Approaches to industrial processes in technology textbooks

Susanne Engström, Royal Institute of Technology
sengstro@kth.se
Pernilla Sundqvist, Mälardalen University
pernilla.sundqvist@mdu.se
Charlotta Nordlöf, Linköping University
charlotta.nordlof@liu.se
Claes Klasander, Linköping University
claes.klasander@liu.se

ABSTRACT

The aim of this study is to explore how technology textbooks can provide students with a basis for expressing knowledge about technical solutions within industrial processes. The base and the delimitation for the study is the formulation of the specific content on industrial processes that must be taught to 13 to 15-year-olds in Swedish schools pursuant to the national syllabus. Textbooks constitute an important foundation for teaching, particularly in the subject of technology, in which teachers may find the breadth of content they are expected to teach challenging. The study analyses the sections concerning industrial processes in four different technology textbooks commonly used for students in the age group 13–15. Analysis involved interpreting content in the form of text, images, assignments etc. related to aspects that are expected to characterise students' descriptions and explanations of technical solutions: understanding of technical solutions purpose and functionality, how components interact as a whole, similarities to other technical solutions and relating them to their own experiences. The results show that these aspects emerge in different ways depending on, among other things, how the area is presented. We found three different ways in which industrial processes are presented in the textbooks: A unique industrial process is described carefully and in detail, Sub-processes and methods are presented systematically and Industrial processes are described as technological systems at a general level. One interpretation is that, as a teacher, you can teach about industrial processes in these different ways and that which one you choose affects to what extent certain aspects of technical solutions are visualised for the students.

Key Words: technology education, technical solutions, textbook analysis, industrial processes

1. INTRODUCTION

In Sweden, the intention in primary school is to increase the use of textbooks. A state public inquiry (SOU 2021:70) concluded that students need textbooks in all subjects to fully acquire knowledge and develop competencies. In the case of the technology subject, according to the curriculum, students should be able to describe, explain, and reason to demonstrate various aspects such as breadth and depth, how they base their understanding on facts or personal experiences, their perception of purpose and functionality, etc. (Swedish National Agency for Education, 2022a). This enables the assessment of students' knowledge and competencies. Textbooks are produced, for example, due to changes in syllabi or because teachers or students express a need for textbooks in a subject. The proposal may also come from a textbook author who has an idea for a new textbook (SOU 2021:70).

Well-functioning textbooks are a key factor in students' academic results (Oates, 2014), including in STEM-education (Chiappetta & Fillman, 2007; Kahveci, 2010). They also provide support for teachers in planning and organising their teaching (Lindensjö & Lundgren, 2000; Oates, 2014). Furthermore, textbooks can offer content support for teachers who may be uncertain about their subject knowledge (Englund, 2006). This is particularly relevant for teachers who are not qualified in the subjects they teach, which is prevalent in Sweden, especially for the technology subject.

In this project, we analyse four technology textbooks with the aim of investigating how their content can provide students with a foundation for describing technical solutions, especially industrial processes. With industrial processes we mean large scale industrial manufacturing processes. We aim to identify characteristics and patterns in the textbooks regarding this aspect.

2. LITERATURE REVIEW

There are several reasons to use a textbook. One reason is to provide structure in teaching. There should be a clear progression between different knowledge areas and abilities. Students should encounter gradually more challenging tasks and texts to promote their knowledge development (Fan et al., 2013). Each textbook incorporates pedagogical and didactic considerations, and the design of the texts in the textbook constitutes "a selection and a specific organization of knowledge for learning" (Lindensjö & Lundgren, 2000, p. 16). Textbooks greatly influence learners' understanding of a subject by shaping the strategies teachers use in the classroom and the order of instruction (Chiappetta & Fillman, 2007; DiGiuseppe, 2014; Stern & Roseman, 2004), and influence learning outcomes by presenting the content that students should learn and promoting the skills and abilities they should acquire through that content (Valverde et al., 2002). Textbooks are often used to enable absent students to catch up and are valuable resources for exam preparation (Englund, 2006). Additionally, textbooks can be seen as documentation of students' progress when they are sent home to parents (Korsell, 2007). Furthermore, textbooks are often a source of facts and examples with breadth and depth. Students utilize the content of the textbook to describe subject matter based on facts and provide examples (Andersson-Bakken et al., 2020).

Textbooks thus play a significant role in students' learning. In the context of technology education in Sweden, students should be given the opportunity to "develop knowledge about technical solutions and how components interact to achieve purpose and functionality" (Swedish National Agency for Education, 2022b, Lgr22). This raises questions about what should be considered knowledge and what is deemed important to include or exclude from the curriculum and the teaching (Deng & Luke, 2008). The knowledge that emerges in textbooks and how it is presented thus becomes an interesting question. Deng and Luke (2008) provide three "conceptions of knowledge" derived from different knowledge classification schemes, which we use when discussing what occurs in technology textbooks for students aged 13–15. The first knowledge distinction they describe is called a *disciplinary conception of knowledge*. This knowledge is characterized by placing ideas, concepts, methods, processes, and facts linked to a specific academic discipline in the foreground. The second "conception of knowledge" is the *practical conception of knowledge*, which "construes knowledge in terms of knowing what to do in practices and actions, with an emphasis on the application of knowledge to practical and sociocultural problems" (Deng & Luke, 2008). Such knowledge can range from embodied knowledge, for example, riding a bicycle, to more explicitly cognitive activities such as writing computer programs. Deng and Luke argue that this constitutes and requires procedural knowledge. Practical knowledge cannot be reduced to simply knowing a set of procedures or skills; it involves making thoughtful choices and actions based on deliberate decisions. The third conception is an *experiential conception of knowledge*. Instead of viewing knowledge as something separate from humans, as the first disciplinary conception does, this experiential conception "locates knowledge in the realm of ordinary human experience" (Deng & Luke, 2008). Knowledge is a process in terms of an ongoing construction of meaning between an actor and their environment and other actors (Deng & Luke, 2008).

In the four textbooks, we limit the analysis to the central content referring to the area of Technical Solutions in the syllabus for the lower secondary school : “Processing of raw materials into finished products and handling of waste in an industrial process, for example in the production of food and packaging” (Swedish National Agency for Education, 2022b, Lgr22). We call the content *Industrial Processes* and the knowledge goal can then be expressed (our own formulation based on knowledge requirements and goals): knowledge of industrial processes and how components collaborate to achieve purpose and functionality. The aim is to obtain an understanding of what knowledge textbooks offer to students regarding industrial processes. The research question is: what is prominent in the textbooks’ texts and images related to industrial processes?

3. METHOD

The data sources for this study are four textbooks in Technology education for pupils aged 13-15 years. In each textbook the pages concerning *Industrial Processes* were chosen: book 1 (20 pages), book 2 (35 pages), book 3 (34 pages) and book 4 (14 pages) respectively. These pages were read thoroughly by the four researchers, however each of us was responsible for the identification of significant units for analysis, choosing quotes and pictures/illustrations and summarising the initial impressions in relation to the aim for the study. The content in the books was also compiled from the aspect of how it could contribute to pupils’ use of the content when describing industrial processes (1) by showing understanding for purpose and functionality, (2) generalising by highlighting similarities with other technological solutions, (3) how parts and sub-processes cooperate as a whole and (4) by relating to personal experiences. These four aspects of describing technology are based on advisory documentation where The Swedish NAE comments on the curriculum (Swedish National Agency for Education, 2022b, Lgr22). From this point a thematic analysis (Braun & Clarke, 2006) was made by the whole research group aiming at finding emerging patterns that could answer our research question.

Thereby, the thematic analysis of the content of the textbooks was first carried out with the aim of identifying sub-themes within the content in the four aspects mentioned above, and then to see patterns in how the content is presented. This means that for each aspect of the content in the textbooks, a number of themes emerged. Then, the themes concerning how the content is presented were interpreted jointly by the four researchers.

4. RESULTS

Under each theme, we qualitatively describe what has emerged in the analysis, i.e., the different ways in which the theme is addressed in the textbooks. A book may address a theme to a greater or lesser extent. We have not analysed to what extent each book addresses each theme or sub-theme.

4.1. Characteristics of the content

4.1.1. Purpose and functionality

The purpose of technical solutions and what they do is described. The described purpose can be more or less clear, and what the technical solutions do and how they work is described in more or less detail. For example, the purpose of industrial processes is described as an economical and efficient way to produce goods, or that a machine cuts pipes in suitable lengths in the production of wheelbarrows.

The functionality of different technical solutions is compared based on what is to be achieved. For instance, pneumatics, hydraulics and the servo motor are described in different processes and are put in relation to each other. For example, "How do you move something a short distance? And maybe in very small steps? For this pneumatics do not work so well because it is not so easy to get a cylinder to stop in small steps. For such movements, an electric servo motor can be used". This shows how the functionality of the electric servo motor is better than pneumatics for the purpose of moving something a very short distance.

Functionality is described from the historical development in terms of economic efficiency and an environmental perspective. For instance, it is described that Henry Ford developed the assembly line to make production more effective, and the development of filters in chimneys to prevent pollution.

Functionality is taken for granted. An uncritical and positive view of technology is discerned where the technical solution is portrayed as the obvious one. Thus, functionality is not mentioned.

4.1.2. Generalising by highlighting similarities with other technical solutions
A general description of process industry is given – more or less detailed, followed by examples that enable generalization on various levels.

Generalization of process industry. The understanding of what a process industry is facilitates by providing several examples, such as paper mills, dairy factories, and steel mills. Through both the brief description of what a process industry is and these examples, students can begin to understand process industries on a general level.

Generalization of technical solutions within process industry. Two approaches were identified. The first approach starts the description of the manufacturing process in the details, for example the process of producing a wheelbarrow, with its principles and methods. In the following it is explained that several of these methods are also used in other manufacturing processes. The second approach departs in the methods and sub-processes, such as mechanical processes and chemical processes, joining methods, and forming methods. These are described, and examples of where they occur are given, e.g. “some examples of mechanical processes are when wood is chipped in the production of pulp, when coffee beans are grained in a mill and when olives are pressed to olive oil with a press machine.”

No enabling for generalization. Technical solutions are described solely through the process that serves as an example. No comparisons or connections are made to other processes or solutions that use the same principles or methods, therefor the text doesn’t support the students in transforming the knowledge to other examples of processes.

4.1.3. How parts and sub-processes collaborate as a whole
The collaborating parts are described at a system level. Collaboration is demonstrated between the different sub-processes. A clear overview of the process is provided, with several examples. An overall system level is in focus. For example, a dairy is described as a technological system, both in text and visualised by a model.

The collaborating parts are described in detail. Collaboration is demonstrated between the parts within the sub-processes. One example is given, such as the production of milk powder, and it is described in detail by text and photos. However, an overview of the entire process is missing, which can contribute to difficulties in seeing whole.

4.1.4. Relate to personal experiences
Using examples most students have experience of. This can be the production of potato chips or toothbrushes – products the students are familiar with and commonly use.

Using analogies. Difficult processes are linked to something the students are familiar with. An example is a description of how milk powder is produced. Here, the separator is described to spin “like a roller coaster” and the evaporation of the water in the milk “happens in a saucepan, tall as a tower”.

Giving experiences to relate to. The students are given experiences, through exercises, which they can use to discuss the industrial process. An example is the production of paper. In the chapter that describes how paper is produced in the paper mill, an exercise for making pulp and paper from used newspapers is included, and the students should compare this to the production in the paper mill they have read about.

4.2. Characteristics for how the content is presented

4.2.1. One unique industrial process is described carefully and in detail
Industrial processes are described with one unique example, which is presented carefully and in detail. Steps and methods in sub-processes are thoroughly explained to contribute to knowledge about the specific process, what the different methods of that process aim to achieve, and how the technical solutions work. No overall picture is provided, which makes it difficult to see the big picture.

4.2.2. Sub-processes and methods are presented systematically
Industrial processes are described based on different categories to show that industrial processes can look different and be divided into different groups with common denominators, such as chemical processes and mechanical processes. Sub-processes and methods are also systematized and categorized to show similarities and differences. Both processes and sub-processes are described at a more general level rather than in detail.

4.2.3. Industrial processes are described as technical systems at a general level
The presentation of the industrial process as a technical system can be more or less comprehensive, from a general description of the process showing how the parts are interconnected as a system, to the industrial process being an example of a technological system, meaning that the industrial process is used as a way to develop an understanding of what a technical system is. In the latter case, the technical systems' terminology is used to describe the parts of industrial processes – sub-processes are referred to as components, the system boundary is defined, how the system interacts with the environment etc.

5. DISCUSSION

In the results of the textbook analysis, both the characteristics of the content and the way it is presented are identified. Relating the characteristics of the content to Deng and Luke's (2008) conceptions of knowledge, we see the presence of two out of three conceptions of knowledge. The content is highly characterized by a disciplinary conception of knowledge. Processes and methods are described theoretically in the presentations. Students are given the opportunity to develop theoretical knowledge through facts and descriptions about the technical solutions in industrial processes. In some books, an even more theoretical image is presented where attempts are made to systematize different methods and processes or describe them as general technological systems. Regarding the experiential conception of knowledge, industrial processes are probably something many students have little, if any, experiential knowledge about. Thus, relating to own experiences might be difficult with this content. However, several attempts are made in the textbooks, for example in assignments where students are asked to do something of a more practical character, e.g., to construct a model of an assembly line and program it based on an Arduino platform and relate it to what they have read in the book about industrial processes.

They also do so by relating the theoretical content to experiences and knowledge the students are assumed to have. However, even though students are given practical tasks, the practical conception of knowledge (Deng & Luke, 2008) is completely absent. The tasks have nothing to do with the actual industrial processes, the content becomes something else, moving away from industrial processes as the main focus.

Regarding how the content is presented, we have identified three different approaches in the analysis:

Firstly, by focusing on how one unique industrial process is described carefully and in detail the students' experiences presentations of sub-processes where the main construction materials are handled, refined and moved to next sub-process for further refinement and assembly the risk is that the overarching aims, methods and flows are omitted. The concepts, ideas, processes and facts Deng and Luke speaks of is thereby to high extent connected to the particular example, not the general.

In contrast - when processes, sub-processes and methods are presented systematically - understanding of concepts, ideas, processes and facts (Deng & Luke, 2008) is general and not related to one example in particular. In this approach the focus is on giving the students an overall understanding of industrial processes and students learn about ways to categorize industrial processes and methods. The students will be able to describe industrial processes at an overall level but lack deep knowledge to understand one specific process in detail. The students will have knowledge about similarities and differences of industrial processes, but at an overall level, for example knowing industrial processes as chemical or mechanical. One risk in this approach is that students don't understand the complexity of each single process. On the other hand, students will be able to see common denominators, even though the products produced are of completely different characteristics.

In the third approach the concept, ideas, facts, processes etc. are more rooted in a tradition of systems thinking (Barak & Williams, 2007; Checkland, 1981; O'Connor & McDermott, 1997) which values an understanding from perspectives where the systems delimitation towards an environment, its inputs, outputs and flows are central in the presentation for the students. Process diagrams are sometimes used as a support in this approach. This has obvious benefits on an analytical level in textbooks but might need more thoroughly presented examples from authentic industrial processes to make the interdependence between the disciplinary perspective and the practical perspective (Deng & Luke, 2008) clearer to the students.

We note that, regarding all the three approaches, the analyzed textbooks do not seem to have coherent views on which examples (black boxes) at different levels to keep closed and which to unpack for the students, not within a textbook or between them.

One interpretation is that as a teacher, you can teach about industrial processes in these different ways. By making them explicit technology teachers can reflect on how they want to teach, as the approach they choose can affect what they can make visible regarding the technical solutions of industrial processes.

6. REFERENCES

Andersson-Bakken, E., Jegstad, KM., & Bakken, J. (2020) Textbook tasks in the Norwegian school subject natural sciences: what views of science do they mediate? *International Journal of Science Education, 42*(8), 1320-1338, DOI: 10.1080/09500693.2020.1756516

Barak, M., & P. J. Williams (2007). Learning elemental structures and dynamic processes in technological systems: a cognitive framework. *International Journal of Technology & Design Education 17*(3), 323-340.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology, 3*(2), 77-101.

Checkland, P. (1981). *Systems thinking, systems practice*. Wiley.

Chiappetta, E. L., & Fillman, D. A. (2007). Analysis of five high school biology textbooks used in the United States for inclusion of the nature of science. *International Journal of Science Education, 29* (15), 1847–1868. https://doi.org/10.1080/09500690601159407

Deng, Z., & Luke, A. (2008). Subject matter. Defining and theorizing school subjects. In F. M. Connelly, M. F. He, & J. Phillion (Eds.*), The SAGE handbook of curriculum and instruction* (pp. 66–87). Sage Publications.

DiGiuseppe, M. (2014). Representing nature of science in a science textbook: Exploring author– editor–publisher interactions. *International Journal of Science Education, 36*(7), 1061–1082. https://doi.org/10.1080/09500693.2013.840405

Englund, B. (2006). *Vad har vi lärt oss om läromedel? En översikt över nyare forskning: underlagsrapport till Läromedelsprojektet.* https://www.skolverket.se/download/18.6bfaca41169863e6a655d8c/1553959190350/Forskarbilaga.pdf

Fan, L., Zhu, Y., & Miao, Z. (2013). Textbook research in mathematics education: development status and directions. *ZDM – The international Journal on mathematics education, 45*(5), 1–14.

Kahveci, A. (2010). Quantitative analysis of science and chemistry textbooks for indicators of reform: A complementary perspective. *International Journal of Science Education, 32*(11), 1495–1519. https://doi.org/10.1080/09500690903127649

Korsell, I. (2007). *Läromedel: det fria valet? Om lärares användning av läromedel.* Liber.

Lindensjö, B., & Lundgren, U.P. (2000). *Utbildningsreformer och politisk styrning.* Liber.

Oates, T. (2014). *Why textbooks count.* Cambridge Assessment.

O'Connor, J., & McDermott, I. (1997). *The art of systems thinking: essential skills for creativity and problem solving.* Thorsons.

SOU 2021:70. *Läromedelsutredningen – böckernas betydelse och elevernas tillgång till kunskap*. https://www.regeringen.se/contentassets/e13e110fdc30401f9bf4a6ee8fa160a7/laromedelsutredningen--bockernas-betydelse-och-elevernas-tillgang-till-kunskap-sou-202170/

Stern, L., & Roseman, J. E. (2004). Can middle-school science textbooks help students learn important ideas? Findings from Project 2061s curriculum evaluation study: Life science. *Journal of Research in Science Teaching*, *41*(6), 538–568. https://doi.org/10.1002/tea.20019

Swedish National Agency for Education. (2022a). *Kommentarmaterial till kursplanen i teknik – grundskolan* https://www.skolverket.se/publikationsserier/kommentarmaterial/2022/kommentarmaterial-till-kursplanen-i-teknik---grundskolan

Swedish National Agency for Education. (2022b). *Läroplan för grundskolan samt för förskoleklassen och fritidshemmet*, *Lgr 22*. Skolverket.

Valverde, G. A., Bianchi, L. J., Wolfe, R. G., Schmidt, W. H., & Houang, R. T. (2002). *According to the book: Using TIMSS to investigate the translation of policy into practice through the world of textbooks.* Springer Dordrecht. Kluwer.