Teaching Computer Science in Secondary Education: A Technological Pedagogical Content Knowledge Perspective

Ioannis Ioannou, Ministry of Education, Cyprus
Charoula Angeli, University of Cyprus, Cyprus

Impetus for the study

- Ongoing debate in secondary computing education about:
  - How can teachers teach computer topics in a learner-centered way through the use of educational technologies within powerful pedagogical frameworks?

Purpose of the study

- The use of Technological Pedagogical Content Knowledge (TPCK) as a framework for guiding the integration of educational technologies in teaching and learning (Angeli & Valanides, 2005, 2009, 2013).
- The use of Technology Mapping design guidelines for redesigning the teaching of the unit Data-Processing-Information (Angeli & Valanides,2013).
- Use the results of this study as baseline data to make changes to the TPCK framework, if needed.
  - Goal is to have a TPCK framework with a focus on the teaching of topics from computing education.

From PCK to TPCK

- In 2005, researchers showed a strong interest in extending pedagogical content knowledge (PCK; Shulman, 1986) in the domain of teaching with technology (Angeli & Valanides, 2005; Koehler & Mishra, 2005; Niess, 2005).
- All views were founded on the common principle that effective technology integration presupposes a conceptualization that must be formulated by considering the interactions among technology, content, and pedagogy.

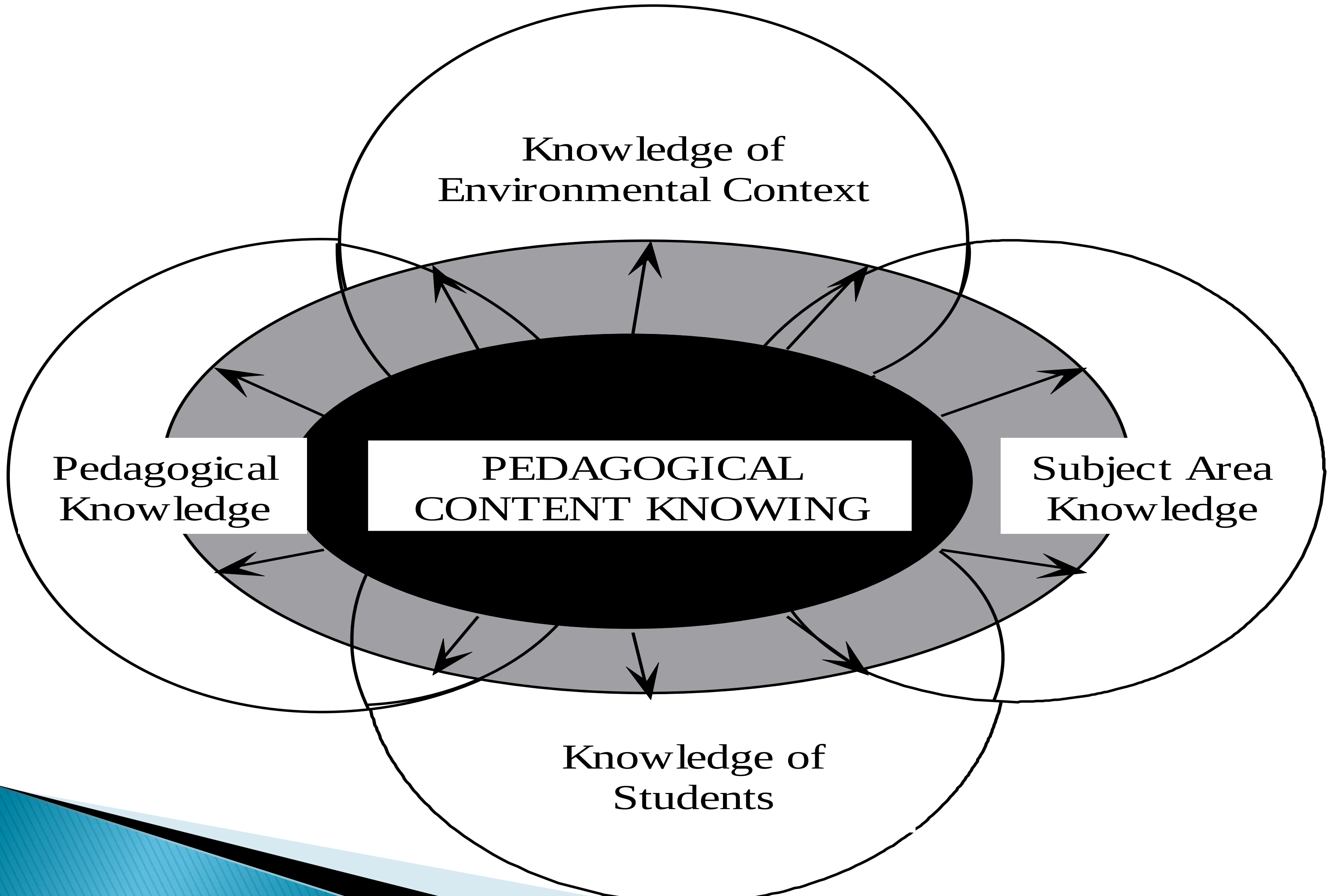
PCK

- According to Shulman (1986, 1987) PCK (pedagogical content knowledge) constitutes a special amalgam of content and pedagogy.
- Shulman (1986, 1987) described PCK as the ways content, pedagogy, and knowledge of learners are blended into an understanding of how particular topics to be taught are represented and adapted to learners' characteristics, interests and abilities.

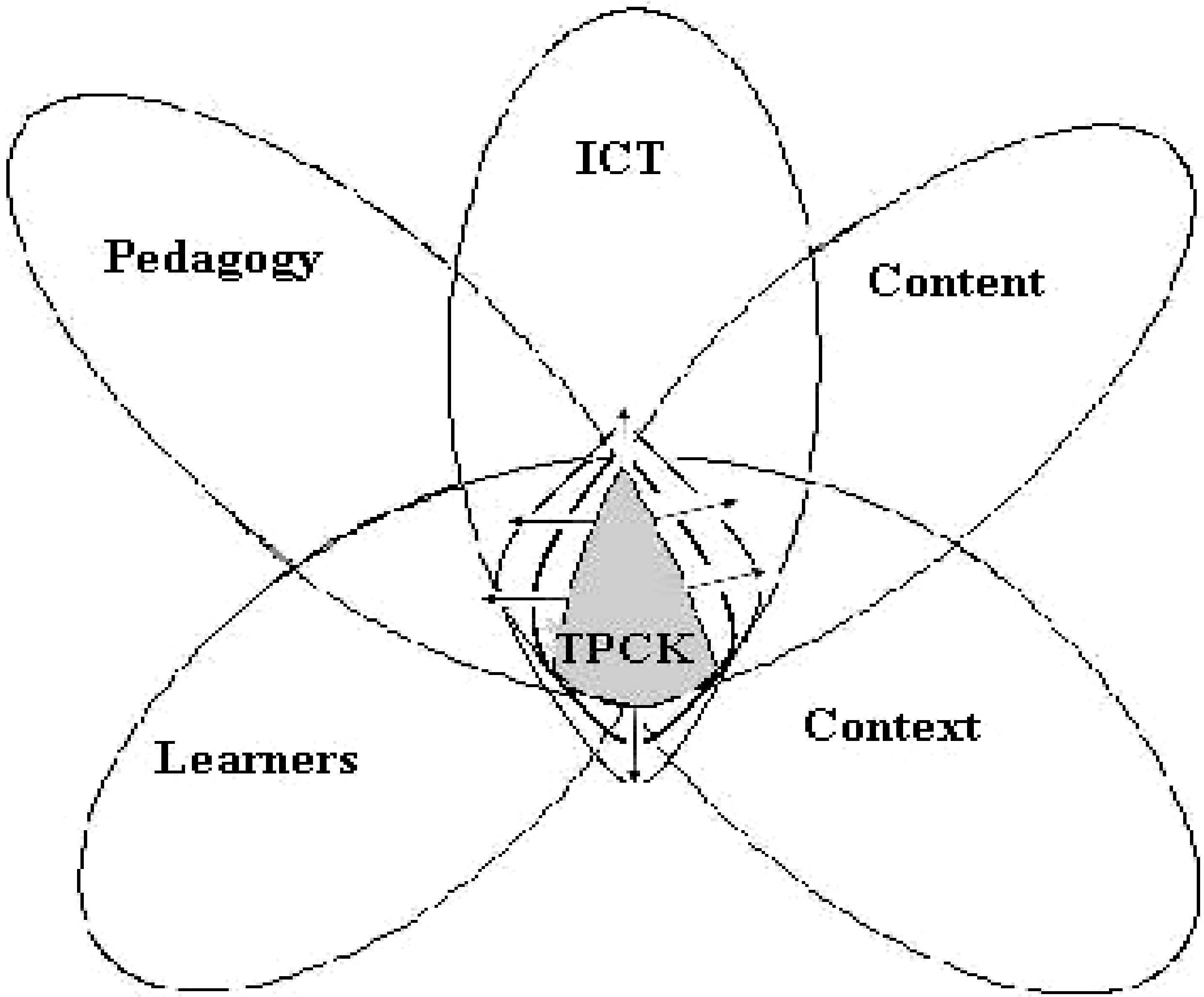
PCK

- Most importantly, PCK relates to the transformation of subject matter knowledge, includes an understanding of what makes the learning of specific concepts easy or difficult, and “embodies the aspects of content most germane to its teachability” (Shulman, 1986, p. 9).

THE KNOWLEDGE BASE OF TEACHING (adopted from Cochran et al., 1993)



Technological Pedagogical Content Knowledge (TPCK) (Angeli & Valanides, 2005, 2009)



TPCK

- ICT knowledge is defined as knowing how to operate a computer, knowing how to use a multitude of tools/software, and knowing about the affordances of tools.
- TPCK is defined as that form of knowledge that makes a teacher competent to teach with ICT.

TPCK

- It can be described as the ways knowledge about tools and their affordances, pedagogy, content, learners, and context are synthesized into an understanding of how particular topics can be taught with ICT, for specific learners in specific contexts, in ways that *signify the added value of ICT* .

TPCK competencies

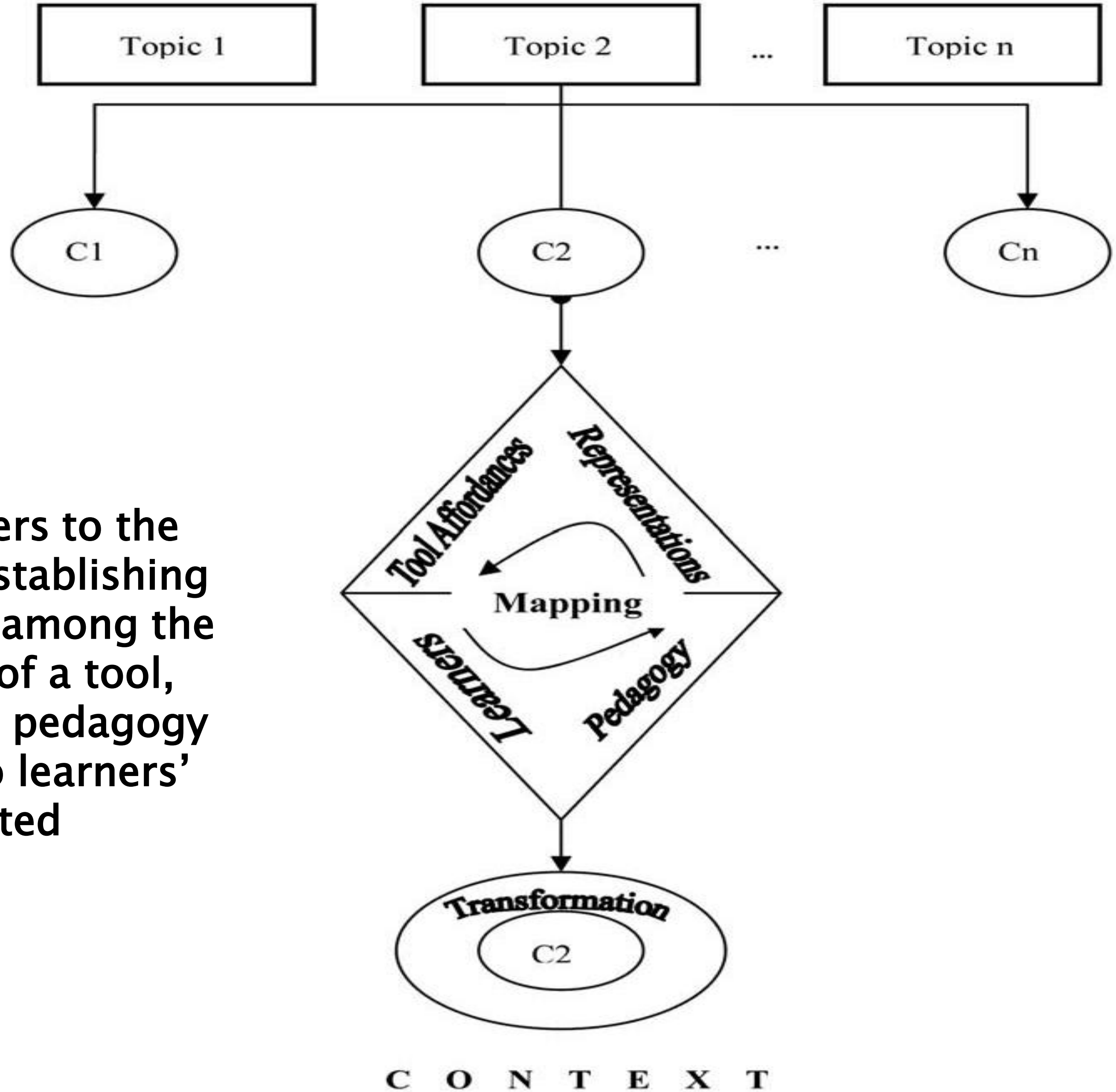
TPCK competency	Examples
1. Identification of topics to be taught with technology in ways that signify the added value of tools, such as topics that students cannot easily comprehend, or topics that teachers face difficulties in teaching them effectively in class.	1. Abstract concepts (i.e., cells in biology) that need to be visualized. 2. Phenomena from the physical and social sciences which consist of certain events and need to be animated (i.e., water cycle, immigration, butterfly life cycle). 3. Complex systems (i.e., ecosystems, organizations) in which certain factors function systemically and need to be simulated or modeled. 4. Topics that require multimodal representations (i.e., textual, iconic, auditory) such as phonics and language learning.
2. Identification of representations for transforming the content to be taught into forms that are comprehensible to learners and difficult to be supported by traditional means.	1. Interactive representations. 2. Dynamic transformation of data. 3. Dynamic processing of data. 4. Multiple simultaneous representations of data. 5. Multimodal representations of data.

3. Identification of teaching strategies, which are difficult or impossible to be implemented by traditional means.	**1. Exploration and discovery in virtual worlds. 2. Virtual visits (i.e., virtual museums). 3. Testing of hypotheses and or application of ideas into contexts not possible to be experienced in real life. 4. Modeling. 5. Complex decision-making. 6. Creation of cognitive conflict. 7. Long distance communication and collaboration with experts. 8. Long distance communication and collaboration with peers. 9. Personalized learning. 10. Adaptive learning.**
4. Selection of an ICT tool and pedagogical utilization of its affordances.	**Affordances of tools.**

5. **Identification of learner-centered strategies for the infusion of technology in the classroom.**

Any strategy that puts the learner at the center of the learning process in order to:

1. **express a point of view,**
2. **explore,**
3. **observe,**
4. **discover,**
5. **inquire,**
6. **collaborate with others,**
7. **resolve cognitive conflict, and**
8. **problem solve.**



Mapping refers to the process of establishing connections among the affordances of a tool, content, and pedagogy in relation to learners' content-related difficulties.

Educational affordances of Excel, technical functions, and evaluation criteria for each affordance

Affordance (sequenced from simple to complex)	Excel technical functions	Evaluation criteria
1. Excel as a tool for organizing data.	1. File – New/Open/Close/Save/Save as/ Page setup/Print area/Print preview/Print/Send to. 2. Edit – Cut/Copy/Paste/Fill/Clear/Delete/Delete sheet/Move or copy sheet/Find/Replace. 3. Insert – Cells/Rows/Columns/Worksheet /Chart Pictures. 4. Format – Cells/Row/Column/Sheet/Style. 5. Tools – Spelling/Speech/Protection. 6. Data – Sort/Text to columns/Group and outline.	1. Meaningful and clear organization of data. 2. Attractive and intuitive organization of data. 3. Appropriate selection of visualizations for the learners. 4. Integrated presentations of pictures, text, numbers, and spoken words. 5. Appropriate symbols to promote emergent literacy.

2. Excel as a tool for providing context-sensitive feedback.	1. Insert – Function/IF.	1. Function is correctly utilized. 2. Feedback is provided in different modalities taking into consideration learners' current level of literacy skills.
3. Excel as a tool for performing calculations.	1. View – Formula bar. 2. Insert – Function/Sum/Average/Count/Max.	1. Functions such as SUM(), AVERAGE(), etc are correctly utilized. 2. Formulae are correct.

4. Excel as a modeling tool.	1. **All of the above as needed.**	1. **Learners see clearly how their decisions/actions affect the outcomes.** 2. **Learners add or remove objects and observe the consequences.** 3. **The results of an action or decision are communicated with the use of appropriate visualizations when possible.** 4. **Aesthetic appeal.**

Method

- A questionnaire was sent to 22 secondary Computer Science teachers.
- Teachers had an average teaching experience of about 10 years.
- Teachers were asked to answer two questions:
  1. Based on your experience identify topics from the secondary education computer science curriculum that you feel are difficult to be understood by students or taught by teachers and explain why.
  2. Specify any misconceptions that you feel your students have about a computer science topic.

Method

- The topic “**Data - Processing - Information**“ was selected and a 45-minute lesson was developed.
- The lesson was taught in an eight-grade classroom (12-13 years old).
  - Five girls and seven boys.
- Students had basic computing skills.
- Excel was selected as the computer tool to be used for teaching the three concepts.

Method

- At the beginning of the lesson, students worked collaboratively in groups of four.
- Each group had to think and solve a different problem, which was taken from daily life.
- Students had to organize the data in a table, figure out how the data needed to be processed, and show the information obtained after the processing.
  - A group member presented to the whole classroom the solution each group proposed.
- The teacher facilitated the session and asked students to identify differences among them.
- Then, the teacher asked them to use Excel in order to solve six problems (plus one extra activity for those students who had extra time).
- Finally, all students had to took a quiz.

Results and Discussion

Computer science topics that teachers believe are difficult to be taught

Topic	*Why the topic is difficult to be taught*
Data, processing, and information	There is a difficulty to explain that information is the result of the processed data.
Main memory and secondary memory	There is a complexity in explaining the differences between the two types of memory as there is a difficulty in representing the two types of memory.
Loops (While/Do or Repeat/Until)	A difficulty arises when the number of repetitions is undefined. Also it is difficult to decide which loop structure to use.
Branching structure	It is difficult to explain the difference between Nested If and Multiple If statements.
Bubble sort algorithm	It is difficult to teach how to use two different counters for sorting a table. There is also a complexity related to teaching the procedure for exchanging the values of two variables with the use of an intermediate variable.
Use of two different types of typical parameters in procedures	It is difficult to teach the differences between the two types of parameters.
Communication protocol	It is difficult to teach how two different digital devices communicate between them.
Central Processing Unit – (CPU)	It is difficult to represent how the CPU operates.
Representation of data in computer language	It is difficult to teach the relation between electricity and computer machine language.
Transformation of data in binary form	It is difficult to teach the presentation and transformation of data in binary form, because students have no prior knowledge related to binary coding.

Results and Discussion

Student misconceptions	
Topic	*Student misconceptions*
Data, processing, and information	Students develop incorrect understandings about the three concepts and believe that data and information are synonyms. While these misunderstandings are not visible early on, they strongly manifest themselves during the teaching of some other computer science topics, such as, Algorithms, Spreadsheets and Databases.
World Wide Web (WWW) and Internet	Students believe that the Internet and WWW are the same thing.
Usefulness of flowcharts	Students do not understand the usefulness of flowcharts before writing up the code of a computer program.
Branching structure – Decision trees	Students tend to confuse the TRUE and FALSE values of a branching structure.
Functions and procedures	Students think that functions and procedures work the same way.
Use of variables in programming	There is a difficulty to understand the significance and the role of variables in programming, due to the fact that in essence students do not understand how the computer memory works.

Results and Discussion

(Table 3)	ACTIVITIES ASSESMENT							
	Activity 1 (10 units)	Activity 2 (10 units)	Activity 3 (10 units)	Activity 4 (15 units)	Activity 5 (15 units)	Activity 6 (15 units)	Quiz (15units)	Extra Activity (10 units)	Total Score
S1	10	10	10	15	15	15	15	10	**100%**
S2	10	7	10	12	15	10	10	10	**84%**
S3	10	10	10	15	15	15	15	10	**100%**
S4	10	10	10	15	15	15	15	10	**100%**
S5	10	10	8	0	0	0	5	0	**33%**
S6	8	6	6	10	8	10	10	0	**58%**
S7	10	10	10	10	0	0	10	0	**50%**
S8	10	10	10	10	10	15	12	10	**87%**
S9	10	10	10	0	0	0	10	0	**40%**
S10	10	10	10	15	15	15	15	10	**100%**
S11	10	10	10	10	10	0	15	0	**65%**
S12	10	10	10	15	15	15	15	10	**100%**
AVERAGE	**9,8**	**9,4**	**9,5**	**10,6**	**9,8**	**9,2**	**12,3**	**5,8**	**76,42%**
STD	**0,6**	**1,4**	**1,2**	**5,4**	**6,4**	**7,0**	**3,3**	**5,1**	**0,26**

Results and Discussion

- Five of the 12 students (41,5%) managed to receive a perfect score (100%) on all Excel activities.
- Only two of the 12 performed poorly (40% and 33%).
- Two students also performed adequately (87% and 84%).
- The vast majority of students, 91,6% obtained a perfect score on the first three Excel activities.
- Average score of students' performance on all Excel activities was 76,42%.

Results and Discussion

- Students' mean performance on the online Quiz was 82%.
  - It indicates that students developed correct understandings about the three theoretical concepts and the differences among them.
  - The framework of TPCK and TM proved to be effective in redesigning the teaching of the unit "Data-Processing-Information".

Results and Discussion

- No changes are recommended at this point about TPCK or TM.
- New TPCK project
  - The teaching of Central Processing Unit.
  - Programming skills with Robotics.
  - Training Computer Science teachers how to develop TPCK.

Thanks!

- Contact information
  - yianni@cytanet.com.cy
  - cangeli@ucy.ac.cy