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Lukáš Hapl,
Kateřina Kostolányová,
Hashim Habiballa
Czech Republic

Pupils' Opinions on Digital Systems Education Enriched by DCBLP Discourse

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Abstract

The article presents knowledge about the modified e-learning on-line synchronous teaching of digital systems, which took place in the period of widespread closure of schools during almost the entire school year 2020/2021 at a secondary school with an IT focus. The importance of teaching digital systems in computer science and the integration of teaching into available lessons is briefly clarified. Furthermore, the content of teaching is presented, including its modification by elements of programming by DCBLP discourse and links to existing knowledge about this use from previous years. The subject of research interest will be the specific effects of changes on students' opinions regarding the content of the subject. For this purpose, a qualitative investigation based on the design of the grounded theory will be used. The work brings partial knowledge that can serve as additional material for the determination of other research questions, hypotheses and identification of potential problems in teaching. The results show the pupils' interest in the digital systems enriched by the programming discourse reveals the possible perception of a long time distance learning in this area.

Keywords: *DCBLP, digital systems, e-learning, Packet Tracer, students' opinions*

Introduction

Secondary technical schools in the Czech Republic are typical example of ISCED 3. From the ontogenetic perspective we speak about the stage of late adolescence framed by the age 15–20 years. It is a right time to develop abilities, knowledge and gain important competencies (Galotti, 2016). The teaching of digital logic (Roth, 2004; Bindal, 2017) is currently not enshrined in the framework educational programs of computer science (18-M). At the time when the school curricula issued by the Ministry of Education, Youth and Sports were valid (roughly until 2008), the teaching of logic was included in the curricula of the relevant fields. After a curricular reform, schools in many cases maintained the teaching of logic by moving to available hours. However, the issue is standardly associated with electrical engineering areas – digital integrated circuits. Schools whose curriculum is based on FEP IT (RVP IT), and which are far from electrical engineering usually prefer a simple theoretical mathematical basis. Based on empirics, it can be expressed that the content of that course of study is usually not very attractive for many students of computer science and this usually corresponds to their study results. However, the issue of digital systems presents knowledge about basic functions, including computers; develops logical thinking, is also used in the construction of conditional expressions in imperative programming. Therefore, it is also valuable for computer science students. The important role of digital logic in the computer science curriculum is mentioned by Connelly (2004). Thus the computer science as a technical discipline with a deep mathematical basis (Booth, 2001) should be considered. There are already documented experiments supporting and enhancing the education of digital logic with tight relation to electronics (Noga & Radwanski, 2007). These experiments are using the simulation software along with HDL based languages. A deeper analysis of the significance of project-oriented learning was done by (Clark et al., 1999). Noticeable are also the intentions to focus on constructivist learning method in the formal logic area (Habiballa, 2004; Habiballa et al., 2018). Overall summary of the milestones related to Mathematical Logic in Computer Science are summarized by Kfoury (2019). There are also other non-procedural paradigm based experiments in teaching theoretical computer science (Wagenknecht, 1998; Devedzic, 1998).

Problem of Research

From previous research, it is clear that digital systems can also be successfully supported by logic (declarative) programming, such as the Prolog language (Clocksin, 1987). Surely the automata-based or HDL programming – such as Python based FHDL (M-Labs, 2020) can be used to support the intention, but the researchers would like to know if using the declarative & imperative programming together would be also beneficial. There are also efforts to independently implement two different paradigms in teaching, and only in the field of teaching theory, and elsewhere in the world (Israel) and not in the Czechia (Gal-Ezer, 1999).

An attempt to combine the idea of Gal-Ezer and the Israeli approach of the CS curriculum in our country was the only experiment carried out at several schools in the Moravian-Silesian Region. The research revealed that *„the more knowledge a student has in the field of programming, the more successful he is in creating finite state machines."* Therefore, in order to support the teaching of digital systems a new programming (non-HDL) discourse was defined combining elements of imperative (structured, object-oriented) and declarative (logical) programming which has been tested in teaching at Secondary school with an IT focus within the FEP IT, specifically at the Secondary School of Informatics, Electronics and Crafts in Roznov pod Radhostem (SSIER). This programming discourse is called Digital Circuits Based Logical Programming (DCBLP) and is developed and used as a didactic tool enriching distance learning of digital systems using programming languages that students commonly learn.

The details of using DCBLP discourse, its principles and applications can be obtained from appropriate papers (Hapl, Habiballa, 2019; Hapl, Habiballa, 2020).

Research Focus

The aim of the investigation is to find out what attitudes the pupils will take towards the subject, how they think about the subject, in which areas they see potential problems and whether they will differ significantly in groups. If so, in which areas will it be possible to identify the differences. In the case of this survey, it is a matter of finding out whether the interconnection of separate professional areas, not quite typical combination of more programming paradigms and modifications of teaching content (using DCBLP) will also have a positive effect on students.

Methodology of Research

General Background of Research

The teaching of digital systems (including DCBLP) at SSIER took the place during the period of school closure during the pandemic caused by SARS-CoV-2 in the school year 2020/2021, in the form of distance learning. Compared to the previous year, when asynchronous teaching in LMS Moodle prevailed (Hapl & Kostolányová & Habiballa, 2020), the distance form was significantly strengthened by synchronous on-line teaching (Kitsantas & Dabbagh, 2010) using Microsoft Teams. The ratio of asynchronous to synchronous teaching can be expressed as 20:80. Only lessons with a direct teaching obligation are included in this ratio. Teaching took the place in parallel in two groups (classes) of the second year of

Modern Information Technology School Education Programme (SEP). Data for the research were gathered after 7 months of teaching, when the students already mastered the subject matter of basic logic functions, Boolean algebra, combinational circuits and partly sequential logic. Pupils in the experimental group were taught areas of digital technology using the DCBLP discourse, specifically the Python-based variant (DCBLPy) and the Cisco Packet Tracer simulation tool. In the control group, the classical teaching of digital technology was implemented without the use of programming languages. The content of the course was the same in both classes. Both groups have the same preconcepts in terms of educational content, including teaching the basics of the Python programming language in the first year of study.

Sample of Research

There were 19 pupils involved in the experimental group, 17 in the control group. The teaching in each group was led by two different teachers. Both teachers had a pedagogical education, approximately the same length of pedagogical practice. The pupils were split into groups randomly at the beginning of their studies no matter the gender, disabilities or any other conditions.

Instrument and Procedures

In this survey, qualitative research is used as a basic methodological approach (Švaříček, 2014) and additionally some of data are expressed quantitatively (mixed approach). The grounded theory was chosen as the basic design for data analysis to create the relations between the categories (Švaříček, 2014; Charmaz, 2006). In-depth interview was used as a method of data collection for the initial examination of opinions. The questions were aimed at finding out the relationship to the subject (explained below). They should also justify their opinion on a specific positive or negative statement on the content of teaching. However, this question serves not as an answer, but as a penetration into the essence of the pupils' answers. The questions asked to the students were formulated with regard to the recommendations for this type of research (Rubin, 2005). The specific basic questions asked to the students were as follows:

- What did you like most about teaching digital systems and for what reason?
- On the contrary, what did you not like about teaching digital systems?
- Is there anything that could help me better understand the curriculum?
- What specifically would I see as the benefits of such a change?

The survey took into account the fact the adolescents, as participants in research, „do not thematize many questions" (Švaříček, 2014, p.177). Thus, they can respond austerely, and it is also necessary to take into account slipping to strong emotional experiences and exaggerate the negative experience. Authors also assume the respondents do not lie in a targeted manner.

Data Analysis

In all cases, the answers and ideas presented by the pupils during the survey were:

1. Transcribed in writing, if not already provided;
2. Subjected to a coding process (open coding);
3. Divided into categories;
4. Subjected to response analysis (analytical induction: Švaříček, 2014, p. 223);
5. Partial conclusions were subsequently drawn from the findings (using peer de-briefing).

The coding process is based not on the keywords in the responses, but on the context of the whole message. Representative and informative messages were selected. Wildcards or phrases in the form of codes were used both *in vivo* and by artificially transforming the content and essence of the communicated idea. The coding was performed separately for both groups. All codes were summarized and divided into six basic categories that characterize teaching:

A) In its content, its forms and methods;
B) In terms of activities developed by the student during teaching;
C) From the point of view of the pupil's perception of the benefit and use;
D) In relation to the subject and the curriculum that the pupil has created;
E) Aids that accompany the student during his studies;
F) *From the point of view of the teacher's personality and his influence on the process (excluded from the analysis in this article).*

A note is created for each code whether the student perceived the area as positive (+), neutral (0), or negative (-).

Results of Research

The results are based on the analysis of deviant (analytical induction) comparing the differences in individual categories with the help of constant comparison between groups.

Tables 1 (control) and 2 (experimental) summarize the assigned codes, the specific occurrence of individual respondents (under their anonymized ID), total occurrences in category, their division into individual categories and the context in which they were recorded (connotations).

Differences in Pupils' Perceptions of Teaching Between Groups

In the control group, theoretical teaching clearly prevails, without a link to other subjects, with suppressed feedback, without significant practical and activating activities leading to the practice of the curriculum in a form close to the students. Pupils' activity and activities using appropriate tools absent. Pupils mention frequent testing without the possibility of proper consolidation of knowledge as a significantly negative element. The prevailing opinion in this group is that the subject is inanimate, unpopular or its content remains misunderstood by many students. None of the students directly declared a positive attitude towards the subject. There is a small mention of distance learning as an obstacle. Only one pupil is aware of interdisciplinary relationships, and it has subsequently been found that he is influenced by the teaching of pupils in the experimental group. Pupils lack a sense of satisfaction from their own teaching activities. They also perceive the usefulness of the subject matter to a limited extent, a larger number of students also miss the real use of teaching and explicitly declare this. Programming, as a possibility of support, is really not used in teaching.

Table 1. Summary of the findings for the control group

	Designation, category name and category content	ID of respondents with the same opinion (total)	Total of various connotations recorded in the category		
			(+)	(0)	(-)
A	**Content, form and methods of teaching**				
	Rushing of tests, rushing of teaching, reasonable difficulty, lack of clarity, distance learning, evaluation, many theories, test as a possibility of consolidating the curriculum	1, 2, 3, 4, 5, 6, 7, 9, 12, 13, 14, 15, 16, 17 (14x)	2x	4x	22x
B	**Activating activities**				
	Necessity of practice, lack of activity, use of classmates' help, suitability of tasks	4, 5, 7, 8, 10, 11, 13, 14, 15 (9x)	1x	2x	8x
C	**Perception of benefits (and future uses)**				
	Lack of usability, current topic	2, 4, 5, 6, 11, 13 (6x)	2x	0x	5x
D	**Relationship to the subject (emotions)**				
	Unpopularity, incomprehensibility	1, 2, 3, 4, 9, 15, 17 (7x)	0x	0x	7x
E	**Tools**				
	Study materials	4, 7, 13 (3x)	3x	0x	0x
Percentage of responses			14,29%	10,71%	75,00%

The experimental group is dominated by practically oriented teaching with a deep connection to theory, students declare sufficient feedback, partially perceive interdisciplinary connections (although secretly in the form of the use of programming language), and acknowledge the systematicity and arrangement of teaching content. According to their statements, simulations are used. They declare the suitability of tasks based on programming in close connection with the content of teaching and the studied issues. They do not mention the use of a different way of programming than they are used to, but a third of the pupils directly mention it positively. Pupils positively mention clarity and activity when working on individual tasks. They also declare the need to concentrate and think about the given problem, and find the available didactic tools to achieve the goal as beneficial. In the experimental group, the pupils also expressed a limited positive

Table 2. Summary of the findings for the experimental group

Designation and name of the category		ID of respondents with the same opinion (total)	Total of various connotations recorded in the category		
			(+)	(0)	(-)
A	**Content, form and methods of teaching**				
	pace of teaching, complexity of content, clarity, practicality, distance learning, feedback, teaching organization, interdisciplinary interconnection	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19 (18x)	9x	8x	12x
B	**Activating activities**				
	Use of simulation with interdisciplinary connection, suitability of tasks, activity during teaching, need for concentration, help of classmates, tasks, use of programming, research	2, 3, 4, 5, 7, 8, 9, 10, 11, 13, 14, 15, 18 (13x)	14x	4x	0x
C	**Perception of benefits (and future uses)**				
	usability, meaningfulness	9, 12 (2x)	2x	0x	0x
D	**Relationship to the subject (emotions)**				
	popularity, liveliness, fun, self-confidence	1, 2, 5, 6, 11, 12, 14, 15, 16 (9x)	8x	0x	1x
E	**Tools**				
	Simulation tool, study materials	2, 4, 5, 8, 9, 11, 12, 13, 19 (9x)	12x	0x	0x
Percentage of responses			64,29%	17,14%	18,58%

opinion on the usefulness, but no one was found to explicitly express the lack of meaning of the content of teaching and the link between teaching and real use. To a greater extent, however, they perceive distance learning as a major obstacle to their further development. Furthermore, one student in connection with distance learning expressed a low level of confidence in creating the code.

In the control group, the supplementary survey showed that the method of teaching, knowledge testing and the content de-facto copies common practices and habits known to students from the period of full-time teaching and therefore they don't positively perceive return to school for full-time teaching. In the experimental group the distance learning is an obstacle for students for several reasons. Firstly, it is the impossibility of direct contact with classmates in solving practical tasks, secondly, the impossibility to try working with direct feedback from the teacher in the classroom with computer technology and thirdly, the pupils also mentioned problems with maintaining attention in the home environment, problems with technology were not mentioned.

Discussion

If the teacher's personality as a category (input variable) is excluded, then the following identified variables and aspects may have a positive effect (as an input) on the educational process during synchronous on-line digital systems teaching and help them gain a better relationship to subject matter:

- Clarity of the presented curriculum;
- Practical use of learned theory;
- Interdisciplinary interconnection;
- Tasks requiring activity and independent problem solving;
- Avoiding hasty testing;
- Programming in conjunction with logic;
- Use of a suitable simulation tool for testing and visualization of programming results;
- Suitable study materials.

Many of these findings are not new from a pedagogical point of view and it is quite clear that appropriate activating, problem-oriented and research activities of students (constructivism) lead to higher motivation, better perception of the subject and its content and in many cases better learning outcomes (Petty, 2009). However, it is also important what these activities are based on. Many of these variables will also depend on the teacher's approach (without taking into account his other personality traits). However, within the researched teaching, there are also such variables that the teacher himself does not personally influence. They are:

- Use of interdisciplinary interconnection;
- Programming in conjunction with logic. This is followed by (ie it is implied):
- Selection of programming and simulation (virtual) or test (and physical) environment.

An important aspect of the teaching in the experimental group is distance learning, which, acts as an obstacle to the social ties necessary for the implementation of teaching. The use of a programming language in a previous educational process without the subsequent use of interdisciplinary links during the teaching of digital systems in a control group does not automatically imply an improvement in the relationship to this subject. However, its appropriate use brings the possibility of enriching teaching and possibly improving the relationship of students to the subject. From this point of view, the DCBLP discourse in the implementation of DCBLPs can be considered as being suitable. An important finding is that the involvement of logic programming among the imperative is not perceived negatively by students.

As the next step it is necessary to find out to what extent the memorization and understanding of the curriculum is affected and also to identify specific situations in which the identified variables have greater or lesser motivational and cognitive impact.

Conclusions

The discussed teaching elements have a positive effect on the pupils' perception of the curriculum. It is also very important that the pupils in the experimental group largely discovered these elements themselves and mentioned them in large numbers – especially positively. In the context of this, it is also important to perceive the expression of the pupils of the control group, who search in vain in the curriculum without adequate didactic support, which corresponds to the empirical observations of some teachers for about the last decade. The findings regarding the negative perception of distance learning in the experimental group with modified teaching seem to be only marginally related, and it turns out that mere questionnaire surveys on distance learning without understanding the context can in some cases significantly distort and simplify reality and mere quantitative interpretation (distance learning is good versus bad) can lead to mistakes and misunderstandings.

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