Chapter 4
Cross-Curriculum System Concepts and Models

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Abstract Systems thinking is a tool for understanding that one could learn to use gradually through practice and continual improvement in relation to different subject areas. In the subject technology, as well as biology, systems are part of the curriculum but there is a lack of knowledge about cross-curricular learning about systems. In this chapter, a qualitative system literature review is used to present and compare system concepts and models used in two different subjects, biology and technology. Furthermore, a reflection on what system aspects might contribute to cross-curricular learning opportunities is done using the structure, behaviour and function (SBF) system thinking model. In the analysis of the 22 articles, 12 about biology education and 10 about technology education, similarities and differences in the structural and behavioural aspects between the two subjects stand out. On the other hand, it became clear that the functional aspect only occurs in relation technological systems. There are system aspects that cross over fields that might have potential for new ways of teaching about systems and develop systems thinking. This is not least important for developing understanding and preparedness to address sustainability issues today and tomorrow, something that all teachers have a responsibility to do.

Keywords Systems thinking · Structure · Behaviour · Function (SBF) model · Cross-curricular · Variation theory · Literature review

Pupils in schools are often faced with many different subjects during one day. They have a biology lesson on oxygen function in the body in the morning, and after lunch, they go to a lesson in history about treadmills and their significance for industrial development. Teachers in the different subjects often do not know, or think about, the similarities between their subjects, they rather indicate the differences that exist between one's own subject and other subjects. However, there are concepts and models that might enhance pupils' learning if they were used in various subjects.

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The aim of this chapter is to present and compare system concepts and models used in two different subjects, biology and technology, and reflect on how an awareness regarding system aspects may contribute to cross-curricular learning opportunities. Learning about systems should include, amongst other characteristics, a focus on methodologies that will foster collaboration, discussion, and reflection (Jacobson & Wilensky, 2006). However, a unified conceptual framework for the development of systems thinking in education is still absent from most schools' curricula (Jacobson & Wilensky, 2006; Plate, 2010).

When I started my research about technological systems almost 20 years ago, I had been teaching technology and science for some years both in teacher education and in compulsory school. During these years, I had on several occasions been struck by the untapped opportunities that exist when it comes to systems thinking. Systems thinking is a tool for understanding that one could learn to use gradually through practice and continual improvement in relation to different subject areas (Mella, 2012). When I was recently observing teaching in biology and technology for student teachers, it came to my consciousness again that systems thinking could be more effectively used in teaching. One session I observed was about the human body, and it was clear that students encounter systems in various subjects without us, as teacher educators, using this opportunity to develop an understanding of systems and systems thinking as a model to see both the parts and the whole of a phenomenon. Seng (2006) proposed that systems thinking is an effective approach for observing reality and constructing sensible and coherent models which make us look for connections in the world around us. As teachers and teacher educators, we could make better use of systems thinking to describe and understand phenomena, to encourage our students and student teachers to see the connections and understand the whole in relation to different subject areas. In the subjects, biology and technology, there are several areas where systems are present. Therefore, in this chapter, I focus on these two subjects when striving for a more developed conceptual framework of systems and systems thinking in education. A literature review of system concepts and models in biology and technology education forms the basis for the comparisons and further reasoning regarding the development of system concepts and models in different subjects.

4.1 Background

Systems thinking can be described as an ability to recognize, describe and model complex aspects of reality as systems. This implies identifying important elements of the system and the varied interdependency between these elements. Mella (2012) describes systems thinking by five rules, where the first one obliges us to "see the trees and the forest" (p. 9).

> To understand reality, we must not limit ourselves to observing only individual objects, elements, or entities; it is necessary to "see" even larger groupings that these compose, attributing to them an autonomous meaning. The converse process is also true: we cannot

> limit our selves only to considering an object in its unity but must force ourselves "to see" its component parts (Mella, 2012, p. 9).

Systems thinking is a holistic approach for examining complex problems and systems that focuses on the interactions amongst system components and the patterns that emerge from those interactions. Systems thinking can help students develop higher-order thinking skills in order to understand and address complex, interdisciplinary, real-world problems (Assaraf & Orion, 2005). Because of these potential benefits, there have been efforts to support the implementation of systems thinking approaches as a cross-curricular method (Forrester, 1993; Sweeney, 2005). Even though there are differences between the systems which are evident in biology and technology, there is potential for the development of general understandings of systems thinking that could support higher-order thinking if effectively promoted in education. Ho (2019) stated that to help students be better equipped to solve problems involving complex systems, it is important to find ways to incorporate systems and systems thinking in education, and in that way enable students to analyse and understand system characteristics. Systems thinking approaches in education are increasingly widespread in disciplines such as biology, engineering, geoscience and sustainable development, but there is yet more to learn about how to develop cross-curricular concepts relevant to systems and systems thinking. There is a lack of research investigating cross-curricular system concepts and models within education.

Making sense of complex systems requires that a person constructs a network of concepts and principles about some domain that represents key phenomena and the interrelationships amongst different levels of the system, whether it is macro to micro or structure to function (Goel et al., 2009; Hmelo-Silver & Pfeffer, 2004). Research has demonstrated that people can transfer deep principles of complex systems across domains when examined in the context of simulations (Goldstone & Sakamoto, 2003). Thus, to be able to transfer knowledge from one context to another it is essential to discern both similarities and differences between contexts (Marton, 2006). Possible aspects to discern in one situation might be irrelevant to another situation. However, to be able to transfer knowledge it is essential to see different things of the same sort (Marton, 2014). In relation to systems components and the connections between components are used to describe a system, in that way they can be understood as the same, interrelated components. However, the nature and function of the components differ depending on the context in which the system exists. In a biological system such as an ecosystem, components are used to describe a food web with animals and green plants. In a technological system, such as a wastewater system, components are used to describe pipes and pumps. Even though these components are different when it comes to their properties and functions in each system, they are understood as components in a system, parts that make up the whole. When teaching about systems in different subjects, one should be aware of aspects that could be experienced as different but at the same time be examples of the same. Components in an ecosystem are different from the ones in a wastewater system but they all play a role in the system as components, this means seeing them as similar in one sense and different in another. Using and understanding this in teaching can help students prepare for the unknown by the means of the known.

4.2 Method

Several models have been developed as conceptual representations of systems thinking which make different levels explicit. The literature review presented in this chapter builds on a sample of research about systems from 2010–2020 using an approach described as structure–behaviour–function (SBF) thinking (see also chapter by Mioduser) (Goel et al., 2009). Hmelo-Silver and Pfeffer (2004) suggest that structure–behaviour–function (SBF) theory may provide a structure for thinking about complex systems in different areas. In the SBF thinking model, the different levels of a system, in terms of structures, behaviours and functions, and their interconnections can be identified (Goel et al., 2009; Hmelo-Silver & Pfeffer, 2004; Hmelo-Silver et al., 2008). The *structure* refers to parts of the system that vary in size and organization and answer the "what" of the system, meaning the components of the system as well as the connections between them. The *behaviour* specifies the "how" of the system, the processes occurring in the system, and the *function* refers to the role or output of the system or subsystems concerning the "why" question, the purpose of the system. The SBF system thinking model has been used for explaining and justifying the design of physical devices such as electrical circuits and heat exchangers (Goel et al., 1996) as well as the respiratory system and an aquarium ecosystem (Hmelo et al., 2000; Hmelo-Silver & Pfeffer, 2004).

4.2.1 The Literature Review

A literature review is useful when the aim is to provide an overview of a certain issue such as system concepts and models in biology and technology education. "Typically, this type of literature review is conducted to evaluate the state of knowledge on a particular topic" (Snyder, 2019, p. 334). To find the characteristics of systems in the subjects biology and technology, a literature review of academic journal papers published from 2010 to 2020 was conducted. Sources were limited to peer-reviewed academic journal papers that are indexed, reliable and searchable because these have a rigorous publication procedure. Therefore, the quality of the journal papers can be trusted (Snyder, 2019). A qualitative systematic review is used to interpret and broaden the understanding of a particular phenomenon, here system concepts and models in biology and technology education (Grant & Booth, 2009). By using a literature review, an identification of what has been accomplished within the area is possible and allows for comparisons of findings from qualitative studies in the two subject areas.

The databases Educational Resources Information Centre (ERIC) and ProQuest were used as a source to find articles that could give a relevant base to present and compare system concepts and models used in two different subjects, biology and technology. Keywords that were used to find relevant journal papers were in the first step a combination of *biology education* and *system*, or *technology education* and *system* within the abstract of a full text peer-reviewed paper between 2010 and 2020.

Biology education AND system - 116 hits

Technology education AND system – 1975 hits

The next step was to narrow the search of technology-related papers using the keywords *technology education* and *technological system.* Technology education is in many countries only connected with computer science, and in this study, technology is understood in a broader perspective where technology refers to human-made artefacts and systems that solve a problem or fulfil a desire (Mitcham, 1994). Therefore, including *technological* in combination with *system* addresses systems of complex, problem-solving components that solve problems or fulfil goals using available means and directed to different kinds of technological areas (Huges, 1987). This was thus a way of trying to reduce the number of papers that solely focus on technology as computer science or as other digital tools.

Technology education AND technological system – 206 hits

Systems are often connected to computers, described as systems per se or as parts of larger systems. The purpose of this study is to focus on the subjects technology and biology in combination with system, not with the main focus on the use of computers as digital tools in teaching. Therefore, in a try to narrowing the search further in both groups', the word computer*, was excluded from the list of 206 hits and 116 hits.

Technology education AND technological systems NOT computer* - 74 hits

Biology education AND systems NOT computer* - 50 hits

After this selection within the database, the abstracts were read carefully to identify those relevant to the school subjects biology and technology in combination with system concepts and models. In this step of the analysis, exclusion criteria were education systems, management systems or the use of technology as pedagogical tools rather than system aspects of a subject. This analysis ended up with 10 technology education papers and 12 biology education papers listed in Tables 4.1 and 4.2.

4.2.2 The SBF Systems Thinking Model

To analyse the remaining papers and break down, the content in relation to system concepts and models the SBF system thinking model (Goel et al., 2009; Hmelo-Silver & Pfeffer, 2004) was used. The purpose was also to identify similarities and

Table 4.1 Technology-related papers presented in alphabetic order of the first author

Technology–10 papers			
Author	Title	Journal	Year
Autio, Ossi; Olafsson, Brynjar; Thorsteinsson, Gisli	Examining Technological Knowledge and Reasoning in Icelandic and Finnish Comprehensive Schools	Design and Technology Education Vol. 21, Iss. 2,	2016
Compton, Vicki J; Compton, Ange D.	Teaching Technological Knowledge: Determining and Supporting Student Learning of Technological Concepts	International Journal of Technology and Design Education Vol. 23, Iss. 3,	2013
Hallström, Jonas; Klasander, Claes	Visible Parts, Invisible Whole: Swedish Technology Student Teachers' Conceptions about Technological Systems	International Journal of Technology and Design Education Vol. 27, Iss. 3,	2017
Harsh, Matthew; Bernstein, Michael J.; Wetmore, Jameson; Cozzens, Susan; Woodson, Thomas; et al	Preparing Engineers for the Challenges of Community Engagement	European Journal of Engineering Education Vol. 42, Iss. 6,	2017
Hope, Gill	Designing Technology: An Exploration of the Relationship between Technological Literacy and Design Capability	Design and Technology Education Vol. 18, Iss. 2,	2013
Jung, Kiho; Otaka, Yuki	The Introduction of a Thin-Bending Wood Horn Speaker as Multipurpose Teaching Material in Japanese Junior High School Technology Classes	World Journal of Education Vol. 9, Iss. 6,	2019
Park, Wonyong	Beyond the 'Two Cultures' in the Teaching of Disaster: Or How Disaster Education and Science Education Could Benefit Each Other	Educational Philosophy and Theory Vol. 52, Iss. 13,	2020
Schooner, Patrick; Nordlöf, Charlotta; Klasander, Claes; Hallström, Jonas	Design, System, Value: The Role of Problem-Solving and Critical Thinking Capabilities in Technology Education, as Perceived by Teachers	Design and Technology Education Vol. 22, Iss. 3,	2017
Schooner, Patrick; Klasander, Claes; Hallström, Jonas	Swedish Technology Teachers' Views on Assessing Student Understandings of Technological Systems	International Journal of Technology and Design Education Vol. 28, Iss. 1,	2018

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Table 4.1 (continued)

Technology–10 papers			
Author	Title	Journal	Year
Svensson, Maria; Ingerman, Ake	Discerning Technological Systems Related to Everyday Objects: Mapping the Variation in Pupils' Experience	International Journal of Technology and Design Education Vol. 20, Iss. 3,	2010

differences in system levels between the papers in biology and technology and reflect on how an awareness regarding system aspects in education may contribute to cross-curricular learning opportunities. The articles were read, the purpose of the articles was identified and the system aspect that was the focus of the articles identified using the SBF systems thinking model where the articles focusing mainly on the organization, size and components of a system were categorized as a structural system aspect. Articles that on the other hand focus on the processes in the system and how the system works were categorized as behavioural system aspects. If the article had a strong connection to the purpose of the system and answers the why-question, they were categorized with a focus on functional system aspects.

4.2.3 Limitations of the Study

A common problem when using a literature review is the risk of making limitation of samples too narrow and failing to describe in detail how the literature review was conducted (Snyder, 2019). With this in mind, the different steps in the selection of relevant articles are described and the process of limiting the search is motivated, but nevertheless, it is possible that articles of relevance fall outside this search because of the chosen limitations. It is also the case that the database used does not cover all articles within the field even if it is a database used for articles relevant in education, which becomes another source of error. Despite this, it is possible to describe indications on system concepts and models used in biology and technology, and reflect on how an awareness regarding system aspects in education may contribute to cross-curricular learning opportunities.

4.3 Results

The SBF systems thinking model, applied to the identified literature about systems in technology and biology education, makes differences and similarities between systems discernible (see Table 4.3). The results of how systems are described in the two subjects are presented first and after that the identified similarities and

Table 4.2 Biology-related papers presented in alphabetic order of the first author

Biology–12 papers			
Author	Title	Journal	Year
Akçay, Süleyman	Prospective Elementary Science Teachers' Understanding of Photosynthesis and Cellular Respiration in the Context of Multiple Biological Levels as Nested Systems	Journal of Biological Education Vol. 51, Iss. 1,	2017
Ballen, J. Cissy & Greene, W. Harry	Walking and talking the tree of life: Why and how to teach about biodiversity	PLOS Biology 15(3)	2017
Berat, AHİ	Thinking about digestive system in early childhood: A comparative study about biological knowledge	Cogent Education; Abingdon Vol. 4, Iss. 1,	2017
Boersma, Kerst; Waarlo, Arend Jan; Klaassen, Kees	The Feasibility of Systems Thinking in Biology Education	Journal of Biological Education Vol. 45, Iss. 4,	2011
Çuçin, Arzu; Özgür, Sami; Güngör Cabbar, Burcu	Comparison of Misconceptions about Human Digestive System of Turkish, Albanian and Bosnian 12th Grade High School Students	World Journal of Education Vol. 10, Iss. 3,	2020
Dam, Michiel; Ottenhof, Koen; Carla Van Boxtel; Janssen, Fred	Understanding Cellular Respiration through Simulation Using Lego® as a Concrete Dynamic Model	Education Sciences; Basel Vol. 9, Iss. 2,	2019
Hart, Emily R.; Webb, James B.; Danylchuk, Andy J.	Implementation of Aquaponics in Education: An Assessment of Challenges and Solutions	Science Education International Vol. 24, Iss. 4,	2013
Kattmann, Ulrich	A Biologist's Musing on Teaching about Entropy and Energy: Towards a Better Understanding of Life Processes	School Science Review Vol. 99, Iss. 368,	2018
Knippels, Marie-Christine P. J.; Arend, Jan Waarlo	Development, Uptake, and Wider Applicability of the Yo-yo Strategy in Biology Education Research: A Reappraisal	Education Sciences, Vol. 8, Iss. 3,	2018

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Table 4.2 (continued)

Biology–12 papers			
Author	Title	Journal	Year
van Mil, Marc H. W.; Boerwinkel, Dirk Jan; Waarlo, Arend Jan	Modelling Molecular Mechanisms: A Framework of Scientific Reasoning to Construct Molecular-Level Explanations for Cellular Behaviour	Science & Education Vol. 22, Iss. 1,	2013
Ozgur, Sami	The Persistence of Misconceptions about the Human Blood Circulatory System amongst Students in Different Grade Levels	International Journal of Environmental and Science Education Vol. 8, Iss. 2,	2013
Tripto, Jaklin; Assaraf, Orit Ben; Snapir, Zohar; Amit, Miriam	How Is the Body's Systemic Nature Manifested amongst High School Biology Students?	Instructional Science: An International Journal of the Learning Sciences Vol. 45, Iss. 1,	2017

differences. In the discussion, these results are used to elaborate on how awareness regarding system aspects used in biology and technology education may contribute to cross-curricular learning opportunities.

The technology-related articles are mainly linked to functional aspects, and the biology-related articles are to a greater extent linked to behavioural aspects. The similarities are mainly related to structural aspects, although there are differences in the two subject areas in how one chooses to describe the structure, as levels and/or as components.

4.3.1 Systems in Biology Education

Research about biological systems in education is related to understanding concepts with a structural character, described as different levels in the systems and how these levels are connected (see, e.g., Knippels & Waarlo, 2018). It is about organizing the system with a focus on the size of different parts, for example starting on the level of the organism and descend from there to the level of the organ and the cell and to ascend to the level of the population and community (Boersma et al., 2011).

In relation to the behavioural aspect, flows of resources are described as a concept of energy and matter related to ecosystems and systems in the body (Akçay, 2017; Çuçin et al., 2020). There are also examples of studies that identify misconceptions in relation to learning about systems in the human body such as circulation and cell systems (see, e.g., Çuçin et al., 2020). The misconceptions are connected to the structural aspect, in the choice of components used to describe the system, as well as

Table 4.3 Overview of the literature and the SBF aspects

Subject area	Article	SBF aspects		
		Structure	Behaviour	Function
Biology education	Akçay, Süleyman		**Flow**—of energy and matter in photosynthesis and cellular respiration **Process**—interactions between energy and matter in ecosystems	
	Ballen, J. Cissy & Greene, W. Harry	**Level**—taxonomy to organizing details of biodiversity		
	Berat, AHİ	**Component**—part in the digestive system	**Process**—what happens in organs	
	Boersma, Kerst; Waarlo, Arend Jan; Klaassen, Kees	**Level**—starting in something small (an organism) and ending in something bigger (the population)		
	Çuçin, Arzu; Özgür, Sami; Güngör Cabbar, Burcu	**Component**—drawings of the human digestive systems with different components **Connection**—between different components in the human digestive systems	**Flow**—input and output	
	Dam, Michiel; Ottenhof, Koen; Carla Van Boxtel; Janssen, Fred	**Level**—cellular respiration from microscopic to macroscopic	**Process**—activities that connect different organization levels	
	Hart, Emily R; Webb, James B; Danylchuk, Andy J	**Component**—physical parts		

(continued)

Table 4.3 (continued)

Subject area	Article	SBF aspects		
		Structure	Behaviour	Function
	Kattmann, Ulrich		**Flow**—energy flow in life processes **Process**—exergonic and endergonic reactions	
	Knippels, Marie-Christine PJ; Arend, Jan Waarlo	**Level**—starting in something small (a molecule) and ending in something bigger (a population)		
	van Mil, Marc H. W; Boerwinkel, Dirk Jan; Waarlo, Arend Jan	**Level**—starting in something small (a molecule) and ending in something bigger (a cell)	**Process**—activities that connect different levels	
	Özgur, Sami		**Flow**—blood circulation	
	Tripto, Jaklin; Assaraf, Orit Ben; Snapir, Zohar; Amit, Miriam	**Level -** hierarchy levels of the organism	**Flow**—matter **Process**—transfer between cells and environment	
Technology education	Autio, Ossi; Olafsson, Brynjar; Thorsteinsson, Gisli		**Process**—the functions in different parts in a mechanical system	**Purpose**—solving problems
	Compton, Vicki J; Compton, Ange D	**Component**—identifying parts in different systems **Connections**—between components to enable a specific function		

(continued)

Table 4.3 (continued)

Subject area	Article	SBF aspects		
		Structure	Behaviour	Function
	Hallström, Jonas; Klasander, Claes	**Component**—visible and invisible parts of the mobile phone, elevator and electric grid	**Flow**—energy, matter and information	
	Harsh, Matthew; Bernstein, Michael J; Wetmore, Jameson; Cozzens, Susan; Woodson, Thomas; et al		**Process**—the influence of human actions in different functions of a system	**Purpose**—solving problems and changing the conditions for humans and for the environment
	Hope, Gill			**Purpose**—solving problems and developing new tools, artefacts and environments
	Jung, Kiho; Otaka, Yuki	**Component**—parts included in a wood horn speaker	**Process**—the functions in different parts in the speaker	
	Park, Wonyong		**Process**—identifying failures in processes	**Purpose**—solving problems and changing the conditions for humans

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Table 4.3 (continued)

Subject area	Article	SBF aspects		
		Structure	Behaviour	Function
	Schooner, Patrick; Nordlöf, Charlotta; Klasander, Claes; Hallström, Jonas	**Components**—identifying parts in different systems	**Flow**—input–output of information **Process**—identifying interruptions in the process, “Black-boxing”	
	Schooner, Patrick; Klasander, Claes; Hallström, Jonas	**Component**—identifying parts in different systems	**Flow**—causality between input and output **Process**—how the parts and the whole of the system operating	**Purpose**—solving problems and changing the conditions for humans and for the society
	Svensson, Maria; Ingerman, Ake	**Component**—identifying parts in different systems. Micro and macrolevel **Connections**—between components to enable a specific function	**Flow**—material, energy and information **Process**—transportation, transformation, control and store of flow in different components	**Purpose**—solving problems and changing the conditions for humans

to the behavioural aspect in the descriptions of flow and processes in different body components.

No functional aspects are evident in the biology-related articles in this study which indicate that there is no specific focus on the role or output of the system or subsystems concerning the “why” question, the purpose of the system.

4.3.2 Systems in Technology Education

Research about technological systems shows that concepts that seem to have significance for learning and understanding of systems are related to components within the structural aspect (see, e.g., Compton & Compton, 2013; Schooner et al., 2018). Components are often described on a general level as physical parts of systems. Thus, in some studies the components mentioned are connected to specific content such as the mobile phone, elevator and electric grid (Hallström & Klasander, 2017) or the wooden horn speaker (Jung & Otaka, 2019). Different characteristics of components are identified and discussed in some studies, for example in Hallström and Klasander (2017), components as visible or invisible are mentioned, and in Svensson and Ingerman (2010) a way of analyzing components on three levels, the level of the object themselves, the micro-level inside objects, the macro-level outside the objects is suggested.

The behavioural aspect in technological systems describes the concepts of flow of resources as energy, matter and information. The flow is normally expressed as the input and output in the system. The processes within components, how the parts and the whole of the system operates, are also included in the behavioural aspect. This has to do with the functioning of the components in the system when transporting, transforming, controlling or/and storing the flow of resources (see, e.g., Schooner et al., 2017; Svensson & Ingerman, 2010).

In relation to the functional aspect, answering the “why” question, solving problems for humans in society seems to be an important concept mentioned in some articles in relation to the purpose of technological systems. There is also a focus on how the functional aspect of systems involves solving problems and changing the conditions for humans over time (see, e.g., Autio, Olafsson & Thorsteinsson, 2016; Park, 2020).

4.3.3 Summarizing the Result of the Literature Review

The results of the literature review indicate that there are system concepts that are used in both biology and technology education. In relation to the SBF systems thinking model, structural and behavioural aspects are found in the biology as well as in technology literature. However, the functional aspect is only identified as an aspect in the technology-related literature. An interpretation of this may be that the conducted studies in technology during the last 10 years have mainly focused on establishing technology as a separate subject. This requires clear motivations and arguments about the purpose of various teaching elements such as technological systems. Another interpretation is that systems in technology to a greater extent are still developing and changing while systems in biology are more established and have been used in teaching for a long time; therefore, their purpose does not have to be discussed. Furthermore, function in biology is more difficult to explain and discuss than in technology. In technology, there is always a system builder behind the technological system whereas in biological systems there is no system builder, described by Dawkins (1996) as the "blind watchmaker". In biological systems "natural selection is the blind watchmaker, blind because it does not see ahead, does not plan consequences, has no purpose in view" (Dawkin, 1996, p. 21). This might also be a reason why the functional aspect does not appear in the articles connected to biological systems.

In respect to the two investigated subjects, the system concepts which therefore have potential for contributing to cross-curricular learning opportunities are aspects related to the structure - *components as part of the system, characteristics of components* and *structural level of components,* and to the behaviour *–the character of flow (energy, matter, information), the input and output, the processes within components and between components and levels.*

4.4 Discussion

Teachers' and teacher educators' knowledge about the similarities and differences in the use of system concepts and models provides an opportunity to see recurring patterns in systems thinking between subjects and disciplines. Such knowledge is essential to meet the global problems we face, not least in relation to our environment (see, e.g., Rosenkränzer et. al., 2016). Systems thinking represents one such pedagogical approach, in which a holistic framework empowers both teachers and students to recognize how fundamental concepts, taught in the classroom, can be used as tools to better address complex, multicomponent modern challenges (Ho, 2019). The identified concepts of the SBF system thinking model have potential as a pedagogical approach, where structural and behavioural aspects in the two investigated subjects biology and technology open up possibilities for identifying things that vary in the mentioned aspects. This could be a first step towards transfer of system knowledge and contribute to cross-curricular learning opportunities.

To be able to generalize and transfer understanding of one systems concept into new contexts, the learner needs to develop the capability to discern differences and similarities of system concepts and the aspects that are critical for understanding the system concepts (Marton, 2006). However, using an understanding of the system concept in one context is not always easily transferred to another context. Magntorn and Helldén (2007) found this in their study about transferring system knowledge from one ecosystem (a forest), studied in detail, to another ecosystem (a pond).

They found that the structural and behavioural levels according to the definition of Hmelo-Silver and Pfeffer (2004) are difficult for the students to transfer to new environments, even though the use of the SBF system thinking model could be a first step in identifying similarities and differences in system concepts supplemented with discerned critical aspects.

Recognizing the three SBF aspects, structure, behaviour and function, as dimensions that can vary between systems, opens up opportunities for cross-curricular learning about systems and systems thinking. If we want to use systems thinking as a pedagogical approach, a way forward could be to use the teaching situations where systems are present but might not be at the core of the content, to learn to discern critical aspects of systems. For this to happen, we have to encounter and experience certain necessary patterns of variation and invariance (Marton, 2014). To give an example, we can think of students that have a lesson about the digestive system in the body, describing different parts of that system and how the food is processed in these parts. Using SBF we can see that the structure and the behaviour of the system are relevant system aspects in relation to this. The teacher, when teaching about this, could draw students' attention to the stomach as a component with processes for transforming matter (food) and compare it with components that have a similar purpose such as a cell or an engine. Identifying similarities (the transformation of matter) and differences (the properties of the structure) could be a way of developing students' awareness of aspects that vary in different system contexts. When looking at systems in biology and technology, it is evident that similarities and differences connected to structural and behavioural aspects are possible to use to visualize variation. In the current literature review, tentative critical aspects in relation to the concept structure and behaviour have been discerned and in that way offer a starting point for cross-curricular opportunities. On the other hand, problems arise with regard to the functional aspect if one tries to answer the question why does this system exist; there is no answer for a biological system but there is always a purpose with the technological systems conceived by man (Dawkins, 1996).

The aim of this chapter is to present and compare system concepts and models used in two different subjects, biology and technology and reflect on how an awareness regarding system aspects may contribute to cross-curricular learning opportunities. A question to ask is what do teachers gain from knowing about cross-curriculum system concepts and models? An answer to that after this literature review is that there are system aspects that cross over fields that might have potential for new ways of teaching about systems. The awareness of critical aspects of system concepts in one system context, for example, a biological system, enhances the likelihood of being able to discern the same and other critical aspects in another system context, for example, a technological system. To be aware of different aspects of systems concepts opens up an opportunity to understand what a system is in new and more powerful ways. It also enables a more nuanced way of understanding specific systems such as ecosystems or wastewater systems. Being aware of systems concepts and systems thinking approaches that exist today in different school subjects and being open to learning in a cross-curricular manner allow learners to better understand and manage various situations in their environment. This is crucial for being able to understand

and deal with sustainability problems in society, something that all teachers have a responsibility to prepare their students for, regardless of which school subject they teach.

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