

A CROSS-SECTORAL APPROACH TO STEM EDUCATION: A MULTI-PERSPECTIVE DESIGN

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Abstract. *The complexity of the STEM education ecosystem at all the educational levels has been risen by the COVID-19 pandemic. The search for a sustainable ecosystem leads to the cross-sectoral approach to STEM education. A sustainable STEM education ecosystem is also characterized by the coherence between the STEM education levels. The research aims at creating a theoretical model of the multi-perspective design of STEM education within a cross-sectoral approach for identifying the implications for further research on the cross-sectoral STEM education. The qualitative research was carried out. Research data were collected through the analysis of published research works. Content analysis was used for the analysis of the collected data. The theoretical novelty of the cross-sectoral STEM education is indicated: the structure and phases of STEM Education implementation and multi-perspective design. The exploratory research allows widening the traditional boundaries of the STEM education (teacher-content-student) with the concepts of educational discipline, conceptual change, all language as the unity, the digitalised educational process, and the cross-sectoral approach. The research is novel in the implications for further research on the cross-sectoral STEM education.*

Keywords: *all language as the unity, conceptual change, cross-sectoral approach, digitalized educational process, educational contents, OST (out-of-school time) providers, STEM (Science, Technology, Engineering, Mathematics).*

Introduction

In the increasingly complex contemporary world, STEM (Science, Technology, Engineering, Mathematics) education is the driver for making Europe climate neutral for our greener future and protecting our natural habitat. Greener sustainable ecosystems aimed at the people well-being as proposed by the European Green Deal will be good for people, planet and economy (European Commission, 2019). It is worth noting that an ecosystem means “an interdependent group of actors (enterprises, people, things) sharing a common

environment to achieve a mutually beneficial purpose” (Gartner Inc., 2017) is meant. “No one will be left behind” (European Commission, 2019). The COVID-19 pandemic has risen the complexity of the STEM education ecosystem (Ahrens & Zasczerinska, 2020) at all the educational levels. It is important to emphasize that the design of a complex ecosystem is based on the multi-perspective analysis.

The search for a sustainable ecosystem leads to the cross-sectoral approach to STEM education. The previous research in STEM education focused on the cross-sectoral collaborations between a school and outside of school (Traphagen & Traill, 2014). Outside of school included afterschool and summer programs, science centers and museums, home with their families, and online (Traphagen & Traill, 2014).

Later, the STEM Learning Ecosystems on the basis of Community of Practice (CoP) were modelled (Allen, Lewis-Warner, & Noam, 2020). A Community of Practice promotes local collaborations among school districts, OST (out-of-school time) providers, businesses, cultural institutions, research organizations, and funders (Allen, Lewis-Warner, & Noam, 2020).

However, a sustainable STEM education ecosystem is also characterized by the coherence between the STEM education levels.

The question that enabled the research is: What is a multi-perspective design of STEM education based on a cross-sectoral approach?

The research aim is to create a theoretical model of the multi-perspective design of STEM education based on a cross-sectoral approach underpinning the elaboration of implications for further research on the cross-sectoral STEM education.

The present work tends to create a theoretical model of the multi-perspective design of STEM education based on the cross-sectoral approach. A model creation is “a qualitative process” (Krippendorff, 2004). Hence, this work is qualitative. Data were collected through the analysis of published research works.

The novelty of the research will be shown in the implications for further research on the cross-sectoral STEM education.

Conceptual Framework

By a conceptual framework, the unity of concepts that are used for a particular study is meant (Ahrens & Zaščerinska, 2014). A concept is defined as a verbal abstraction drawn from observation of a number of specific cases (Watt & van den Berg, 2002).

The research proceeds in accordance to the key concepts represented in a logical sequence: perspective → STEM → education → cross-sectoral approach → design.

Perspective embodies “certain fundamental assumptions” (Barry, 2002).

STEM refers to Science, Technology, Engineering and Mathematics (Zaščerinska, Andreeva, & Aleksejeva, 2015). They can also be defined as educational disciplines. Also, by STEM as educational disciplines, subject content is meant (Zaščerinska, 2011). Both the educational discipline and contents relate to the subject knowledge that develops (Zaščerinska, 2013) in the following sequence: Phase 1 the existing knowledge, Phase 2 the knowledge variety, Phase 3 the new knowledge.

STEM as educational disciplines are closely connected with the theory of Conceptual Change (Rustaman, 2020). The conceptual change is advanced in the following way: Phase 1 the existing concept is actualized, Phase 2 the quasi-concept is foregrounded, Phase 3 the new concept is arrived.

Both STEM perspectives, namely subject content and conceptual change, are closely inte-related with the language perspective (Zaščerinska, 2013). Language is considered as the unity of all language (mother tongue, foreign language, academic language, etc) (Zaščerinska, 2013). The language enhancement moves from the General English and Academic Native Language in Phase 1 through English for Academic Purposes in Phase 2 to Mother Tongue in Phase 3 (Zaščerinska, 2013).

Another aspect is that STEM often requires interdisciplinary knowledge, thereby adopting the methodology of interdisciplinary studies (Ahrens, Purvinis, Zaščerinska, & Andreeva, 2016).

STEM education is delivered through the educational process (Zaščerinska, Zaščerinskis, Andreeva, & Aleksejeva, 2013). The educational process sequentially evolves: it starts in Phase 1 with teaching, then it moves to Phase 2 to peer-learning, and, finally, it arrives at Phase 3 learning (Ahrens & Zaščerinska, 2010). Together with the development of the technological progress, the process of STEM education has been digitalized. The digitalisation of the process of STEM education proceeded (Aleksejeva, Zascerinskis, Abjalkiene, Gukovica, Zascerinska, & Ahrens, 2021)

- from the in-person only educational process
- through the blended one which combined both the in-person and digital educational processes
- further to the only online educational process catalysed by the COVID-19 pandemic, and
- to the hyflex (hybrid flexible) educational process which simultaneously mixes both the on-campus and off-campus educational processes.

The cross-sectoral approach to STEM education in this work implies different education sectors. These education sectors imply school, vocational, higher and adult education.

The term “design” is also synonymously understood as “model” in this research. The pedagogical meaning of model is “a pattern” (Belickis et al., 2000). A model in mathematics is “an interpretation of a theory” (Kühne, 2005). In engineering, business and computer sciences, a model describes a system (Banks, Carson, Nelson, & Nicol, 2004). This research considers the term “model” via the interdisciplinary analysis. The disciplines used for the formulation of the newly defined notion of the term “model” include pedagogy, mathematics, engineering, business and computer sciences. Thus, the model notion means “a pattern of individual’s or individuals’ interpretation of a phenomenon” (Ahrens, Purvinis, Zaščerinska, & Andreeva, 2015). Models can be expressed in different presented forms. Models can be verbal, graphic, computer, etc. A model can be characterized (Ahrens, Purvinis, Zaščerinska, & Andreeva, 2015). Figure 1 represents the structure of characteristics. The model characteristics are described by parameters (Ahrens, Purvinis, Zaščerinska, & Andreeva, 2015).

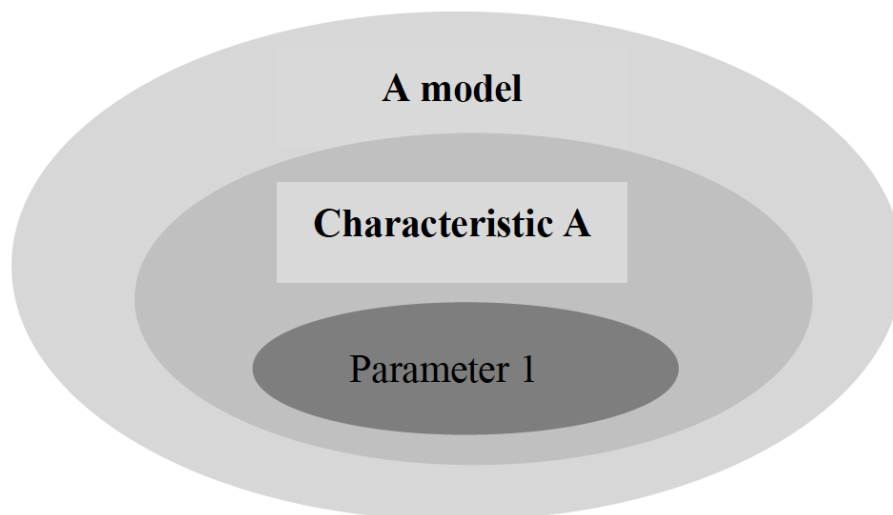


Figure 1 Model elements (Ahrens, Purvinis, Zaščerinska, & Andreeva, 2015)

Business Dictionary (2015) defines a parameter. In accordance with their definition, a parameter is “definable, measurable, and constant or variable characteristic, dimension, property, or value, selected from a set of data (or population) to understanding a situation (or in solving a problem)” (Business Dictionary, 2015).

Thus, the present conceptual framework represents a multi-perspective viewpoint on the cross-sectoral STEM education. The present conceptual framework is built on the concepts of

- educational discipline,
- conceptual change,
- educational content,
- subject knowledge,

- the unity of language,
- the digitalised educational process, and
- the cross-sectoral approach.

Research Methodology

Creation of a theoretical model refers to a qualitative process (Krippendorff, 2004). Thereby, this research is of a qualitative nature.

The present research is exploratory. It was carried out in November – December 2021. In this work, the exploratory relates to being open at the outset of the study (Ahrens, Zascerinska, Bhati, Zascerinskis, & Aleksejeva, 2021). The exploratory methodology was chosen due to a couple of reasons. First, the exploratory study is characterised by a high degree of flexibility (Ahrens, Foerster, Zaščerinska, & Wasser, 2020). Another reason was that the exploratory research lacks a formal structure (Ahrens, Foerster, Zaščerinska, & Wasser, 2020) that gives a freedom to researchers to build their own structure. Finally, the exploratory research aims “to identify the boundaries” of the STEM education (Ahrens, Foerster, Zaščerinska, & Wasser, 2020).

The methodological approach of this work is grounded on “the development of the system of the external and internal perspectives” (Ahrens, Zascerinska, & Aleksejeva, 2021). It should be pointed that many researchers use “the methodology of the external and internal perspectives”, for example Shields (2020). However, our approach shows not only the perspectives’ fission but also their fusion and synthesis. Our methodology, being the development of the system of the external and internal perspectives, is realized in three phases:

- Phase 1 starts with the external perspective,
- Phase 2 leads to the system of the external and internal perspective,
- Phase 3 brings to the internal perspective.

The research information and facts were collected from the published research works found via the google search.

The method for the analysis of the research data was content analysis. Content analysis refers to a qualitative research method. Content analysis or a set of methods to compress and categorize large amounts of textual information in order to classify, structure and systematize (Žogla & Lasmanis, 2009) was used in this work.

Content analysis was employed in accordance with (Žogla & Lasmanis, 2009)

- the formulated scientific aim of the research,
- the elaborated research question and the authors’ intention to verify this by analyzing the selected material;
- the determined amount of material to be collected and later analyzed;

- the identified techniques of information retrieval and analysis units the researchers were interested in.

A qualitative process is identified as “a methodology mostly used within the interpretive approach” (Thanh & Thanh, 2015). The methodological view on the research materials and facts under study is expressed in their interpretation from the point of view of pedagogical theory (Žogla & Lasmanis, 2009) in this paper. The research data are interpreted by the researcher(s) who is involved in the research implementation. This means “the researcher is the interpreter” (Ahrens, Purvinis, Zascerinska, Miceviciene, & Tautkus, 2018).

During the analysis of the content of the collected data, the researchers relied on (Žogla & Lasmanis, 2009)

- the specifics of the subject and object in research in pedagogy;
- theoretical knowledge of pedagogical methodology;
- the generalized program to the research and its procedure;
- the existing experience in the use of content analysis in the social and humanitarian sciences;
- the specifics of the investigated problem.

For the multi-perspective design of STEM education, the theoretical methods were applied. “Analysis of scientific literature, theoretical modelling, systematisation, synthesis, comparison, and generalisation” (Ahrens, Bhati, Zascerinska, Zascerinskis, Aleksejeva, & Abjalkiene, 2021) have been realised.

Research Results

The design of STEM education considers that the process, namely conceptual change, educational process, etc, is implemented in three phases (Zaščerinska, 2013).

Table 1 show the multi-perspective design of STEM education based on the cross-sectoral approach. The design is founded on the conceptual framework presented in this research.

Table 1 The multi-perspective design of STEM education (the authors)

Nr.	Perspective	The development of the system of the external and internal perspectives			Reference
		The external perspective	The system of the external and internal perspectives	The internal perspective	Zaščerinska, 2013
		Phase 1	Phase 2	Phase 3	
1.	STEM Subject content/ knowledge	Existing knowledge	Knowledge variety	New knowledge	Zaščerinska, 2011

2.	Conceptual change	Existing concept	Quasi-concept	New concept	Zaščerinska, 2013
3.	Language	General English and Academic Native Language	English for Academic Purposes	Mother Tongue	Zaščerinska, 2013
4.	The educational process	Teaching	Peer-learning	Learning	Zaščerinska, 2013
5.	The digitalised educational process and the language means	HOT (Here or There) - Hybrid virtual educational process in General English and/or Academic Native Language	COIL – Collaborative Online International Learning in English for Academic Purposes	Hyflex (hybrid flexible) learning in Mother Tongue	Aleksejeva, Zascerinskis, Abjalkiene, Gukovica, Zascerinska, & Ahrens, 2021
6.	The interdisciplinary studies	Two or more scientific disciplines explore the same issue or phenomenon	Two or more scientific disciplines present their synergetic view on the issue or phenomenon	Integrated disciplines	Ahrens, Purvinis, Zaščerinska, & Andreeva, 2016
7.	The cross-sectoral approach (school, vocational, higher and adult education)	STEM is separately delivered in two different educational institutions of two different educational levels	STEM is simultaneously instructed to the students of two different educational institutions of two different educational levels	Integrated STEM at two different educational institutions of two different educational levels	The authors

The multi-perspective design of STEM education is found to be (Ahrens, Zaščerinska, Lange, & Aleksejeva, 2021)

- a system process as its properties are linked,
- a complex process as its elements are intertwined,
- a linear process as it proceeds from one stage/phase to another,
- a cyclic process as it can be repeated,
- of social nature as it changes within and by the Community of Practice,
- of bi-modal nature as it includes both: the external and internal perspectives.

Conclusions

The theoretical novelty of this research is shown in Table 1. It the cross-sectoral STEM education within the system of external and internal perspectives. Another theoretical novelty is disclosed by the multi-perspective construction of the cross-sectoral STEM education as illustrated in Table 1. One more theoretical novelty is presented by identifying a certain sequence of the phases for acquiring the STEM content in the cross-sectoral STEM education based on the multi-perspective design.

The theoretical analysis allows establishing a regularity in the cross-sectoral STEM education:

- the structure of the cross-sectoral STEM education within the system of the external and internal perspectives has been defined as the combination of educational discipline, conceptual change, educational content, subject knowledge, the unity of language, the digitalised educational process, and the cross-sectoral approach,
- the mutual development of the system of external and internal perspectives and STEM knowledge and/or concept by teachers and students is provided in the jointly created academic environment based on a particular structure and implemented in a logical order as described in Table 1.

The exploratory research allows widening the traditional boundaries of the STEM education (teacher-content-student) with the concepts of educational discipline, conceptual change, the unity of language, the digitalised educational process, and the cross-sectoral approach.

Such implications for further research on the cross-sectoral STEM education have been formulated: the cross-sectoral STEM education

- has become a multi-perspective phenomenon,
- has shown its complex nature (linked and intertwined elements),
- has revealed its bi-modal structure as it includes both external and internal perspectives,
- requires the application of innovative paradigms and approaches for theoretical analysis,
- investigation could be based on novel principles of analysis such as the system of external and internal perspectives.

The presented analysis has some limitations. The inter-connections between the perspectives of the cross-sectoral STEM education revealed in Table 1 have been set. The implementation of the theoretical analysis only limits the theoretical modelling and interpretations as well. If other methods have been applied, then, different results could be attained.

Further work tends to focus on the expert evaluation of the proposed multi-perspective design of the cross-sectoral STEM education. Future work will

include the implementation of empirical studies to examine the efficiency of the proposed multi-perspective design of the cross-sectoral STEM education. A curriculum of the cross-sectoral STEM education is to be designed. A training programme for the cross-sectoral STEM education teachers is to be prepared and evaluated. STEM educational materials are to be developed and assessed. The comparative exploration of the cross-sectoral STEM education based on the multi-perspective design and implemented in different countries could greatly impact further development of cross-sectoral STEM education.

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