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Conceptualization of Technology as a Curriculum Framework of Technology Education

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Abstract: *Technical (technological) and engineering knowledge is characterized by constant variability and unpredictable dynamics of development. Therefore, the system of technological knowledge can't be compared to the content base of most other subjects or areas. While the knowledge of other areas is relatively stable, technological knowledge is subject to constant upgrading and alignment with the dynamics of technology development. Due to the tremendous growth and pervasiveness of knowledge, the technology and engineering is faced with the problem of appropriate systematization, while the technology education faces the problem of conceptualizing, selecting and elaborating such knowledge for learning and teaching purposes. In this light, experts and teachers face the problem of conceptualizing technical knowledge in order to achieve the desired learning goals in a very limited time. Thus the openness of the curriculum is becoming more a serious alternative to the today's content-limited curriculum. Therefore, this paper presents an overview of selected concepts of technological knowledge as an attempt to facilitate the future development of the technology education curriculum. In this connection, conceptualization of technology is proposed, as a unique model that takes into account different ways of conceptualizing technology in an individual's mind. Such conceptualization can become a universal framework for the development of the curriculum of technology education.*

Keywords: *conceptualization of technology, curriculum framework, technical education, technology education, technology and engineering education.*

1. INTRODUCTION

Technical and engineering knowledge, from the beginnings of systematic development to the present day, are characterized by exponential growth, constant change of technological reality, and the highly unpredictable dynamics of development. Such dynamics greatly influences and directs the course of development of the economy and society, but also the life of every individual, whereby the education of an individual for such a society is no exception. As a result, the overall technology education faces the problem of growing technological knowledge and alignment with such growth, with the problem of technical and engineering training, but also with the problem of personal advancement and excellence in technology and production [1]. The lack of appropriate and generally accepted terminology [2], [3], but also the taxonomy of technological knowledge and mechanisms that should allow for dynamic changes in the curriculum of technology education, further complicate these problems. Namely, the system of technological knowledge, as the content and cognitive (epistemological) basis of a particular curriculum, can't be compared to the content base of most other subjects or areas. While the knowledge of most other subjects is characterized by relative durability, technological knowledge is subject to constant expansion and alignment with the dynamics of technology and engineering development. The aforementioned growth and changes of the technological knowledge, repeatedly puts in the first place the problem of appropriate system of technological knowledge, while the technology (and technical) teaching area is faced with the problem of conceptualization of technology, but also the choice and transformation of technological knowledge for learning and teaching purposes. Therefore, the openness of the curriculum continues to be imposed as a serious alternative to the traditional and content-limited curriculum. In such light, the issue of exemplars (What to choose?), but also the concept of technological knowledge, is imposed on experts and teachers so as to achieve the desired learning goals in a very limited time that allows the curriculum. Solutions to the problem of proper conceptualization and systematization of technological knowledge will certainly affect the teachers training, without which the successful realisation of the curriculum is not feasible.

Conceptualisation term refers to the formation of ideas or principles about something, especially in the human mind [4]. In this paper conceptualization primarily refers to setting up technological ideas and principles in a certain system that comes from the human mind and should be understandable to the mind of another person. In that sense, technological knowledge is usually conceptualized, and conceptualization itself may depend on purposes or reasons. Thus technological knowledge can be conceptualized because of the systematic differentiation from the other knowledge, due to the development of the epistemological basis of the technology education, due to the more successful conceptualization of the technology in the mind of the individual, and to the easier structuring of the curriculum. When it comes to education, conceptualisation seeks to identify those factors that functionally and independently of time ensure a successful life and work in a technological (technical) environment, embody culture and encourage the development of civilization [5]. When it comes to curriculum development, conceptualization can be meta-orientation, i.e., educational philosophy, dominant psychology of learning and teaching, respect for the social context, as well as theoretical and practical principles of curriculum development [6]. Therefore, if conceptualization is to be carried out to suit the educational needs, which will have a lasting value and be universally applicable, it is necessary to take into account the conceptual frameworks (systematization) of technological knowledge and the conceptual framework for curriculum development.

Based on the aforementioned starting points, this paper provides a review and analysis of the conceptual frameworks of the technological knowledge and the performance link in the teaching, which aims to establish the optimal conceptualization of technology appropriate to each technology education. At the same time, conceptualization of technology is presented as a curriculum framework, which could serve as a starting point for the development and further elaboration of the curriculum of technology education.

2. PROBLEM OF CURRICULUM CONCEPT

The conceptualization of technological knowledge in the curriculum of the technological (technical) teaching area has long been based solely on the technological contents. Thus, in the Croatian educational system, since the introduction of technical education in the 50s of the last century, the curriculum of general technical education was based on the content derived from the fundamental branches of technology and engineering. This education included areas such as construction, electrical engineering, graphic communications, agriculture, transport, engineering, and information technology. Knowledge of these areas was the basis for the transformation of technological knowledge into educational contents. The advocates of such a concept was argued that these areas constitute a permanent basis for the technical culture of modern man and are the starting point for determining the content of general technical (technology) education [7]. Instead, the contents became a limiting factor of the curriculum, which often did not track social development and the context in which education was realized. In addition, the nature of technological knowledge was neglected, as an important epistemological basis, which turned the realization of the curriculum into direct teaching of dictated contents. Therefore, considerations of technological knowledge, contents and activities was pointed to the need to look at those declarative and procedural knowledge and practical skills that are common to all fields of technology [8], [9]. In this way, they tried to include in the curriculum only those contents and knowledge that are directly applicable in everyday life as well as those who anticipate social needs and have an educational function [9]. Nevertheless, conceptualization based on technical contents has so far remained the main approach and starting point for curriculum development of any technology (technical) and engineering education in the Croatian education system. In this sense, the epistemological foundations that technological knowledge does not validated in relation to "truth", but to a successful "function" [10], [11] are most often ignored. Thus, technological knowledge is subject to constant review and assessment of adequacy with regard to the social and economic context. It can be said that such conceptualization involves only the knowledge derived from the philosophy that Mitcham [2] calls the engineering philosophy of technology, while the humanistic philosophy of technology is present only declaratively but not in reality. Such a strictly determining and structuring of technological (technical) contents, without looking at their applicative, futurological and sociological dimensions, is in fact the limitation of education and training to the measurable amount of information that is useless in the life's reality [5]. Such a concept has for years shown its weaknesses in all areas of education, and has had a particularly negative impact on technology education. Namely, by applying existing conceptualization, it is not possible to keep up with the growth of technological knowledge and make a suitable choice and didactic transformation of content that will have sense and meaning for students. For this reason it is necessary to change the approach for conceptualization and structuring of technological knowledge, but also the concept on which the traditional and content-oriented curriculum of technology education is based. Due to the finding of an acceptable concept of curriculum, it is important to carry out an analysis of the existing conceptualisations (classification) of technological knowledge, as well as the analysis of the taxonomy of knowledge, relevant to the point of view of technology education.

3. CLASSIFICATION OF KNOWLEDGE AND TECHNOLOGY EDUCATION

Knowledge, as an important category in the education process, is the subject of many scientific and expert discussions that tried to define and classify knowledge from different perspectives. When it comes to education, it is important to note that knowledge can't be treated as an absolute category that exists independently of human being, but is a category that is part of an individual but also of social groups with the same epistemological beliefs [12]. With regard to classifications, this work will be limited to those which are generally accepted and may be linked to the technology education. Scientists generally agree that there are two basic categories of knowledge, explicit and tacit or implicit knowledge [11]. Explicit knowledge can be explained as knowledge that exists in the available and conscious form and as such can be articulated [11] or as knowledge that can be expressed in words and other symbolic representations [12]. Tacit knowledge can be explained as knowledge that is not articulated (can't be described), but also as knowledge that is implicit and can be articulated but with some difficulties [12]. This is actually the trait of the one who knows more than he can say [13], or as knowledge that can only be developed through practice and can only be validated in practice [11]. In this, explicit and tacit knowledge should be seen as a spectrum rather than as definitive points, because in practice all knowledge is a mixture of tacit and explicit elements [14]. From the aspect of technology education, explicit knowledge is knowledge contained in documents and artefacts [14], which an individual can verbalize or express through abstract symbolism. Tacit knowledge includes *know-how* and cultural knowledge [14] and is expressed through the practical application of knowledge and can be validated during and after that process. Despite such a general classification, it is important to note that researchers increasingly distinguish the above types from the "embedded knowledge" category [14], [15]. Embedded knowledge is the knowledge that is encountered in business rules, processes, manuals, organization culture, code of conduct and ethics [14], but also contextual issues related to processes, products, objects, structures, and customary practice, legislative and political aspects [15]. This knowledge is important from the aspect of technology education, because many standards, rules, procedures, experience indicators, customary practice etc. are present in this area. In cases where embedded knowledge is important for an individual's professional performance, it can become part of explicit knowledge, and in cases where is important practical application, and part of the tacit knowledge. However, in technology education, this knowledge is often found in many standards, rules and empirical coefficients that are not learn "by memorizing" but are used "as needed". Such knowledge is sometimes a product of experiential knowledge (without explanation as to how it has come about), sometimes lacked explanations and are often part of traditions and conventions that are local or regional and are not globally applicable.

During the development of technology education, various subcategories of knowledge have been introduced. Compton [11] refers to these subcategories as: procedural knowledge (knowing how to do it), conceptual knowledge (understanding the relationship between knowledge), device knowledge (knowledge of devices or systems), descriptive knowledge (descriptions based on valid criteria), prescriptive knowledge (knowledge about function as validity criteria) and evaluative knowledge (as a integration of descriptive and prescriptive knowledge). Since this classification is a product of several different authors with different views and starting points, the inconsistency of this approach is noticed. In education, the dimensions of knowledge [16], [17], or the quality of knowledge may be more appropriate in place of the subcategories mentioned above. Thus Krathwohl [17] presents four dimensions of knowledge: factual (declarative), conceptual, procedural and metacognitive knowledge. Factual knowledge is the basic element that students must know to learn about discipline or solve problems. Conceptual knowledge represents the knowledge of the interrelationships between the basic elements within a larger structure that enable them to function together. Procedural knowledge is knowledge of how to do or investigate something, the criteria for using skills, algorithms, techniques and methods. Metacognitive knowledge represents knowledge of cognition in general, as well as awareness and knowledge of one's own cognition [17]. In technical education, the goals are often focused on achieving the level of application of knowledge in the cognitive domain, which is necessarily accompanied by the corresponding skills at the level of precision in the psychomotor domain, and the adoption of certain values in the affective domain. The level of application of knowledge involves the use of procedures for carrying out activities and is closely related to procedural knowledge [18]. Thus, procedural knowledge is the fundamental dimension of the level of application of knowledge that can not be achieved without performing practical activities. In other words, procedural knowledge is not a knowledge of how something is done but a unique cognitive dimension of an individual's ability to apply specific skills and algorithms, techniques and methods, and criteria for the use of particular procedures [16]. Although conceptual knowledge is often identified with explicit, and procedural with tacit, it does not always have to be so. Namely, linking knowledge into the meaningful concepts can have elements of tacit knowledge just as procedural knowledge can be transformed into a particular standard, rule, or "cookbook", thus ceasing to be tacit knowledge [11]. Achieving a metacognitive dimension of knowledge, whereby a learner adopts optimal ways of learning and progress, and develops self-confidence and self-consciousness, assumes many different experiences, i.e. a high level of procedural knowledge.

4. CONCEPTUAL FRAMEWORK OF TECHNOLOGICAL KNOWLEDGE

Enormous growth of technological knowledge has caused a high complexity of the existing, content-based classifications of scientific-technological and engineering knowledge. Therefore, many more serious attempts to create taxonomies, classifications or conceptual frameworks of technological knowledge have been recorded over the past decades.

Among the first classifications (conceptualization) of technological knowledge is worth mentioning of the one developed by Staudenmaier [19], as a result of extensive study of sources in the area of philosophy of technology. Staudenmaier has structured all the technological knowledge according to their common features: *scientific concepts*, *problematic data*, *engineering theory* and *technical skills.* Scientific concepts make up the scientific foundations of technological knowledge, as well as the wide potential of applying scientific knowledge in technological activities and their development. In order to allow for the acquisition of knowledge, it is necessary to implement the specific requirements of theoretical concepts in specific situations. The problematic data refers to the development of a knowledge that can’t be developed theoretically. This implies phenomena that are not demystified at the theoretical level or can’t be demystified, thus contributing to the development of new practical technological knowledge. Engineering theory includes crucial, experimentally verified and formally structured knowledge (knowledge in the narrow sense). This theory is a precondition for solving specific problems, but is not directly related to their solving. Technical skills are the basis for judgment, activity and work and enable real-world understanding of technology, development of skills and competencies. Experts criticize this concept because of the strict "technological" approach and the absence of the social and ecological component [5], which should provide the necessary authenticity and meaningfulness in the technological education.

A somewhat more complex classification of technological knowledge is given by Vincenti [20], where knowledge is classified as: *Fundamental Design Concepts*, *Design Criteria and Specifications*, *Theoretical Tools*, *Quantitative data*, *Practical Considerations*, and *Design Instrumentalities*. Fundamental design concepts here consist of operational principles and normal configurations. The design criteria and specifications relate to the conditions, frameworks and rules under which the artefact is designed and constructed. The theoretical tools here include mathematical tools, explanations and scientific basis for the functioning of artefacts or technologies. Quantitative data refer to the standards, coefficients and experiential values required for the development of artefacts. Practical considerations include finite solutions, examples, cases, ways of customizing artefacts or technologies, while design instrumentalities are engineering tools and systems that help develop a product or technology. This concept offers a systematic approach to engineering knowledge, mostly theoretical and those related to design and construction, but without the practical problem solving and product or technology realization. This concept is criticized because certain categories (theoretical tools and quantitative data) are not exclusive areas of technological knowledge [11], but it is easy to find examples that fit into multiple categories and those that do not fit into any one [21]. The absence of social and ecological categories, this classification does not seem appropriate for technology education.

The next classification was offered by Rophol [22], which classifies technical knowledge as: *Technological Laws*, *Functional Rules*, *Structural Rules*, *Technical Know-How*, and *Socio-Technological Understandings*. Technological laws here represent the scientific foundations of technical knowledge, and include theoretical concepts of how something works and concrete situations-examples. Functional rules relate to the development of knowledge that is impossible to develop theoretical (basically, solving problems). Structural rules make the most important, verified and formally structured theoretical technical knowledge. Procedural knowledge refers here to knowledge gained through practical activities, enabling understanding of technology and the development of skills and competencies. Social-technical understanding is knowledge of the relationships between technology, natural environment and society. This concept and its application is identical to Staudenmaier, with an important addition to acknowledging the knowledge about the interrelationships of technology, society and nature. In education this means that students need to gain insight into the social justification of a particular technology, but also to the consequences for the natural environment and human. Some experts criticize this concept because of insufficient breadth because some knowledge can't be classified into any category (e.g. standard components) but also because of the methodological inconsistency of taxonomy [21].

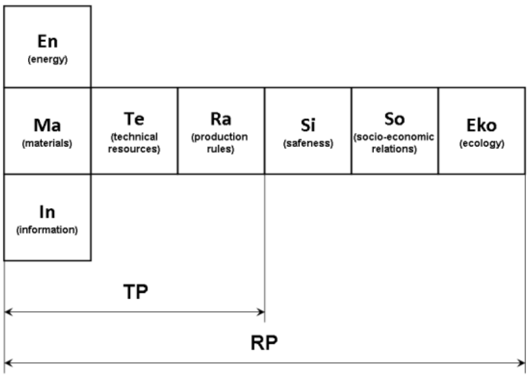

Figure 1. *Framework of the technical knowledge [23], [24]*

The conceptual framework, important from the point of view of the current general technical education in Croatia, was offered by Majetić [23], [24] (Figure 1). This concept is derived from traditional, content-based elements of technology. Majetić conceptualized technical knowledge into the underlying elements of the technological process (TP) and working process (RP). The technological process thus comprises: material (substance), energy, information, resources, and rules under which the process is performed. The working process includes: safety at work, socio-economic relations and ecology (this element is subsequently associated with the original concept). This concept is first developed for vocational education and then for general technological education, which is why it is mainly applicable to production activities. But in the curriculum there are no resources or time for such activities, so the concept has remained largely inapplicable according to the author's idea. Implementation in teaching was carried out by didactical transformation of selected content into the catalogue themes, thus transforming the concept into a dictated closed curriculum. All this has prevented the implementation of many meaningful activities in teaching, and the systematization of technological knowledge in pupils' awareness.

The next classification of technological knowledge was offered by de Vries [25], and is mainly based on technological practice and development, that is, artefact knowledge. So de Vries lists four categories of knowledge: *Physical Nature Knowledge*, *Functional Nature Knowledge*, *Means Ends Knowledge,* and *Action Knowledge*. Physical nature knowledge refers to operational explicit knowledge and understanding of the physical properties of the artefacts. Functional nature knowledge includes knowledge of the function that an artefact can fulfil or of rules that can ensure its functionality. Means ends knowledge refers to knowledge of the relationship between physical and functional, i.e. criteria and mechanisms for assessing the suitability of artefacts. Action knowledge refers to knowledge about the ways in which "actions" that lead to desired outcomes are performed. Although this classification is structured "broadly", limiting technology to the artefact knowledge only seems insufficient to apply to education.

Interesting conceptualization of technology is suggested by Barlex [26], as an *ideas about technology* and *ideas of technology*, which makes a certain curriculum frame of the technology education. Barlex states that *ideas about technology* would mainly inform the development of a perspective on technology while the *ideas of technology* would be essential for enabling technological capability [26]. The ideas about technology here relate to starting points that distinguish technology from other areas: used for development of technologies and products to intervene in the natural and made worlds; it uses knowledge, skills and understanding from a wide range of sources; in technology there are many possible and valid (better or worse) solutions to technological or manufacturing challenges; the worth of technologies or products is a matter of judgment; always have unintended consequences which cannot be fully predicted by creators. Ideas of technology are in fact technological knowledge (and skills). Technological knowledge here includes: *Knowledge of materials*, *Knowledge of manufacturing*, *Knowledge of functionality*, *Knowledge of design*, and *Knowledge of critique with regard to impact*. This concept may seem to be a good starting point for developing a curriculum of technology (technical) education, but with certain constraints. Namely, the classification of knowledge is based mainly on conceptualization from activities (on product development), which are a good basis for the development of knowledge, but not the only way for conceptualization of technology.

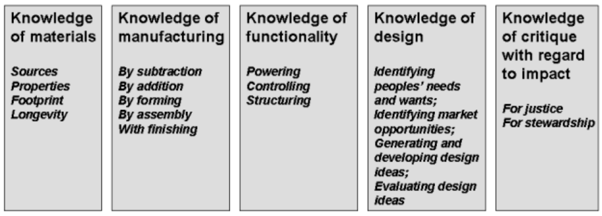

Figure 2. *Ideas of technology [26]*

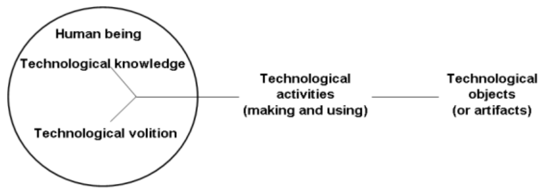

Figure 3. *Modes of the manifestation of technology [2]*

Views of different classifications bring different concepts of technological knowledge, which are often not fully applicable in contemporary education. The reasons should be sought in the fact that taxonomy of knowledge is not a purpose for itself and that there is a big difference between the technological knowledge system outside the context of education and the way in which technological knowledge is acquired and developed. In this light Mitcham [2] in the extensive review of engineering and humanistic philosophy of technology, introduces a different ways of the conceptualizations of technology. Mitcham does this from the conceptual framework of the manifestations of technology (Figure 3), as a result of analysing various philosophical discussions. According to this framework, technology can be manifested through artefacts (objects), as activities, and as technological knowledge, which can't be observed outside the human volition aspect. Thus, knowledge does not exist outside of human being and his volition aspect, which is why this important manifestation of technology have to be taken into account.

From such a framework, Mitcham [2] also elaborates different types of technology, i.e. ways of the conceptualizations of technology, such as: *Types of Technology as Object*, *Types of Technology as Knowledge, Types of Technology as Activity*, *and Types of Technology as Volition*. Therefore, technology can be manifested, and thus structured through various technological objects, as the most obvious evidence of such a structure. It can manifest through the structured technological knowledge, whose quality largely depends of the human volition aspect. Finally, technology can be manifested through the various activities, specific for this area. This conceptual framework can represent a sufficiently open foundation for adaptation for different purposes, as well as for the needs of education.

5. CONCEPTUALIZATION OF TECHNOLOGY AS A CURRICULUM FRAMEWORK

Any development of the curriculum framework of technology education presupposes the appreciation of different concepts, classification

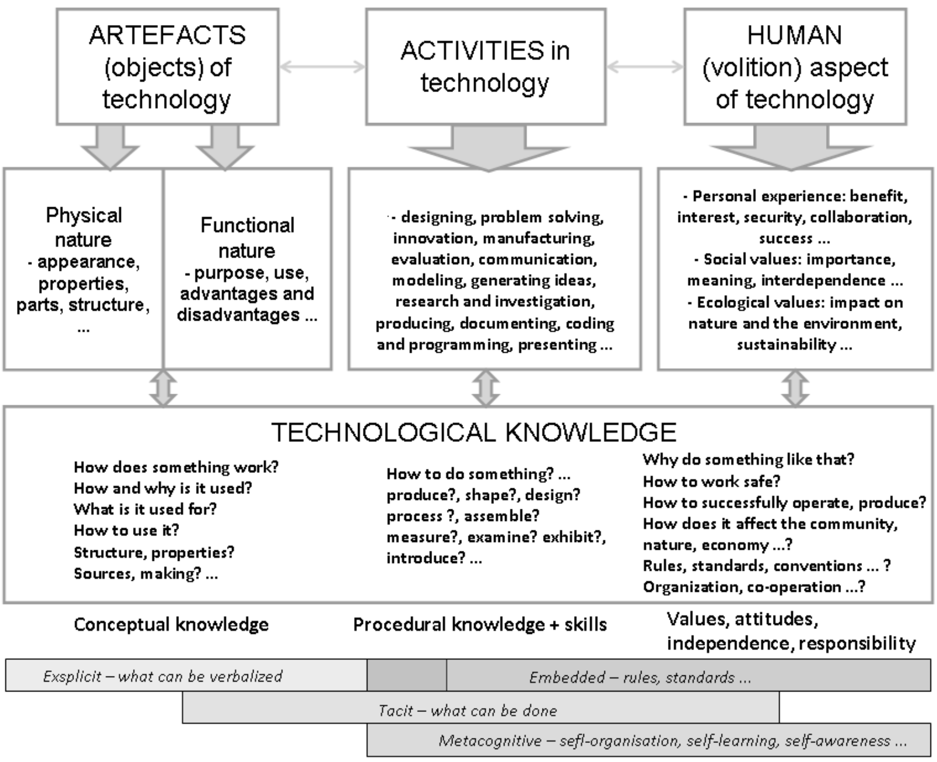

Figure 4. *Curriculum Framework of Technology Education*

and taxonomy of technological knowledge, as well as the type of knowledge in general, some of which have been previously presented. In this regard, it is necessary to develop a framework that will be sufficiently open for application at different levels of the technology education, and adaptable for different educational needs and different contexts of learning and teaching. For this reason, the conceptual framework for the development of the curriculum of technology education is proposed here, which is largely inspired by the framework given by Mitcham [2]. This framework is particularly important because it takes into account the human aspect of technology, but also the different ways of conceptualizing technology, which is important for education. The proposal of the curriculum framework of technology education is presented in Figure 4.

From the framework it can be seen that different approaches to the conceptualization of technology here represent certain macro-concepts or domains of the curriculum. According to this framework, the process of learning technology usually begins with insight and experimentation with objects (artefacts) of technology, that is, by recognizing the physical and functional characteristics of artefacts. However, with the artefacts, the learner must carry out various meaningful activities, which are the basis for individual development. Activities are mostly related to the application of processes, steps, procedures, operations, methods, etc. In practice, this is most often modelling, generating ideas, research and investigation, producing, documenting, evaluation, but also designing, problem solving, systems approaches, inventions, and manufacturing [27]. However, in order for an individual (student) to accept such activities, it is necessary to respect the human aspect of technology. For this reason, the activities should have sense and meaning for the student (should be done in a suitable teaching context). Therefore, it is important that every activity has a clear purpose (something useful) and prominent good and bad consequences (for the individual, society, environment). With such significant activities, the learner needs to gain insight into how technology shapes and influences it personally, on other people, on culture, on society, and on nature. Based on the experience gained, students need to think, discuss, communicate, share ideas, exchange information, etc., which helps them systematize acquired knowledge in their own mind. All of the above, from insight into artefacts, activities with them, to communication, organization and cooperation, basically represents technological knowledge. Through the systematization of the knowledge of the artefacts and only partially from the activity, the learner can achieve the conceptual dimension of knowledge, often called explicit knowledge. Successful realization of the activity, where knowledge of the artefacts, rules and standards is applied and communicated and cooperates with other participants, the student gains procedural knowledge. This way of acquiring knowledge in technology education is at the same time the only way to develop metacognitive skills. This knowledge is largely considered to be tacit knowledge, though it incorporates the embedded knowledge. By exchanging experience, expressing attitudes, presenting results, reflecting on activities, communicating and collaborating with the real world, etc., the student accepts the value system, develops argued attitudes and becomes independent and responsible. This systematized knowledge can be considered as part of a tacit knowledge, while the successful implementation of the activity in this domain confirms the adoption of the embedded knowledge. Nevertheless, the greatest contribution in this part relates to the metacognitive dimension of knowledge, that is, self-organization and self-learning, and the gradual development of awareness of one's own preferences and possibilities. Only on the basis of one's own experiences, a learner can gain insights (with the help of teacher) into a certain system, discover their own preferences and opportunities, and develop accordingly.

6. CONCLUSION

This paper presents an overview of selected classifications, concepts and taxonomy of technological knowledge, as well as general taxonomy of knowledge, primarily from the aspect of education and the curriculum development. Conceptualization of technological knowledge is especially important for the development of the curriculum framework, because today's technological knowledge can't simply transformed into teaching. Although each of the concepts presented has its own advantages, some are more suitable for adapting to educational needs. It is important to understand that, as opposed to a traditional content-based structure, knowledge should be seen as a process or path of knowledge in which a human (volition) aspect plays a major role.

Based on the analysis of the taxonomy, concepts and classifications and the stated starting points of the role of human in the process of acquiring knowledge, the conceptual framework of the curriculum of technology education was developed. This framework respects different manifestations of technology, i.e. different ways of conceptualizing technology in an individual's mind. For this reason, manifestations of technology here are transformed into the curriculum domains as: artefacts of technology, activities in technology, human aspect of technology, and technological knowledge. The basis for student achievement is the activities that need to be carried out with the artefacts, and everything must be done with the respecting of the volition aspects of the students. In such a process, the student adopts technological knowledge, and the teacher should help him to systematize knowledge in the own mind.

Although the proposed curriculum framework does not offer a final or "instant" solution for teaching, it can be an open starting point for developing each operational curriculum of technology education. The role of the teacher in this process is crucial because on the basis of the framework, it is necessary to develop its own operational curriculum. Therefore, instead of performing content-restricted topics, the teacher should be able to choose artefacts and realize activities, and the sense and meaning of these activities should be adjusted to the pupils' interests and needs, the level and purpose of education, and the needs of the community and society. During and after the activities performed, the teacher should systematize the acquired experience and knowledge of student as part of the technological knowledge system. Teacher, as the most important quality factor of teaching, can assume responsibility for the development of students' technological competences only if they have a high level of freedom in creating their own teaching, as the proposed framework allows.

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