevel Inventory Management Strategies in Supply Chains: An In-Class Spreadsheet Simulation Exercise", *Decision Sciences Journal of Innovative Education*, Vol. 12, No. 2, pp. 79-89.
- Frankel, R., Bolumole, Y. A., Eltantawy, R. A., Paulraj, A. & Gundlach, G. T. (2008), "The domain and scope of SCM's foundational disciplines : insights and issues to advance research", *Journal of business logistics : JBL*, Vol. 29, No. 1, pp. 1-30.
- Fransson, G. & Holmberg, J. (2012), "Understanding the Theoretical Framework of Technological Pedagogical Content Knowledge: A Collaborative Self-Study to Understand Teaching Practice and Aspects of Knowledge", *Studying Teacher Education*, Vol. 8, No. 2, pp. 193-204.

- Ghauri, P. N. & Grønhaug, K. (2005), "*Research methods in business studies : a practical guide*", Financial Times Prentice Hall, Harlow.
- Gligor, D. M. & Holcomb, M. C. (2012), "Understanding the role of logistics capabilities in achieving supply chain agility: a systematic literature review", *Supply Chain Management*, Vol. 17, No. 4, pp. 438-453.
- Goodnough, K. (2006), "Enhancing Pedagogical Content Knowledge through Self-Study: An Exploration of Problem-Based Learning", *Teaching in Higher Education*, Vol. 11, No. 3, pp. 301-318.
- Grant, D. B., Lambert, D. M., Stock, J. R. & Ellram, L. M. (2006), "*Fundamentals of Logistics Management*", McGraw-Hill Education, Maidenhead, Berkshire.
- Grantham, K. & Cudney, E. (2011), "Leaning and Greening the Supply Chain: A Teaching Case Study for Engineering Students", *Industry and Higher Education*, Vol. 25, No. 1, pp. 53-58.
- Gravier, M. J. & Farris, M. T. (2008), "An analysis of logistics pedagogical literature: Past and future trends in curriculum, content, and pedagogy", *International Journal of Logistics Management*, Vol. 19, No. 2, pp. 233-253.
- Groth, R., Spickler, D., Bergner, J. & Bardzell, M. (2009), "A Qualitative Approach to Assessing Technological Pedagogical Content Knowledge", *Contemporary Issues in Technology and Teacher Education (CITE Journal)*, Vol. 9, No. 4, pp. 392-411.
- Gumus, M. & Love, E. C. (2013), "Supply Chain Sourcing Game: A Negotiation Exercise", *Decision Sciences Journal of Innovative Education*, Vol. 11, No. 1, pp. 3-12.
- Handfield, R. B., Edwards, S. A. & Stonebraker, J. S. (2011), "NC State's Supply Chain Resource Cooperative Educates in the Real World", *Interfaces*, Vol. 41, No. 6, pp. 548-563.
- Harrison, A. & van Hoek, R. I. (2011), "*Logistics management and strategy : competing through the supply chain*", 4 ed., Pearson/Financial Times Prentice Hall, Harlow.
- Humphrey, R. & Simpson, B. (2012), "Writes of passage: writing up qualitative data as a threshold concept in doctoral research", *Teaching in Higher Education*, Vol. 17, No. 6, pp. 735-746.
- Håkansson, J. & Sundberg, D. (2012), "*Utmärkt undervisning : Framgångsfaktorer i svensk och internationell belysning*", Natur & Kultur.
- Isaksson, K. & Hüge-Brodin, M. (2013), "Understanding efficiencies behind logistics service providers' green offerings", *Management Research Review*, Vol. 36, No. 3, pp. 216-238.

- Jahre, M. & Persson, G. (2008), "Origins and influences of logistics thinking : is there a Nordic approach?". in Arlbjörn, J. S., Halldorsson, A., Jahre, M. & Spens, K. (Eds.) *Northern lights in logistics & supply chain management*. Copenhagen Business School Press.
- Jang, S.-J. (2011), "Assessing College Students' Perceptions of a Case Teacher's Pedagogical Content Knowledge Using a Newly Developed Instrument", *Higher Education: The International Journal of Higher Education and Educational Planning*, Vol. 61, No. 6, pp. 663-678.
- Jonsson, P. (2008), "*Logistics and supply chain management*", McGraw-Hill, Maidenhead.
- Kansanen, P. (2009), "Subject-matter didactics as a central knowledge base for teachers, or should it be called pedagogical content knowledge?", *Pedagogy, Culture & Society*, Vol. 17, No. 1, pp. 29-39.
- Kinchin, I. M. & Miller, N. L. (2012), " 'Structural Transformation' as a Threshold Concept in University Teaching", *Innovations in Education and Teaching International*, Vol. 49, No. 2, pp. 207-222.
- Kind, V. (2009), "Pedagogical Content Knowledge in Science Education: Perspectives and Potential for Progress", *Studies in Science Education*, Vol. 45, No. 2, pp. 169-204.
- Kitchenham, B. & Charters, S. (2007) Guidelines for Performing Systematic Literature Reviews in Software Engineering. *EBSE Technical Report*. Keele University / Durham University.
- Knight, D. B., Callaghan, D. P., Baldock, T. E. & Meyer, J. H. F. (2014), "Identifying threshold concepts: case study of an open catchment hydraulics course", *European Journal of Engineering Education*, Vol. 39, No. 2, pp. 125-142.
- Kopczak, L. R. & Fransoo, J. C. (2000), "Teaching supply chain management through global projects with global project teams", *Production and Operations Management*, Vol. 9, No. 1, pp. 91-104.
- Kovacs, G., Tatham, P. & Larson, P. D. (2012), "What Skills Are Needed to be a Humanitarian Logistician?", *Journal of Business Logistics*, Vol. 33, No. 3, pp. 245-258.
- Kumar, S. & Kopitzke, K. K. (2008), "A practitioner's decision model for the total cost of outsourcing and application to China, Mexico, and the United States", *Journal of business logistics*, Vol. 29, No. 2, pp. 107-139.
- Kumar, S. & Kropp, J. (2006), "Studying the operational efficiencies of a multi-product supply chain using excel spreadsheet model", *Technovation*, Vol. 26, No. 10, pp. 1186-1200.

- Lambert, D. M. (1975), "*The development of an inventory costing methodology: A study of the costs associated with holding inventory*", Dissertation, Ohio State University, Department of Marketing.
- Langley, C. J., Coyle, J. J., Gibson, B. J., Novack, R. A. & Bardi, E. J. (2008), "*Managing supply chains : a logistics approach*", 8 ed., South-Western, Mason, Ohio.
- LeCompte, M. D. & Goetz, J. P. (1982) Problems of Reliability and Validity in Ethnographic Research. *Review of educational research*. American Educational Research Association.
- Lee, H. L., Padmanabhan, V. & Wang, S. (1997), "The Bullwhip Effect in Supply Chains", *Sloan Management Review*, Vol. 38, No. 3, pp. 93-102.
- Lindberg-Sand, Å. & Sonesson, A. (2008), "Compulsory higher education teacher training in Sweden: Development of a national standards framework based on the Scholarship of Teaching and Learning", *Tertiary Education and Management*, Vol. 14, No. 2, pp. 123-139.
- Lindskog, M. (2012), "*On systems thinking in logistics management : a critical perspective*", Linköping Studies in Science and Technology, Dissertations No. 1456, Department of Science and Technology, Linköpings universitet.
- Loughran, J. (2013), "Pedagogy: Making Sense of the Complex Relationship Between Teaching and Learning", *Curriculum Inquiry*, Vol. 43, No. 1, pp. 118-141.
- Lutz, H. & Birou, L. (2013), "Logistics education: A look at the current state of the art and science", *Supply Chain Management*, Vol. 18, No. 4, pp. 455-467.
- Major, C. H. & Palmer, B. (2006), "Reshaping teaching and learning: The transformation of faculty pedagogical content knowledge", *Higher Education*, Vol. 51, No. 4, pp. 619-647.
- Mangan, J., Lalwani, C., Butcher, T. & Javadpour, R. (2012), "*Global logistics and supply chain management*", 2 ed., Wiley, Chichester.
- Marsick, V. J. & O'Neil, J. (1999), "The Many Faces of Action Learning", *Management Learning*, Vol. 30, No. 2, pp. 159-176.
- McKinnon, A. (2010), "Assessing the Environmental Effects of Logistics". in McKinnon, A., Cullinane, S., Browne, M. & Whiteing, A. (Eds.) *Green Logistics - Improving the Environmental Sustainability of Logistics*. Kogan Page.
- Merkuryev, Y., Bikovska, J. & Merkuryeva, G. (2011), "Supply chain dynamics: Simulation-based training and education", *International Conference on Harbour, Maritime and Multimodal Logistics Modelling and Simulation*, Vol. 1, pp. 221-230.
- Merriam, S. B. (1998), "*Qualitative research and case study applications in education*", Jossey-Bass, San Francisco.



- Meyer, B. C. & Bishop, D. S. (2011), "The Ordering Challenge: An Online Game to Introduce Independent Demand Inventory Concepts", *Decision Sciences Journal of Innovative Education*, Vol. 9, No. 2, pp. 315-320.
- Meyer, J. & Land, R. (2003) Threshold concepts and troublesome knowledge: linkages to ways of thinking practising within the disciplines. *Enhancing Teaching-Learning Environments in Undergraduate Courses Project*. Edinburgh, School of Education, University of Edinburgh.
- Meyer, J. H. F. & Land, R. (2005), "Threshold concepts and troublesome knowledge (2): Epistemological considerations and a conceptual framework for teaching and learning", *Higher Education*, Vol. 49, No. 3, pp. 373-388.
- Momanu, M. (2012), "The Role of Context in Didactic Knowledge Building: An Epistemological Approach", *Scientific Annals of the 'Alexandru Ioan Cuza' University of Iasi: Educational Sciences Series*, Vol. 16, pp. 45-56.
- Murphy, P. R. & Poist, R. F. (1991), "Skill Requirements Of Senior-Level Logistics Executives: An Empirical Assessment", *Journal of Business Logistics*, Vol. 12, No. 2, pp. 73-94.
- Murphy, P. R. & Poist, R. F. (2007), "Skill Requirements Of Senior-Level Logisticians: A Longitudinal Assessment", *Supply Chain management: An International Journal*, Vol. 12, No. 6, pp. 423-431.
- Murphy, P. R. & Wood, D. F. (2010), "*Contemporary Logistics*", 10 ed., Pearson Higher Ed.
- Naslund, D. (2005), "Online Testing for Logistics and Operations Management", *Decision Sciences Journal of Innovative Education*, Vol. 3, No. 2, pp. 357-365.
- Neumann, G. & Gerecke, A. (2005), "Using Information and Communication technologies to Provide Hybrid Lab Sessions in Logistics Process Control", *ICTE in Regional Development: 2005 Annual Proceedings*, pp. 54-61.
- Ngai, E. W. T., Moon, K. K. L. & Poon, J. K. L. (2012), "Design and Implementation of a Supply Chain Learning Platform", *Journal of Educational Computing Research*, Vol. 47, No. 3, pp. 293-327.
- Niess, M. L. (2013), "Central Component Descriptors for Levels of Technological Pedagogical Content Knowledge", *Journal of Educational Computing Research*, Vol. 48, No. 2, pp. 173-198.
- Oskarsson, B., Ekdahl, B. & Aronsson, H. (2013), "*Modern logistik: för ökad lönsamhet*", 4 ed., Liber.
- Oskarsson, B. & Lindskog, M. (2010) Diagnostic testing as a basis for differentiated course design in logistics and SCM : An evaluation of the systems thinking inventory. *Proceedings of the 22nd NOFOMA conference*. Kolding, Denmark.

- Osmond, J., Bull, K. & Tovey, M. (2009), "Threshold concepts and the transport and product design curriculum: reports of research in progress", *Art, Design & Communication in Higher Education*, Vol. 8, No. 2, pp. 169-175.
- Ozelkan, E. C., Teng, S. G., Johnson, T., Benson, T. & Nestvogel, D. (2007), "Building Lean Supply Chain and Manufacturing Skills through an Interactive Case Study", *Industry and Higher Education*, Vol. 21, No. 4, pp. 265-278.
- Park, S. & Oliver, J. S. (2008), "Revisiting the Conceptualisation of Pedagogical Content Knowledge (PCK): PCK as a Conceptual Tool to Understand Teachers as Professionals", *Research in Science Education*, Vol. 38, No. 3, pp. 261-284.
- Parker, R. S., Kent, J. L. & Brown, T. S. (2001), "The Perceived Importance of Statistics in the Logistics and Transportation Industry", *Journal of Education for Business*, Vol. 76, No. 4, pp. 185.
- Pettersen, R. C. (2008), "*Kvalitetslärande i högre utbildning : introduktion till problem- och praktikbaserad didaktik*", Studentlitteratur.
- Phillips, K. R., De Miranda, M. A. & Jinseup "Ted, S. (2009), "Pedagogical Content Knowledge and Industrial Design Education", *Journal of Technology Studies*, Vol. 35, No. 2, pp. 47-55.
- Pieczyk, M. I. & McKinnon, A. C. (2010), "Forecasting the carbon footprint of road freight transport in 2020", *International Journal of Production Economics*, Vol. 128, pp. 31-42.
- Pupavac, D. (2006) Beer game in the function to illustrate the bullwhip effect in a supply chain. *MIPRO 2006 - 29th International Convention Proceedings: Computers in Education*.
- Rahman, S. & Qing, N. (2014), "Graduate students' perceptions of supply chain skills for supply chain managers", *Benchmarking: An International Journal*, Vol. 21, No. 2, pp. 276-299.
- Ramsden, P. (2003), "*Learning to teach in higher education* ", 2 ed., RoutledgeFalmer, London.
- Regeringskansliet (2014), "Universitet och högskola", available at: <http://www.regeringen.se/sb/d/1895>, (accessed 2014-09-21).
- Reyes, P. M. (2007), "Parallel Interaction Supply Chain Game: An Extension of the Beer Game", *Decision Sciences Journal of Innovative Education*, Vol. 5, No. 2, pp. 413-421.
- Rezat, S. & Sträßer, R. (2012), "From the didactical triangle to the socio-didactical tetrahedron: artifacts as fundamental constituents of the didactical situation", *ZDM Mathematics Education*, Vol. 44, No. 5, pp. 641-651.
- Riemer, K. (2010), "A software solution for facilitating the beer game", *IEEE Learning Technology*, Vol. 12, No. 1, pp. 17-19.

- Romanovs, A., Soshko, O. & Merkuryev, Y. (2010) Information technology focused training in logistics. *2010 9th International Conference on Information Technology Based Higher Education and Training, ITHET 2010*.
- Sandri, O. J. (2013), "Threshold concepts, systems and learning for sustainability", *Environmental Education Research*, Vol. 19, No. 6, pp. 810-822.
- Sauber, M. H., McSurely, H. B. & Tummala, V. M. R. (2008), "Developing supply chain management program: A competency model", *Quality Assurance in Education*, Vol. 16, No. 4, pp. 375-391.
- Saunders, M., Lewis, P. & Thornhill, A. (2007), *Research methods for business students*, 4 ed., Financial Times/Prentice Hall.
- Schoenberg, N. E. & Ravdal, H. (2000), "Using vignettes in awareness and attitudinal research", *International Journal of Social Research Methodology*, Vol. 3, No. 1, pp. 63-74.
- Segall, A. (2004), "Revisiting Pedagogical Content Knowledge: The Pedagogy of Content/The Content of Pedagogy", *Teaching & Teacher Education: An International Journal of Research and Studies*, Vol. 20, No. 5, pp. 489-504.
- Senge, P. M. (2006), *The fifth discipline : the art and practice of the learning organization*, 3 ed., Random House Business, London.
- Settlage, J. (2013) On Acknowledging PCK's Shortcomings. *Journal of Science Teacher Education*, Vol. 24, pp. 1-12
- Shulman, L. S. (1986), "Those Who Understand: Knowledge Growth in Teaching", *Educational Researcher*, Vol. 15, No. 2, pp. 4-14.
- Shulman, L. S. (1987), "Knowledge and Teaching: Foundations of the New Reform", *Harvard Educational Review*, Vol. 57, No. 1, pp. 1-22.
- Siddiqui, A., Khan, M. & Akhtar, S. (2008), "Supply chain simulator: A scenario-based educational tool to enhance student learning", *Computers & Education*, Vol. 51, No. 1, pp. 252-261.
- Smith, K. M. (2013), "Recognition of Problem Insufficiency: A Proposed Threshold Concept Emergent in Student Accounts of Memorable Interior Design Educational Experiences", *Journal of Interior Design*, Vol. 38, No. 4, pp. 37-54.
- Smith, M. K. (2012), "What is pedagogy?", available at: <http://infed.org/mobi/what-is-pedagogy/>, (accessed 2014-06-25).
- Sodhi, M. S., Byung-Gak, S. & Tang, C. S. (2008), "ASP, The Art and Science of Practice: What Employers Demand from Applicants for MBA-Level Supply Chain Jobs and the Coverage of Supply Chain Topics in MBA Courses", *Interfaces*, Vol. 38, No. 6, pp. 469-484.

- Sweeney, D., Campbell, J. & Mundy, R. (2010), "Teaching supply chain and logistics management through commercial software", *International Journal of Logistics Management*, Vol. 21, No. 2, pp. 293-308.
- Thai, V. V. (2012), "Competency requirements for professionals in logistics and supply chain management", *International Journal of Logistics: Research & Applications*, Vol. 15, No. 2, pp. 109-126.
- Thai, V. V., Ibrahim, K. B., Ramani, V. & Huang, H. Y. (2012), "Competency profile of managers in the singapore logistics industry", *Asian Journal of Shipping and Logistics*, Vol. 28, No. 2, pp. 161-182.
- Thomchick, E. (1997), "The use of collaborative learning in logistics classes", *Journal of Business Logistics*, Vol. 18, No. 2, pp. 191-205.
- Tiberghien, A., Vince, J. & Gaidioz, P. (2009), "Design-based Research: Case of a teaching sequence on mechanics", *International Journal of Science Education*, Vol. 31, No. 17, pp. 2275-3314.
- Tipi, N. (2009), "Teaching and assessing supply chain modelling modules in higher education", *International Journal of Learning*, Vol. 16, No. 3, pp. 283-292.
- Tsang, A. K. L. (2011), "Students as Evolving Professionals: Turning the hidden curriculum around through the threshold concept pedagogy", *Transformative Dialogues: Teaching & Learning Journal*, Vol. 4, No. 3, pp. 1-11.
- Tucker, V. M., Weedman, J., Bruce, C. S. & Edwards, S. L. (2014), "Learning Portals: Analyzing Threshold Concept Theory for LIS Education", *Journal of Education for Library & Information Science*, Vol. 55, No. 2, pp. 150-165.
- Tyworth, J. E. & Grenoble, W. L. (1991), "Spreadsheet Modeling In Logistics: Advancing Today's Educational Tools", *Journal of Business Logistics*, Vol. 12, No. 1, pp. 1-25.
- Waters, D. (2003) *Inventory control and management*. 2 ed., Wiley.
- Veal, A. J. (2005), *Business research methods : a managerial approach*, 2 ed., Frenchs Forest, NSW.
- Veal, W. R. & MaKinster, J. G. (1999), "Pedagogical Content Knowledge Taxonomies", *Electronic Journal of Science Education*, Vol. 3, No. 4.
- Webster, S. (2008), *Principles and tools for supply chain management*, McGraw-Hill Higher Education.
- Weltman, D. & Prater, E. (2012), "'Wait Just a Minute Professor We Have an Unstable Inventory System!' Experiences and Recommendations for Teaching Reorder Point Analysis with the Basic EOQ Model", *Operations Management Education Review*, Vol. 6, pp. 91-100.

- Wiger, M. (2013), "*Logistics Management in a Healthcare Context: Methodological development for describing and evaluating a healthcare organisation as a logistics system*", Linköping Studies in Science and technology, Thesis No. 1602, Department of Management and Engineering, Linköping University.
- Viiri, J. (2003), "Engineering Teachers' Pedagogical Content Knowledge", *European Journal of Engineering Education*, Vol. 28, No. 3, pp. 353-359.
- Wikipedia (2014), "Opportunity cost", available at: [http://en.wikipedia.org/wiki/Opportunity\\_cost](http://en.wikipedia.org/wiki/Opportunity_cost), (accessed 7/10/2014).
- Wu, Y.-C. J. & Huang, S. K. (2013), "Making on-line logistics training sustainable through e-learning", *Computers in Human Behavior*, Vol. 29, No. 2, pp. 323-328.
- Yin, R. K. (2009), "*Case study research : design and methods*", 4 ed., SAGE, London.
- Zeng, A. & Johnson, S. (2009), "Integrating a discovery-based laboratory to teach supply chain management fundamentals in an undergraduate management course", *Innovations in Education & Teaching International*, Vol. 46, No. 1, pp. 71-82.
- Zepke, N. (2013), "Threshold concepts and student engagement: Revisiting pedagogical content knowledge", *Active Learning in Higher Education*, Vol. 14, No. 2, pp. 97-107.
- Zhong, R. Y. & Huang, G. Q. (2014), "RFID-enabled learning supply chain: A smart pedagogical environment for TELD", *International Journal of Engineering Education*, Vol. 30, No. 2, pp. 471-482.
- Zhu, S., Xie, F. & Levinson, D. (2011), "Enhancing Transportation Education through Online Simulation Using an Agent-Based Demand and Assignment Model", *Journal of Professional Issues in Engineering Education & Practice*, Vol. 137, No. 1, pp. 38-45.
- Ziarati, R., Griffiths, J., Bennett, M. & Payne, P. (1995), "University of Central England-Rover partnership", *Logistics Information Management*, Vol. 8, No. 6, pp. 8-12.

# Papers

The articles associated with this thesis have been removed for copyright reasons. For more details about these see:

<http://urn.kb.se/resolve?urn=urn:nbn:se:liu:diva-111665>