IN SEARCH FOR STANDARDS: TEACHING MATHEMATICS IN TECHNOLOGICAL ENVIRONMENT

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In the literature review on teacher education aimed at integrating technology to mathematics lessons we presented in the topic study group 43 at the 13th ICME conference, we brought to the fore a lack of standards for teaching mathematics with technology, which is, in our view, an issue for the actors of teacher education. In this paper, we tackle this issue by presenting existing ICT standards at the international and national levels and analyse them through the lenses of TPACK model and double instrumental genesis. We argue that the existing standards are too general, as they are neither school level, nor subject matter specific. We call the mathematics education community to take this issue in consideration.

Keywords: Mathematics teachers' knowledge for ICT; Standards for teaching with ICT; TPACK model, Double instrumental genesis

INTRODUCTION

Teacher education was one of the four central themes discussed at ICME 13 congress in the Topic Study Group 43, *Uses of technology in upper secondary mathematics education (age 14 to 19)*. In our contribution to this theme (Tabach & Trgalová, 2016), we noticed, in a number of research papers, a disappointment with the outcomes of teacher education programs. The gap between teachers' needs and the teacher education contents is deemed as the main reason. This brings to the fore a necessity for teacher educators to understand better what teachers need to know in order to use efficiently ICT, which raises the issue of ICT competency standards. We thus searched for an institutional framework regarding teachers' knowledge for teaching mathematics with technology. Surprisingly, we could hardly find such standards for mathematics teachers or even for teachers in general. Therefore, we recommended that "*Elaboration of ICT standards for mathematics teacher education might become one of the goals of the mathematics education international community*" (Hegedus at el., 2016, p. 30).

In this paper, we aim to expand on the issue of standards that we consider crucial for teacher education: standards aiming at teachers, and specifically mathematics teachers working with ICT. We relate to both international and national levels.

THEORETICAL PERSPECTIVE

Several researchers suggested theoretical frameworks for examining and analyzing teacher knowledge in general. In theorizing about the unique knowledge needed for teaching with digital technology, Mishra and Koehler (2006) introduced the concept of Technological Pedagogical Content Knowledge (TPCK or TPACK): the knowledge and skills teachers need to meaningfully integrate technology into instruction in specific content areas.

The notion of TPCK emerged from Shulman's (1986) construct of pedagogical content knowledge (PCK). Shulman rejected the view of Content knowledge (CK) and Pedagogical knowledge (PK) as two distinct bodies of knowledge, and suggested a partial overlap between them. This overlap implies a unique type of knowledge, specific for teachers, PCK. Along similar line of thoughts, Mishra and Koehler (2006) suggested an additional body of knowledge, Technological, which partially overlaps CK and PK. The resulted image of teachers' knowledge is captured in Fig. 1, and includes seven bodies of knowledge.
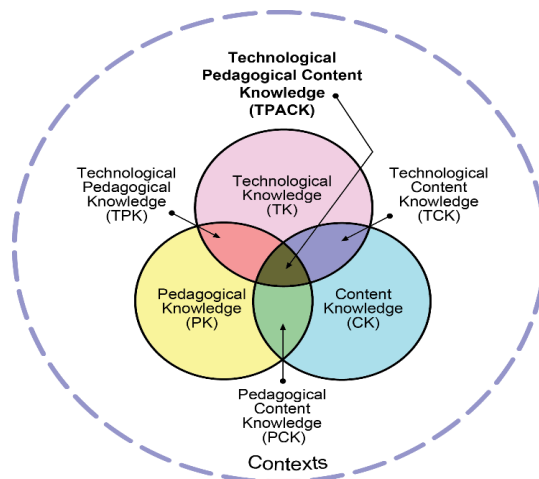

Figure 1: TPACK (with permission from TPACK.org)

The TPACK framework was used by many researchers and several different interpretations are currently accepted (Voogt et al., 2012): T(PCK) as extended PCK; TPCK as a unique and distinct body of knowledge; and TP(A)CK as the interplay between three domains of knowledge and their intersections. In the current paper we adopt the latter view.

The theoretical construct of *double instrumental genesis* (Haspekian, 2011) brings forth the implication of both personal and professional instrumental geneses in teachers using ICT. While the first is related to the development, from a given artefact, of a teacher's personal instrument for mathematical activity, the second results in a professional instrument for her didactical activity. These two processes mobilize knowledge of the artefact (TK), ability to solve mathematical problems using it (TCK), to orchestrate ICT-supported learning situations (TPK) and to teach mathematics with ICT (TPACK).

METHODS

In this paper, we review institutional documents in an attempt to answer the following questions: What knowledge standards are set for teachers working in technological environments? What are the specificities for mathematics teachers that are unique to this sub-group of teachers?

Two types of data sources were available for us. At the international level, we searched the web for organizations that published documents on the subject. We found the UNESCO ICT Competency Framework for Teachers (2011) and the International Society for Technology in Education (ISTE[1]) Standards-T (2008), both sources relate to teachers in general. At the national level, we consider the NCTM (2001) from the US, specific for teaching mathematics, yet focused mainly on standards for learning, as well as available documents from France and Israel to have a wider national perspective.

While reading each of the data sources, we tried to relate them to one of the four knowledge areas that pertain to technology, as reflected by the TPACK framework.

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[1] International Society for Technology in Education, http://iste.org

FINDINGS

ICT standards around the world

UNESCO ICT Competency Framework for Teachers (ICT-CFT) (2011) sets out "*the competencies required to teach effectively with ICT*" (p. 3). The framework stresses that

> "it is not enough for teachers to have ICT competencies and be able to teach them to their students. Teachers need to be able to help the students become collaborative, problem solving, creative learners through using ICT so they will be effective citizens and members of the workforce" (ibid.).

The Framework is therefore organized in three different approaches to teaching corresponding to three stages of ICT integration. The first is Technology Literacy "*enabling students to use ICT in order to learn more efficiently*", the second is Knowledge Deepening "*enabling students to acquire in-depth knowledge of their school subjects and apply it to complex, real-world problems*" and the third is Knowledge Creation "*enabling students, citizens and the workforce they become, to create the new knowledge required for more harmonious, fulfilling and prosperous societies*" (p. 3). It is interesting to note that these stages are formulated in terms of students' abilities to exploit the ICT potential as a result of the ways teachers use ICT. All aspects of teachers' work, namely understanding ICT in education, curriculum and assessment, pedagogy, ICT, organization and administration, and teacher professional learning, are addressed at the three stages (Fig. 2).
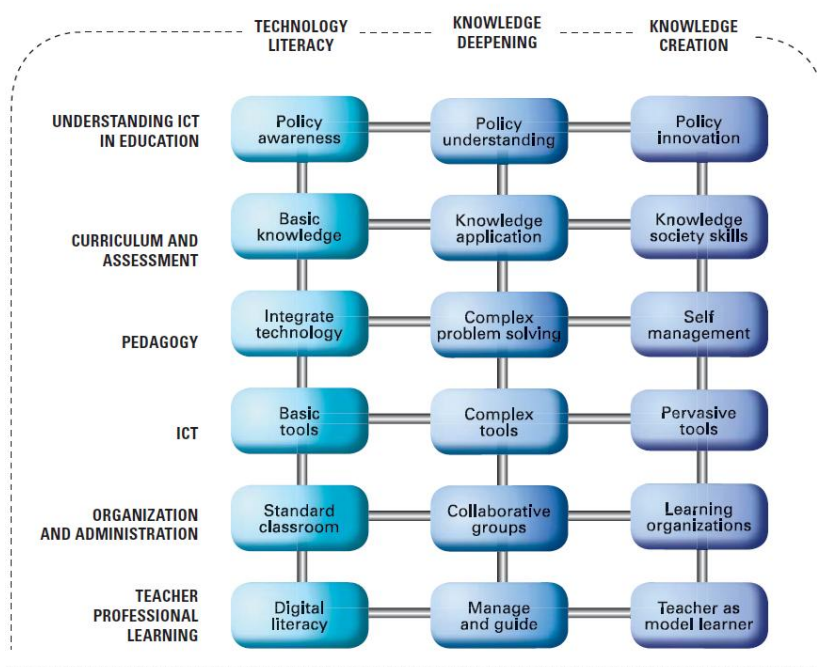

Figure 2. The UNESCO ICT Competency Framework for Teachers (UNESCO, 2011, p. 13)

The authors of the UNESCO framework claim that

> "[t]he successful integration of ICT into the classroom will depend on the ability of teachers to structure the learning environment in new ways, to merge new technology with a new pedagogy, to develop socially active classrooms, encouraging co-operative interaction, collaborative learning and group work. This requires a different set of classroom management skills. The teaching skills of the future will include the ability to develop innovative ways of using technology to enhance the learning environment, and to encourage technology literacy, knowledge deepening and knowledge creation" (ibid., p. 8).

The Framework specifies competencies teachers need in all aspects of their work. At the level of Technology Literacy,

> "teacher competences […] include basic digital literacy skills and digital citizenship, along with the ability to select and use appropriate off–the-shelf educational tutorials, games, drill-and-practice software, and web content in computer laboratories or with limited classroom facilities to complement standard curriculum objectives, assessment approaches, unit plans, and didactic teaching methods. Teachers must also be able to use ICT to manage classroom data and support their own professional learning." (ibid., p. 10).

Referring to the TPACK model, we may consider "basic digital literacy" as part of TK and the ability to select appropriate resources to "complement […] standard didactic teaching methods" as part of TPACK. TPK and TCK are mentioned together with the TPACK at the further level, Knowledge Deepening:

> "teacher competences […] include the ability to manage information, structure problem tasks, and integrate open-ended software tools and subject-specific applications [TCK] with student-centred teaching methods and collaborative projects in support of students' in-depth understanding of key concepts [TPACK] and their application to complex, real-world problems. To support collaborative projects, teachers should use networked and web-based resources to help students collaborate, access information [TPK], and communicate with external experts to analyze and solve their selected problems. Teachers should also be able to use ICT to create and monitor individual and group student project plans, as well as to access information and experts and collaborate with other teachers to support their own professional learning' (ibid., p. 11).

Finally, at the level of Knowledge Creation, teachers

> "will be able to design ICT-based learning resources and environments; use ICT to support the development of knowledge creation and the critical thinking skills of students [TPACK]; support students' continuous, reflective learning [TPK]; and create knowledge communities for students and colleagues" (ibid., p. 14).

The UNESCO document provides examples of syllabi for teacher education that demonstrate ways how to operationalize the ICT competency framework. In the Table 1, a few examples of tasks suggested in the syllabi at the three levels, technology literacy (TL), knowledge deepening (KD) and knowledge creation (KC), of teachers' competencies are given, organized according to the TPACK model and the double instrumental genesis concept.

These examples of teachers' competencies show that the UNESCO ICT framework takes into account both teacher's personal and professional ICT knowledge and skills, although the first are only present at the TL and KD levels, the teachers at the KC level being certainly considered as having a sufficient personal mastery of technology. All technology-related categories of the TPACK model are present, although the TPACK itself is not specific to whatever subject matter.

	Personal instrumental genesis	Professional instrumental genesis
Teachers should be able to...	TL - Describe the purpose and basic function of graphics software and use a graphics software package to create a simple graphic display (TK)	TL - Identify the appropriate and inappropriate social arrangements for using various technologies (TPK)
	TL - Use common communication and collaboration technologies, such as text messaging, video conferencing, and web-based collaboration and social environments (TK)	TL - Match specific curriculum standards to particular software packages and computer applications and describe how these standards are supported by these applications (TCK)
	TL - Use ICT resources to support their own acquisition of subject matter and pedagogical knowledge (TCK, TPK)	TL - Incorporate appropriate ICT activities into lesson plans so as to support students' acquisition of school subject matter knowledge (TPACK)
	KD - Identify or design complex, real-world problems and structure them in a way that incorporates key subject matter concepts and serves as the basis for student projects (TCK)	KD - Structure unit plans and classroom activities so that open-ended tools and subject-specific applications will support students in their reasoning with, talking about, and use of key subject matter concepts and processes while they collaborate to solve complex problems (TPACK)
	KD - Operate various open-ended software packages appropriate to their subject matter area, such as visualization, data analysis, role-play simulations, and online references (TCK)	KC - Help students reflect on their own learning (TPK)

Table 1. Examples of teachers' competencies mentioned in the UNESCO ICT framework.

The ISTE Standards-T (2008) define five skills teachers "*need to teach, work and learn in the digital age*":

(1) "Teachers use their knowledge of subject matter, teaching and learning, and technology to facilitate experiences that advance student learning, creativity, and innovation", (2) "Teachers design, develop, and evaluate authentic learning experiences and assessments incorporating contemporary tools and resources", (3) "Teachers exhibit knowledge, skills, and work processes representative of an innovative professional", (4) Teachers [...] exhibit legal and ethical behavior in their professional practices", and (5) "Teachers continuously improve their professional practice […], exhibit leadership in their school and professional community by promoting and demonstrating the effective use of digital tools and resources".

These skills are rather general and relate to various aspects of teacher profession. These skills do not relate to TK per-se. It seems that in these standards, teachers' TK is taken as a starting point. Also, as the standards are not subject specific, they do not relate to TCK. In fact, this set of skills is about TPK. Note that the standards encompass various aspects of teacher's profession – designing, teaching, evaluating, leading their peers in school and in their professional community, as well as legal behavior. A hint that some adaptation to the content taught is needed can be found in the beginning – "*Teachers use their knowledge of subject matter…*". Yet, it is not directly conveying that adaptation of these skills to different content areas within K-12, namely focusing on TPACK, may yield different results for different subject matters.

To summarize, at the international level the standards mostly aim at teachers in general, with no specific adaptation to any school subject. As a result, the documents refer to teachers' TPK, rather

than TCK or TPACK, which are only referred to by evoking "didactic teaching methods" or "support of students' in-depth understanding of key concepts".

ICT standards at the national level

The National Council of Teachers of Mathematics (NCTM) organization published document statement and positions aimed to the US, yet these documents are influential beyond the national level. In many countries, they serve as model for the national documentation. The NCTM relates specifically to mathematics teachers, as can be viewed from an explicit relation to mathematics, as well as to digital tools specific to mathematics.

NCTM (2011) claims that

> "Programs in teacher education and professional development must continually update practitioners' knowledge of technology and its application to support learning. This work with practitioners should include the development of mathematics lessons that take advantage of technology-rich environments and the integration of digital tools in daily instruction, instilling an appreciation for the power of technology and its potential impact on students' understanding and use of mathematics."

The NCTM position toward technology in mathematics education emphasizes three conditions for an efficient integration of technology, which should guide the development of teacher education programs: teachers' awareness of the technology added value in terms of students' understanding of mathematics, which is about TPACK; teachers' continuous upgrading of their knowledge of technology and its use in teaching, which relates both to teachers TK and TPK; and designing teaching resources taking advantage of affordances of digital tools, which is about TPACK.

In a position statement from 2015 the NCTM further stated that

> "Effective teachers optimize the potential of technology to develop students' understanding, stimulate their interest, and increase their proficiency in mathematics. When teachers use technology strategically, they can provide greater access to mathematics for all students."

The document further relates to particular technologies to be used, from mathematical and non-mathematical domains:

> "Content-specific mathematics technologies include computer algebra systems; dynamic geometry environments; interactive applets; handheld computation, data collection, and analysis devices; and computer-based applications. Content-neutral technologies include communication and collaboration tools, adaptive technologies, and Web-based digital media."

Teachers are viewed as orchestrators and coaches of strategic use, and their leading consideration should stem from the mathematics they are teaching. Technology is used at the service of mathematics. Although not specifically stated, it seems that for the NCTM, TCK, TPK and TK all play central role in the knowledge teachers need to have in order to teach with ICT. This impression is enhanced by the fact that in most of the publication, ICT appears at the background rather than up front.

The situation in Israel is quite different in terms of teachers' standards for teaching in ICT environment in general, and for mathematics teachers in particular. At the national level of preservice teacher education, the only reference is made to the 21th century skills in general. In other words, they refer to TK which is expected from all citizens and are not particular to teachers. At the mathematics education level, again there are no particular standards as to what do

mathematics teachers need to know. This is not typical, as the Israeli ministry of education is very centralistic in its approach.

France was, until 2014, one of the European countries in which a certificate of digital skills, called "certificate of computer science and Internet", was required to become a primary or a secondary teacher. Since 2014, this certification is integrated in the preservice teacher education. This certification was created in 2010 to vouch for professional skills in the pedagogical use of digital technologies, common and necessary to all teachers and trainers for the exercise of their profession. National standards of competencies related to the certification comprise two main parts: (A) general skills related to the exercise of the profession, and (B) skills needed for ICT integration into the teaching practice. The general skills (part A) are organized in three domains: "A1 - mastery of professional digital environment" (e.g., select and use the most appropriate tools to communicate with the actors and users of the education system), "A2 - development of skills for lifelong learning" (e.g., use online resources or distance learning devices for self-training), and "A3 - professional responsibility in the education system" (e.g., take into account the laws and requirements for professional use of ICT). The skills for ICT integration are classified in four domains: "B1 - Networking with the use of collaborative tools" (e.g., search, produce, index, and share documents, information, resources in a digital environment), "B2 - design and preparation of teaching content and learning situations" (e.g., design learning and assessment situations using software that is general or specific to the subject matter, field and school level), "B3 – pedagogical enactment" (e.g., manage diverse learning situations by taking advantage of the potential of ICT (group, individual, small groups work), and "B4 - implementation of assessment techniques" (e.g., use assessment and pedagogical monitoring tools). While the skills from the part A refer mostly to TK, those from the part B refer to TCK, TPK and TPACK. Numerous intersections can be found between the French national and UNESCO international standards, mainly in considering various aspects of teachers' profession, not only reducing it to their classroom activity, leading to taking into account both personal and professional mastery of ICT. Like the other standards presented above, the French ones are common to all teachers, whatever their school level and the subject matter taught.

CONCLUSION

In the current paper, we asked two connected questions: What knowledge standards are set for teachers working in technological environments? What are the specificities for mathematics teachers that are unique to this sub-group of teachers? To answer the two questions, we searched for institutional documents, both at the world-wide level and at the national level. In the findings section we detailed our analysis of the few documents we found, through the lenses of the TPACK framework for teachers' knowledge and the double instrumental genesis concept. We found a document composed by the UNESCO with elaborated ICT standards for teachers in general – regardless of the subject matter or grade level. The second document was composed by the International Society for Technology in Education organization, again at the general level. We were surprised to find only these two documents. We would like to point out that the two documents did not address any specific grade level – as if the standards for teaching in an ICT environment at any grade level were the same. Also, the documents did not address any specific subject matter, or did not suggest that particular adaptations are needed for teaching various school subjects.

At the national level we searched for documentation from three countries –US, France and Israel. There are profound differences between the three countries in terms of national level standards for teaching with ICT as well as some striking similarities: like at the international level, both in Israel

and France the reference is made only to teaching in general, with no relation to specific age level or subject domain. Yet, while in Israel there is some reference to 21th ICT skills needed for any citizen, centering on TK, in France we saw awareness to both the personal TK as well as professional knowledge needed for teaching, in line with the double instrumental approach. The findings from the US are different in the sense that the standards specifically aim at teaching mathematics. Indeed, the analysis shows that these standards relate to all types of TPACK knowledge. However, they lack specifications.

We are currently at a time of change in terms of teachers' technological knowledge – the newcomers to this profession are expected to be more skillful at the personal level than the veterans. Yet, we think that teachers' mastery of ICT, both in terms of TK and TCK should not be taken for granted. Rather, this personal level in the double instrumental genesis should be addressed by standards. Moreover, we call for much more elaborated sets of standards for teaching in ICT for different age groups and school subjects, to allow for the professional level of instrumental genesis to be promoted.

REFERENCES

Haspekian, M. (2011). The co-construction of a mathematical and a didactical instrument. In M. Pytlak, E. Swoboda, & T. Rowland (Eds.), *Proceedings of the seventh Congress of the European Society for Research in Mathematics Education. CERME 7*, Rzeszow.

Hegedus, S., Laborde, C., Brady, C., Dalton, S., Siller, H. S., Tabach, M., Trgalova, J., & Moreno-Armella, L. (2016). *Uses of Technology in Upper Secondary Mathematics Education*. Springer.

ISTE (2008). *ISTE Standards for Teachers*. Online http://www.iste.org/standards/standards/standards-for-teachers [Retrieved February 20, 2017].

NCTM (2011). Technology in Teaching and Learning Mathematics. A Position of the National Council of *Teachers of Mathematics*. Online http://www.nctm.org/Standards-and-Positions/Position-Statements/Technology-in-Teaching-and-Learning-Mathematics/ [Retrieved September 17, 2015]

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for integrating technology in teacher knowledge. *Teacher College Records, 108*(6), 1017-1054.

Shulman, L. (1986). Those who understand: knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Tabach, M., & Trgalová, J. (2016). Teacher education: what, how and why? *Invited paper presented in the TSG43 at the ICME13 congress*, July 2016, Hamburg.

UNESCO (2011). *UNESCO ICT competency Framework for Teachers*. Online http://unesdoc.unesco.org/images/0021/002134/213475E.pdf [Retrieved February 20, 2017].

Voogt, J., Fisser, P., Pareja Roblin, N., Tondeur, J. & van Braak, J. (2012). *Technological pedagogical content knowledge – a review of the literature. Journal of Computer Assisted Learning, 29*(2), 109-206.