VZ (2133)/17

Příloha č. 2 k RD č. 34/2016

Výroční zpráva projektu specifického výzkumu na rok 2017 – zakázka č. 2133

Název projektu: Výzkum aplikace informačních a komunikačních technologií do vzdělávání
Specifikace řešitelského týmu

Odpovědný řešitel: **RNDr. Andrea Ševčíková,** K-DR-INT; ID (dle STAGu): P15K0160, (studijní program ICT ve vzdělávání, PdF UHK)

Studenti doktorského studia na PdF UHK: **Mgr. Simona Pekárková,** K-DR-INT; ID (dle STAGu): P15K0159, (st. program ICT ve vzdělávání, PdF UHK)

Studenti magisterského studia na PdF UHK: -

Školitelé doktorandů: **prof. RNDr. Eva Milková, Ph.D.**

Další výzkumní pracovníci: -

Celková částka přidělené dotace: 159 604.23,-Kč
Stručný popis postupu při řešení projektu (max. 2 strany)

Návrh projektu byl koncipován tak, aby výsledky byly dále využité ve *výzkumu prováděném v rámci disertační práce navrhovatelky Andrey Ševčíkové a výzkumu prováděném v rámci disertační práce spoluřešitelky Simony Pekárkové.*

V rámci řešení projektu byly sledovány dva výzkumné záměry:

První výzkumný záměr (RNDr. Andrea Ševčíková):
Analýza multimediálních studijních materiálů pro výuku vět a jejich důkazů v předmětech zabývající se teorií grafů

Cílem výzkumného záměru byla realizace elektronických studijních materiálů pro výuku vět a jejich důkazů v předmětech zabývajících se teorií grafů, které byly navržené na základě výsledků SV 2016 a analýza jejich vlivu na znalostí studentů zařazených do předmětů (DIMA pro studenty FIM) zabývajících se teorii grafů a grafovými algoritmy s využitím statistické analýzy výstupů z úvodních znalostí z matematické logiky (pre-testů) a závěrečných testů (post-testů). Součástí výzkumu byl též *výzkum* preferencí učebních stylů studentů s pomocí on-line instrumentu profesora Feldera - ILS (Index of Learning Styles) a na základě tohoto výzkumu navržení inovace elektronických studijních materiálů pro podporu výuky vět a jejich důkazů.

V únoru a březnu 2017 přes 60 studentů FIM v rámci předmětu Diskrétní matematika (DIMA) vyplnilo dotazník Index of learning styles (ILS) profesora Feldera. Pomocí tohoto dotazníku byly detekovány preference jednotlivých pólů dichotominích dimenzí učebních stylů.

V únoru 2017 proběhlo úvodní testování znalostí a dovedností z matematické logiky výše uvedených studentů, tj. studenti vypracolali připravený pre-test.

V květnu 2017 proběhlo pomocí testů IST 2000 R testování matematických dovedností studentů.

V průběhu května až července proběhlo závěrečné testování studentů, tj. studenti vypracovali post-test.

Ve zbylých měsících jsme se zaměřili na využití dat získaných ILS dotazníku k návrhu inovace multimediálních studijních materiálů, respektujících preference učebních stylů, pro podporu výuky teorie grafů s důrazem kladeným na porozumění prostřednictvím vizualizace důkazů matematických vět. Také proběhla analýza závěrečných projektů. Byly porovnány zjištěné výsledky s výsledky získanými ve výuce bez podpory elektronických materiálů pro podporu vět a jejich důkazů.

Druhý výzkumný záměr (Mgr. Simona Pekárková):
Kultivace matematických kompetencí u předškolních dětí pomocí digitálních technologií.

Cílem druhého výzkumného záměru bylo analyzovat přínos nových technologií na oblast matematických kompetencí u předškolních dětí. Přínos a vliv na učení pomocí ICT byl sledován v kognitivních oblastech, jako je prostorová představivost, vizuální percepce a matematické dovednosti. Součástí výzkumu byla analýza vzájemné korelace mezi jednotlivými zvolenými oblastmi matematických kompetencí. Byly zjišťovány počáteční úrovně všech zmíněných oblastí u předškolních dětí. Výuková aplikace zaměřená na rozvoj daných oblastí byla použita jako vzdělávací nástroj.

Výuková aplikace, dokončena v září 2016, byla v průběhu období od října 2016 do února 2017 použita v pilotním výzkumu a odzkoušena na vzorku 20 předškolních dětí ve věku 4-6 let v MŠ Kratonohy. V průběhu dubna a června byly provedeny potřebné úpravy ve výukové aplikaci na základě výstupů a zjištění v rámci pilotního výzkumu. Od září do prosince 2017 byl proveden experimentální výzkum na vzorku 50 dětí v MŠ v Pardubicích zjišťující přínosy ICT v rozvoji matematických kompetencí - konkrétně v oblastech prostorové dovednosti, matematických dovedností a zrakového vnímání. Vybrané MŠ byly poskytnuty přístroje - tablety, školení pedagogů příslušné MŠ proběhlo před zahájením experimentálního výzkumu.

Pro zhodnocení úrovně zmíněných oblastí matematických kompetencí ve fázi pretestu a posttestu byly použity standardizované testy. Pro fázi intervence, září až prosinec 2017, byla použita upravená výuková aplikace.

Výstupy výzkumu byly prezentovány doktorandkami na mezinárodní vědecké konferenci ICEEPSY 2017 v Portugalsku v říjnu 2017 a na konferencích, prezentovaných školitelkou, s výstupem publikace článků v odborném periodiku.

Splnění kontrolovatelných výsledků řešení:

Časopisy:

[1]**Maněna, V., Milková, E., Pekárková, S., Dostál, R.** Integration of mobile technologies and social networks into activation methods in education. *International journal of education and information technologies.* North atlantic university union, 2017. 6s. ISSN: 2074-1316.
Kód UT ISI: 000417788400005.
Kód RIV: AM - Pedagogika a školství.
Forma: J_ČLÁNEK V ODBORNÉM PERIODIKU (ID: 43873491) (RIV ID: 50013882)
– hrazeno ze SV2102 PřF

[2]**Milková, E., Ševčíková, A.** Algorithmic thinking and mathematical competences supported via entertaining problems. *International journal of education and information technologies.* North atlantic university union, 2017. 7s. ISSN: 2074-1316.
Kód UT ISI: 000417788400012.
Kód RIV: AM - Pedagogika a školství.
Forma: J_ČLÁNEK V ODBORNÉM PERIODIKU (ID: 43873445) (RIV ID: 50013836)

- hrazeno ze SV2133 PdF

[3]**Pekárková, S., Milková, E.** Spatial Skills of Preschool Children supported by Game Application. *International journal of education and information technologies*. North atlantic university union, 2017. 5s. ISSN: 2074-1316.
Kód RIV: AM - Pedagogika a školství.
Forma: J_ČLÁNEK V ODBORNÉM PERIODIKU (ID: 43873492) (RIV ID: 50013883)
– hrazeno ze SV2102 PřF

Proceedings:

[4]**Ševčíková, A., Milková, E., Pekárková, S.** Visualization as a convenient tool to support the teaching of mathematical proofs. *International conference on Education and educational psychology (ICEEPSY 2017)*. London : Future science, 2017. 10s. ISSN: 2357-1330.
Kód RIV: AM - Pedagogika a školství.
Forma: D_ČLÁNEK VE SBORNÍKU (ID: 43873446) (RIV ID: 50013837)
- hrazeno ze SV2133 PdF

[5]**Pekárková, S., Milková, E., Ševčíková, A.** AFFECTIVE DOMAINS, INTRINSIC MOTIVATION AND GAME-BASED APPLICATION IN EARLY CHILDHOOD EDUCATION. *International conference on Education and educational psychology (ICEEPSY 2017)*. London : Future science, 2017. 7s. ISSN: 2357-1330.
Kód RIV: AM - Pedagogika a školství.
Forma: D_ČLÁNEK VE SBORNÍKU (ID: 43873447) (RIV ID: 50013838)
- hrazeno ze SV2133 PdF

Typ výstupu	Plán	Skutečnost	Poznámka
Počet dizertačních prací			
Počet diplomových prací			
Jimp - výstup v impaktovaném časopisu			
Jneimp – výstup v databázích Scopus a WoS	1	3	
Jrec – výstup v recenzovaném časopisu			
B – odborná kniha			
C – kapitola v odborné knize			
D – článek ve sborníku (WoS)	2	2	předpoklad zařazení sborníku do WoS
Počet výsledků celkem	3	5	

Přehled realizovaných výdajů:

		Plán v Kč	Poznámka
a)Osobní náklady	mzda Ševčíková	5 952	řešitelka – doktorandka KF PdF
	zdravotní pojištění Š	535,63	
	sociální pojištění Š	1488	
	úrazové pojištění Š	24,99	
	odměna Pekárková	8 000	spoluřešitelka – doktorandka KF PdF

	DPP	10 000	externí zakázka
	Celkem osobní náklady	**26 000,62**	
b)Stipendia	-	0	
c)Materiálové náklady	tonery	16048,6	
	kancelářské potřeby	8 953	
	Celkem materiálové náklady	**25 001,6**	
e)Služby	fee ICEEPSY	14 584,31	Ševčíková
	fee ICEEPSY	14 559,16	Pekárková
	fee EMET	16 843,7	Ševčíková (už navýšený o 21%)
	překlady článků	9 000	ŽL
	testování IST 2000 R	9 000	ŽL
	Celkem služby	**63 987,17**	
g)Cestovné	na konf. ICEEPSY	12 851	Ševčíková – cestovné, ubytování, diety
	na konf. ICEEPSY	12 501	Pekárková – cestovné, ubytování, diety
		17 088	letenky
	cestovní pojištění	220	Ševčíková
	cestovní pojištění	220	Pekárková
	Celkem cestovné	**42 880**	
jiné	kurzovné ztráty	1 088,93	
	bankovní poplatky	647,05	
	haléřové vyrovnání	-0,40	
	Celkem jiné	**1 735,58**	
Celkem		**159 604,97**	**přidělené dotace: 159 604,23 Kč**

Povinné přílohy:

a) kopie publikačních výstupů
b) výpis (export) z OBD – výsledky publikační činnosti podpořené projektem,
c) vyúčtování dotace - „Výsledovka po účtech s pohyby“ z ekonomického informačního systému Magion

Datum:
4. 1. 2018

Podpis odpovědného řešitele

Seznam literatury podle šablony ID záznamu

[1]**Maněna, V., Milková, E., Pekárková, S., Dostál, R.** Integration of mobile technologies and social networks into activation methods in education. *International journal of education and information technologies.* North atlantic university union, 2017. 6s. ISSN: 2074-1316. Kód UT ISI: 000417788400005.Kód RIV: AM - Pedagogika a školství.
granty: 0
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granty: 0
Spec. výzkum: S.
Forma: D_ČLÁNEK VE SBORNÍKU
(ID: 43873447) (RIV ID: 50013838)

Integration of mobile technologies and social networks into activation methods in education

Vaclav Manena, Eva Milkova, Simona Pekarkova and Roman Dostal

Abstract—Information and communication technology has the potential to transform the way people work together, access information, think and build new knowledge. The article presents new forms of mobile technologies and social networks usage in educational process. Authors focus on activation methods that can be enriched with these technologies. Presented methods have been experimentally verified and are based on the research which was realized at schools in the Czech Republic.

Keywords—activation methods, BYOD, mobile technologies, motivation, social networks.

I. Introduction

RECENTLY, possibilities of mobile learning and collaborative learning have been increased due to evolution of mobile technologies and its market penetration through smartphones and tablets, but also due to high acceptance of these technologies among young people. Some characteristics such as social relationships or the mobile technologies and information and communication technologies have an important influence over human learning. Some researchers state this [1], [2] and they show a big interest in studying and researching how these new technologies can affect the teaching and learning process [3].

In terms of main 21st century competences, the competency of the ability to use technology interactively, has been classified and defined by OECD. OECD's Education panel clearly defined the importance of ICT for the future generation life. They proposed "information dimension" which should be taken in account as one of the most important domain. Information and communication technology has the potential to transform the way people work together, access information, think and build new knowledge. Technology can be used interactively and beneficially if we understand its nature and reflect on its potential.

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Eva Milková is full professor and supervisor of Simona Pekárková. She works at the Department of Informatics, Faculty of Science, University of Hradec Kralove (http://lide.uhk.cz/prf/ucitel/milkoev1/).

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Increasing pupils' motivation to learn is the constant problem in all types of education and age groups. The present time offers teachers a lot of options to increase the attractiveness of the education. If we combine proven educational methods with modern technologies, we can obtain good results: students might be more motivated and involved into educational process. Pupils enjoy education and acquire new skills with using modern technologies such as tablets and smartphones.

Activation methods are considered as very powerful tools for increasing motivation to learn. If we unite these methods with modern technology, effectiveness of education will increase and learning benefits become even more stable and permanent. (cf. [4], [5])

II. Theoretical Background

A. Activation Methods

The activity can be understood as the mobilization of natural psychic powers, increased efforts, focusing on action. The teaching activity of students represents the formation of positive attitudes to learning themselves.

An active teaching method breaks the traditional stereotype of teaching, giving space for the creativity of teachers. The activation methods can be defined as "practices that lead teaching to achieve the educational goals based on their own teaching work of students, whereby the emphasis is on solving problems" [6]. These methods emphasize active participation of students in the classroom and direct involvement in teaching activities.

Generally speaking, activation methods require more energy and effort from teacher, but on the other side, teacher acquires important benefits: more motivated and involved students, who enjoy the education process. One of the big advantages of using activation methods is that teacher may also gain experience with pupils from different situations. Nevertheless, activation methods cannot replace traditional teaching in all cases. Sometimes it is more useful to use them as a complement to classical lessons (see Table I).

Table 1. Comparison of different teaching forms [7]

Comparison criterion	Forms of teaching		
	Classic education	*Teaching with activation methods*	*Combination of both forms*
Time required to prepare lessons	Low	High	Medium
Teaching aids	Low	High	Medium
Time required for implementation into the lesson	Low	High	Medium
Development of thinking, creativity	No	Yes	Yes
Increases the interest in the subject matter	No	Yes	Yes
Self-recognition	No	Yes	Yes
Changing relationships in the classroom	No	Yes	Yes
Space for students	No	Yes	Yes
Increases systematization	Yes	No	Yes

B. BYOD

If we decide to use modern technology and social networks in the classroom, in the first place we encounter small availability of these technologies in the school. This problem is partially smaller when teaching ICT, where at least a computer and access to the internet are at disposal. On the other hand, when teaching other subjects, the situation is worse. In spite of the fact that some schools have mobile classrooms with laptops or tablets, there is still insufficient number of devices very often. Furthermore, another problem can be either lack of coverage of the wifi signal or slow wifi network.

For instance, one possible solution is to ask pupils to use their own devices such as smartphones and tablets. This approach is commonly described as BYOD (bring your own device), or sometimes is also called BYOT (bring your own technology). As we found out in our research, the students have sufficiently powerful smartphones, often with connection to the internet. The combination of social networking and mobile technologies are very popular among the pupils. Therefore, we gain new opportunities in the lessons which might be also thought, thanks to technology, outside the classroom. To sum up, the use of social networking in education literally calls for the use of mobile technology.

Mobile devices offer a new opportunity for learning even in environments outside of school. Because they are truly personal tools, mobile devices enable continuous creation of personal learning environment (PLE). Mobil devices can enable to influence effectively content of education and they bring new opportunities in children's learning.

Speaking about mobile learning, mLearning for short, we can simply describe it as a teaching method carried out on mobile devices. According to Cochrane [8] it is not "eLearning on tablets", but rather a way of teaching qualitatively and methodologically different from traditional eLearning. According [6] and [9] mobile devices allow for better use of a broader portfolio of classroom forms of teaching and methods when compared to traditional eLearning. Included among these forms and methods are: tours in a museum, field work, research activities, didactic outdoor games, learning through life situations or group or cooperative learning (cf. [10]).

III. RESEARCH

A. Aims

The main objective of the research was to analyze which social networks are being used by young people, with the emphasis on the age group under the age of 13 years. Furthermore, we focused on the use of social networks among the University of Hradec Králové teachers and students-future teachers studying there. Our study was also aimed at specific differences in using social networks among selected age groups. We assumed that Facebook might bet the mostly used social networks across all age group.

Thus, the next aim of our research was to focus on the frequency of use and types of mobile devices, which respondents used for working with social networks. We concentrated mainly on smartphones and tablets thanks to the fact that we assumed that most users prefer work with social networks on some type of mobile device. However, we followed up the use of laptops and desktop computers as well. In case of smartphones and tablets, we payed attention to the possible accessibility of internet connection.

B. Methods

The Data was collected using a non-standardized electronic questionnaire with closed answers. The electronic questionnaire was created in Google Forms and contained terms of branching by age group of respondents. The questionnaire was optimized for use on mobile devices. The sample size which we wanted to target was at least 30 answering respondents from each age group. This goal of involving enough respondents was successfully achieved because the group with the least representation (age 30+) consisted of 35 respondents.

The content validity of the questionnaire was assessed by three independent experts from the area of psychology, informatics and pedagogy. The content of the test was based on the research [11], carried out broadly in the Czech Republic. The questionnaire reliability was assessed on the basis of the Cronbach alpha calculation ($\alpha = 0.78$).

C. Research sample

The research sample consisted of 807 respondents, consisting of pupils, students and teachers from Hradec Králové and the surrounding area. The amount of men and women was proportionally balanced: there were 51.2 % of women and 48.8 % of men in the research sample. Detailed distribution of respondents' age is presented in Fig. 1.

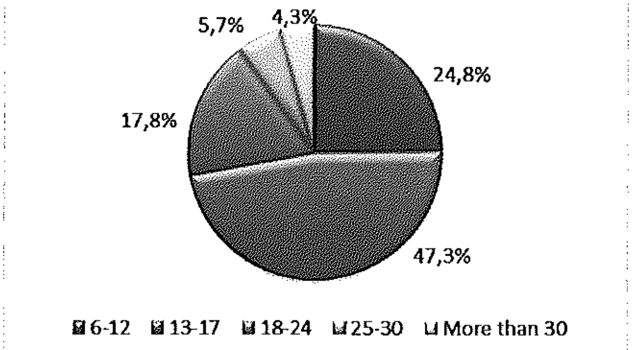

Fig. 1 Age distribution of respondents

For the sake of clarity and the fact that almost all social networks have a minimum age requirement of 13 years, the age of the respondents was divided into the following intervals: 6-12 years, 13-17 years, and 18 years and over (this category is referred to as 18+). Following research results are presented for those age categories.

D. Results

As we expected, the use of social networks is very intensive in all aforementioned age groups (see Fig. 2). More than 94 % of users in the age group from 13 to 17 years use at least one social network. The use of social networks in the age group 18+ is also very high (84.4 %), but this result is nothing unexpected and was predicted by researchers as well.

But the most surprising and alarming fact is that more than 75 % of respondents in age of 6 – 12 years use at least one social network. Moreover, this number might be in fact even higher because some children were afraid to confess in their responses that they are actively using some social network. We can clearly sum up that our results correspond with situation in other European countries [12] and are consistent with global research in the Czech Republic [11].

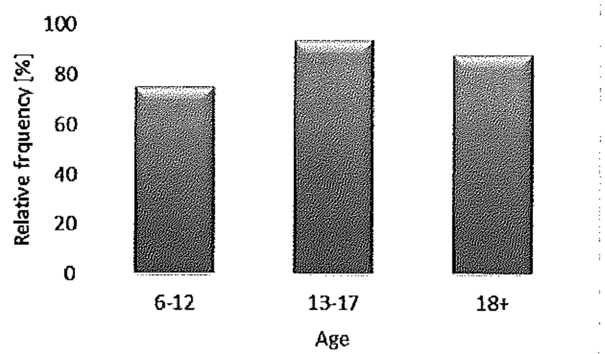

Fig. 2 Percentage of social networks' users in selected age groups

Majority of respondents use social networks more than one hour per day. Typical use of social networks is one to four hours a day (see Fig. 3). Although only relatively small amount of respondents reported that they use social networks more than six hours a day, this number can be fairly higher: many users are connected almost all day on their mobile devices but they do not realize it and do not perceive this reality as being connected with social networks.

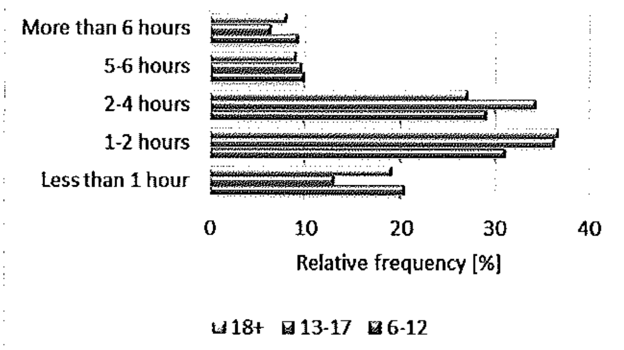

Fig. 3 Daily amount of time that users spend on social networks in selected age groups

Facebook is the most popular social network among all age groups. It is being followed by Instagram which has great popularity among all age groups as well (see Fig. 4). Due to our findings the high number of Facebook users younger than 13 years is caused by the fact that it is very easy to create "fake" profile with fictive age.

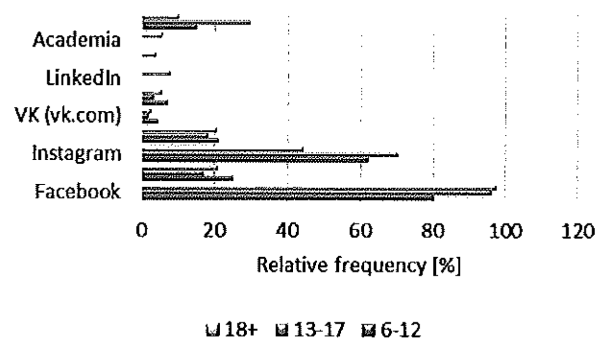

Fig. 4 Popularity of social networks in selected age groups

More than 80 % of users in all age groups use smartphone for being in touch with social networks. More than 40 % of respondents use tablets for being connected with social networks – that is significantly more than in other age groups (see Fig. 5).

More than 90 % of all respondents use WiFi connection to the internet on their mobile devices (see Fig. 6). In addition, more than 50 % of users in all age groups use data tariff. The number of data tariff users might be increasing in the future as mobile operators keep lowering the prices of data services.

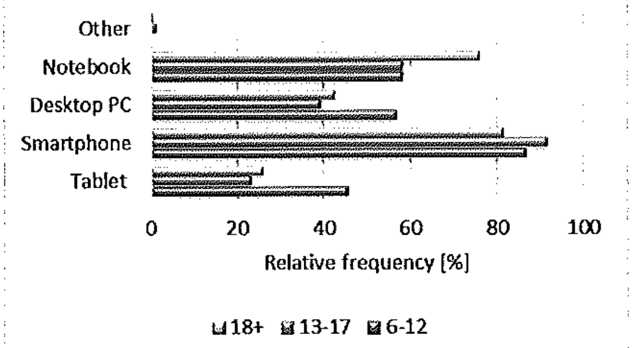

Fig. 5 Devices that respondents use for accessing social networks at school in selected age groups

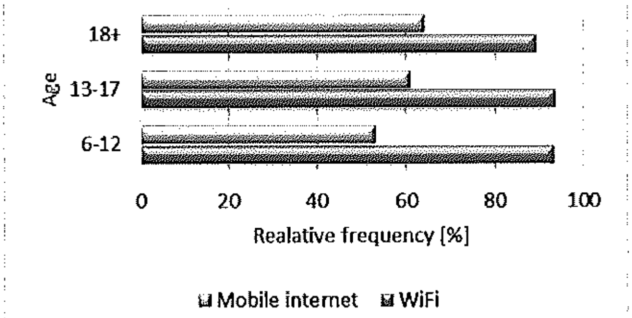

Fig. 6 Types of internet connection that respondents use on their mobile devices

Furthermore, we focused on particular reasons which might discourage others from using social networks. Naturally, reasons vary among all age groups. Concerning the age group 6-12 years the most referenced answer giving by respondents was "my parents forbid me to use social networks" while the users in the age group 13 – 17 years were mostly afraid of the fact that their parents could find their profile on a social network. Detailed distribution of answers is shown in Fig. 7.

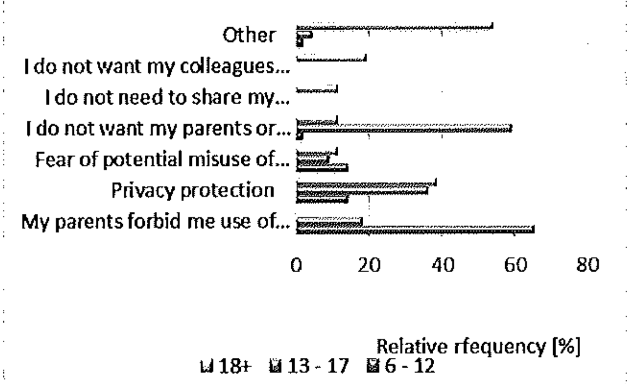

Fig. 7 Respondents' reasons for not using social networks in selected age groups

IV. Examples of Selected Activities

During the research, the authors have designed and tested a few of the activities that can be used in teaching and in educational process in primary and secondary schools. Selected activities using a combination of social networking and mobile technology are presented in the following text. The examples are illustrated on Facebook and Instagram social networks which represent the most popular networks among selected age groups.

A. Facebook Group

Facebook group represents a group where a teacher can serve as an administrator or moderator of the task or project. Pupils can publicly communicate and upload their contributions on the "timeline". Individual contributions are immediately displayed to the other members of the group. The other advantage is that others can react immediately after reading a post on the subject and contribute their opinions and suggestions at the same time. Next, users have the opportunity to communicate privately together when they decide. This is considered as useful choice for users who need to discuss a concrete post before publishing it to the group. Additionally, users can share pictures, charts, videos and make also comments on these files.

Example

In History lesson, teacher creates Facebook group "Charles IV, Holy Roman Emperor". The pupils are divided into groups of two or three. Each group of the pupils gets a single task: the life of Charles IV, the predecessors of Charles IV, foundation of Charles University, wife of Charles IV, children of Charles IV, etc. Each group of the pupils communicate between each other and comment on the individual's contributions. It is also enable them to share each of the links, where the information is found. The teacher is in the role of moderator who controls, corrects, motivates and checks entire project. The teacher sees the activity of all groups. That´s way both, the teacher and the pupils, can easily receive feedback which is beneficial for developing of working motivation and for goal achievement itself.

B. Polling in Facebook Group

Another option, that teacher might incorporate in their teaching process, is Facebook poll. The users might take advantage of commenting on everything and every group member sees how each poll point stands. Moreover, other tools which are available on Facebook might enable to involve and get students more active. For instance, users can upload a photo and let other users vote by expressing their own reactions, attitudes and opinions (Like, Love, Haha, Wow, Sad, and Angry).

Example

In Art education lesson, pupils create proposals of poster, school logo, photography on given topic etc. The pupils can take photographs with the help of mobile phone. Mobile phone enables them taking pictures of drawings and other types of hand-made materials as well. After taking picture and publishing it into their created group, the pupils can discuss the images posted and vote for the best proposal. Such an activity is also suitable for involving pupils from other classes. Besides it teachers can organize a contest among pupils from different schools as well.

C. *Facebook Page*

Teacher can create Facebook page and add pupils as page moderators. The page can be created for specific classroom, topic or some particular event (school's trip, excursion etc.). After the page is created, it might be used even as communication platform for teachers, parents and public. It is convenient and efficient that the page can be accessible from the internet, without need to have Facebook account.

Example 1

Teacher creates (in cooperation with pupils) school or classroom page, where pupils, teachers and parents can follow the latest information about what is happening in the school. Users can discuss topics, offer cooperation and come up with different ideas on how to improve school life.

Example 2

Electronic reader's diary. The page can be used for discussion of read books, where pupils write a short review about books that they have read and recommend this book to others. The pupils may discuss peer-reviewed books and add likes or other reactions to book chosen. According to their reactions, everybody in the group can find out the level of popularity of the books. Despite pupil's actual preferences the teacher can then initiate discussion about the best and worst rated book in lesson.

D. *Instagram*

According to the research results, Instagram is used mostly by younger pupils. Its main advantage is simplicity of use in general. Despite it does not have as many advanced option as Facebook it can be used fast and easily. Surely, this is one of the main reasons why Instagram is so popular among young children. Nevertheless, Instagram can only be fully used with mobile application and the web version is very limited. The application is available for Android, iOS, and Windows 10 Mobile. Instagram supports hashtags. The photo contains the time and place of acquisition, so teacher can use this information when checking published images.

Example

Searching for the oldest building in a town. In History lesson, pupils go out with their smartphones and take photos of old building in the town. They add hashtags (like #gothic, #baroque etc.) and texts from information tables. After adding a hashtag, the pupils watch the popularity of their photos and photos published by their classmates. The pupils receive an overview on how they stand. It motivates them to search for other buildings and to have appropriate competition. Pupils get acquainted with the architecture of the city and its history.

V. Discussion

Technology related to teaching/learning plays a vital role in 21st century education [13]. (cf. e.g. [14], [15]). The needs to serve the learners become urgent to make learning activities more motivating, funny and engaging for the students who are continuously surrounded with every form of new technology [16].

Activating methods themselves can be very powerful tools for increasing students' motivation and their engagement into educational process. These methods may have also powerful and positive impact on attractiveness of learning.

If we combine them with mobile technology and social networks, we create and receive a strong and effective mix attitude and didactic methods, which can be interesting and helpful for both of group - students and teachers also. One of the keys for successful implementing these technologies into educational process is that they need to be easy to use and easily accessible and available for teachers and students. Both Facebook and Instagram are very easy to understand and users already have basic skills with interacting with them, even before they start to work with them at school. Tablets and smartphones are easily available because pupils and teachers already own them often and they also bring them to school every day. Of course, some technical problems with using own devices may appear. But in general, these disadvantages cannot beat advantages that we may gain from the use of activating methods and new technology. Using this new approaches for teaching means a teacher should handle new challenges of this creative and interactive way of education. It means they also need to know how use mobile technology and social networks in classroom in an efficient and safe way.

VI. Conclusion

Integration and incorporation of ICT, including of mobile technologies and social media, in education seems to be unavoidable. There is a constantly growing need of change in using of ICT. Furthermore, a question of use of ICT as means that can bring new benefits has already occurred a few last years. The goal of many professionals is how to use ICT not only as substitution for a textbook but how to enhance development of personal key competencies of students and how to support their active takeover of responsibility for their own education. Mobile technology and social networks are used by pupils extensively not only in leisure, but also in school. The combination of mobile devices and social networks can logically be used as suitable tool for making learning attractive and can caused increase of pupil's motivation.

As our research shows new activation methods might to enhance collaboration and cooperation among the pupils which might influence positively their learning outcomes. Some previous researches using computer-supported and collaborative learning have proved positive impact of this method on promoting of interaction, collaboration, help each other, motivation and interests in learning as well [17].

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Algorithmic thinking and mathematical competences supported via entertaining problems

Eva Milkova, Andrea Sevcikova

Abstract—The essential part of studies at the faculties instructing students in the field of computer science is not only the development of student's ability to think algorithmically, but also to enhance their mathematical competences - the ability to develop and apply mathematical thinking in order to solve a range of problems in everyday situations. Besides a deep analysis of the topic and discussion on mutual relationships within the problem solving, the involvement of students into the subject is a very important educational factor. Practical and entertaining problems attract students not only to know more about the explained subject matter, but also and more importantly, to apply gained knowledge. If an interesting task is assigned as prototype to a new topic using a picture and resulting explanation of the task solution, both spatial and verbal working memory is required and students recall the explained subject matter much better. In the paper we pay attention to the role of entertaining problems as a useful study material supporting development of both, algorithmic thinking and mathematical competences.

Keywords—Algorithmic thinking, entertaining problems, learning style preferences, mathematical competences, visualization.

I. Introduction

Computers have become the most empowering tool humankind have ever created. They are the tools of communication, the tools of creativity, and they can be shaped by their user.

An essential part of studies at faculties preparing students in the area of computer science is the development of their mathematical competences and ability to think algorithmically. Students must be able to create various algorithms solving given problems starting with easy ones and consecutively increase their knowledge and shifts during studies till the level where they deeply understand much more complex problems. Subjects dealing with graph theory and combinatorial optimization serve very well for development and deepening of students' capacity for the mentioned skills and knowledge.

People learn and process information in different ways, thus to recognize student's strengths and weaknesses in a subject better, it is valuable to learn how to respond under different circumstances and how to approach information in a way that best addresses students' particular needs.

One of the suitable means to approach the instruction to the students is considered multimedia, respectively suitable implementations of different types of media in the instruction with regard to didactic knowledge of content and students' needs.

Very important educational factor is students' involvement into a subject. If an appropriate task is introduced and examined within a topic, students recall the explained subject matter much better and their involvement progresses when looking for similar examples.

The aim of the paper is to discuss the role of entertaining tasks provided in the subjects dealing with graph theory and combinatorial optimization, as a useful study material supporting the ability to develop and apply mathematical thinking in order to solve a range of problems in everyday situations with regard to preferred learning styles of students. The paper is loosely based on papers [1], [2].

II. Learning Styles Preferences

There are plenty of learning style models. At our university we have chosen the Felder-Silverman learning style model and on this model based questionnaire called the Index of Learning Styles. Let us point out here at least the following remarks (cf. [3], [4])

Felder [5] defines individual learning styles as follows "The ways in which an individual characteristically acquires, retains, and retrieves information are collectively termed the individual's learning style".

The Felder-Silverman learning style model was created by Richard M. Felder on Dr. Silverman's expertise in educational psychology and his experience in engineering education.

Felder's model includes four dichotomous learning style dimensions which indicate students' preferences for certain poles of the dimensions:

Sensing or *Intuitive* - this spectrum determines how we perceive or take in information: sensory (external) – sights, sounds, physical sensations, or intuitively (internal) – possibilities, insights, hunches.

Visual or *Verbal*, this spectrum determines how we prefer

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the information to be presented: visual – pictures, diagrams, graphs, demonstrations, or auditory – through words or sounds.

Active or *Reflective* - this spectrum determines how we prefer to process the information: actively – through engagement in physical activity or discussion, or reflectively – through introspection.

Global or *Sequential* - this spectrum determines how we prefer to organize and progress understanding information: sequentially – in continual steps, or globally – in large jumps, holistically.

Felder and Silverman [6] claim that a balance of the two dimensions is desirable, i.e. it is valuable to be able to function both ways.

The research conducted in last years at our university (see e.g. [7], [8] and [9]) shows that most of our students are visual learners. The results show that in fact 98% are *strong visual learners*.

More students belong to the *moderate till strong* learners belonging to the *sensing* dimension (about 72%).

Concerning the other two dimensions, active/reflective and sequential/ global, most students belong to the mild level of these dimensions more of them to the „left side", which means to the *mild active* and *mild sequential dimension*.

Therefore, it is important that we prepared such educational materials, which support a student's preferences, and at the same time emphasize the less preferred dichotomous dimension. With regard to the above results the main aim of our study materials is:

- To visualize each new concept at first, and then to use oral explanation of its meaning, property, application and related theorems.
- To develop the student's ability to form images in mind.
- To learn students how to describe various situations with the aid of graphs, solve the given problem expressed by the graph, and translate the solution back into the initial situation.
- To examine each concept and problem from more than one point of view and to discuss various approaches to the given problem solution with respect to the previously explained subject matter.
- To let students thoroughly practice the explained concept and its properties, and let them add their own applications concerning the topic.

III. Visualization

According Felder and Silverman [6] "Visual learners remember best what they see--pictures, diagrams, flow charts, time lines, films, and demonstrations. Verbal learners get more out of words--written and spoken explanations. Everyone learns more when information is presented both visually and verbally." This claim is in accordance with advocates of dual coding theory who argue that people retain information best when it is encoded in both visual and verbal codes [10]. Memory for some verbal information is enhanced if a relevant visual is also presented or if the learner can imagine a visual image to go with the verbal information. Likewise, visual information can often be enhanced when paired with relevant verbal information, whether real-world or imagined. [11]

The dual coding theory has been applied to the use of multimedia presentations. As multimedia presentations require both, spatial and verbal working memory, individuals dually code information presented and are more likely to recall the information when tested at a later date [12].

Multimedia applications included into the learning process is undoubtedly one of the alternatives to convey to students often very sophisticated subject matter in the way which is familiar to them at present. Multimedia is a suitable tool for linking theory and practice [13]. (cf. [14])

There are several multimedia applications used as a useful support of various subjects at our university. For the subjects dealing with the graph theory and combinatorial optimization was created GrAlg program, whose main purpose is a visual representation of basic graph-concepts and graph-algorithms.

A. GrAlg Program

The program GrAlg was developed by our student within his thesis [15] and it can be downloaded from the page http://lide.uhk.cz/prf/ucitel/milkoev1/en_index.htm in the section GRAFALG > Lecture. The main possibilities of the program are as follows. (cf. [2])

The program enables the creation of a new graph represented by figure, editing it, saving graph in the program, in its matrix representation and *also saving graph in bmp format*.

The ability to save graphs in bmp format allows teachers and students easy creation of needed graphs for their tasks (texts and/or presentations) where they describe various practical situations with the aid of graphs and solve the given problem.

It also makes it possible to *display some graph properties* of the given graph.

Students can use not only graphs prepared by the teacher but also graphs created by themselves and explore the properties of these graphs.

The program enables to *add colour to vertices and edges*, to *add text next vertices, and to change positions of vertices and edges* by "drop and draw a vertex (an edge respectively)".

In this way the teacher can complete her/his in-class explanation in such a way that makes topic more comprehensible.

The program allows the user to *open more than one window* so that two (or more) objects or algorithms can be compared at once. Window size can be adjusted as needed.

This option enables the teacher to explain the problem from more points of view and show mutual relations among used graph-concepts and algorithms on graphs. In such way students can follow these mutual relations among concepts and algorithms, and remember those relations when using this option also by their self-study.

In the GrAlg program there is the option to *run step by step programs* visualizing all of the subjects explained algorithms in a way from which the whole process and used data structures can clearly be seen.

Step by step the solution of an algorithm allows students to follow the whole algorithm in their speed and compare it or its result only with their own solution.

Remark: Most of figures presented in this paper were created in the GrAlg program.

IV. Entertaining Tasks

Practical and entertaining tasks encourage students to know more about the explained subject matter and to apply acquired knowledge. If an interesting task is assigned as a prototype to a new topic by means of a picture and subsequent explanation of the task solution, both spatial and verbal working memory are required and students recollect the explained subject matter much better. Their engagement progresses when looking for similar examples. (cf. section III)

Motivation means literally the desire to do things. It's the crucial element in setting and attaining goals. Motivation is regarded as a crucial drive by which learning behavior can be stimulated.

Usage of puzzles can be compared with gamification, which is the use of game-like elements in non-game context. The main goal of gamification is to motivate participants and encourage expected behaviors in a meaningful way [16]. The similar approach for motivating and engaging participants can be used by means of puzzles. Integrating puzzles elements into educational context coupled with effective pedagogy has the potential to increase students' motivation and improve their learning outcome.

In the section on a particular topic from the graph theory, namely on Hamiltonian circles, we present examples of appropriate tasks enhancing algorithmic thinking and mathematical competences with regard to above discussed approach to the preferred learning style preferences of students. We also introduce here in specific subsections some areas used as valuable source of entertaining tasks.

A. Entertaining tasks based on the historical background

The history serves as a good source of practical examples and puzzles. In the area of graph theory there is a very interesting book Graph Theory 1736 – 1936 [17]. The most important problems from 1736 till 1936 are introduced there. In this book is also explained how the study of various graphs arose from the consideration of recreational problems.

As an example let us briefly illustrate a problem called "The Icosian Game" created by the famous Irish mathematician William Rowan Hamilton. This problem can serve as an appropriate prototype of Hamiltonian graphs, i.e. graphs containing a Hamiltonian circle - a circle containing all the vertices of a graph.

The Icosian Game

The object of the game was to find paths and circuits on the following dodecahedron represented by Fig. 1, satisfying certain specified conditions. In particular, the first problem was that of finding a circuit passing just once through each vertex of the graph [17].

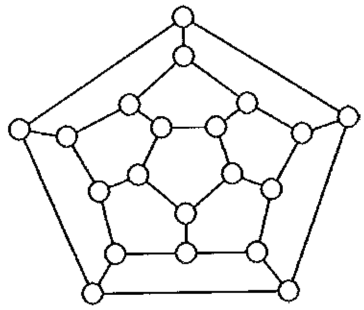

Fig. 1 dodecahedron

One possible solution of the mentioned problem is presented in the Fig. 2.

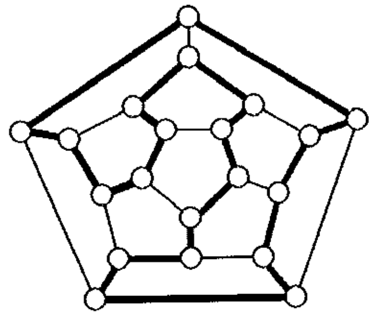

Fig. 2 hamiltonian circle in the given dodecahedron

B. Enjoyable tasks based on puzzles

There are an endless number of puzzles and logic problems in books like "Mathematics is Fun", in riddles magazines and on the Internet.

Let us go back to Hamiltonian graphs mentioned above.

To determine whether a given graph is or is not Hamiltonian belongs to the NP complete problems. However, there are four basic rules that students can apply when discussing small graphs and through them to better acknowledge the characteristics (qualities) of Hamiltonian circle concept.

1. If a given graph has n vertices, then a Hamiltonian circle has exactly n edges.
2. If vertex v has degree k, then a Hamiltonian circle has to contain exactly two edges incident with vertex v.
3. When constructing a Hamiltonian circle in a graph with n vertices, no circle containing less than n vertices is allowed to be created (closed) during the process.
4. Once a constructed Hamiltonian circle contains two edges incident with vertex v, the remaining edges incident with vertex v are excluded.

To deepen imagination and enhance students' facility to find out a Hamiltonian circle in the given graph we offer students not only graph represented by a figure, but also a puzzle similar to the following puzzle "Beads", to be solved.

The puzzle Beads

Join all the beads on the figure Fig. 3 into a closed, non-crossing path (i.e. circle from the graph theory point of view). The beads have various shapes. Each bead can be entered and left once only. The line joining the beads must follow the lines of the existing grid. However, the paths between each pair of vertices have to be direct, i.e. the paths cannot be bent.

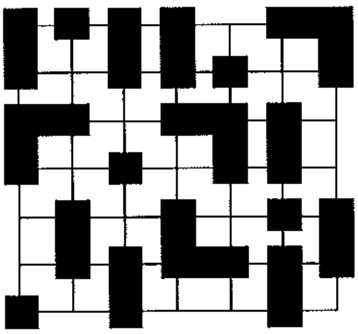

Fig. 3 given grid with beads

To solve the puzzle, we proceed in the following steps.

1. Finding a graph-representation of the given puzzle:
   - We remove unsuitable lines from the given grid.
   - We add letter to each bead. In this way we get a simple undirected graph (Fig. 4- beads represent vertices, lines represent edges), a graph-representation of the puzzle.

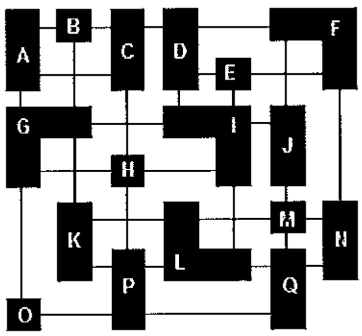

Fig. 4 graph representation of the given grid with beads

2. Solving the problem expressed by the graph: We use the rules to find a Hamiltonian circle in the gained graph (Fig. 5 – bold edges).

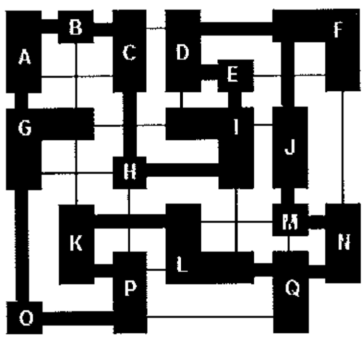

Fig. 5 bold edges denoting a Hamiltonian circle (A, B, C, H, I, E, D, F, J, M, N, Q, L, K, P, O, G, A)

3. Translation of the solution into the initial situation: We denote the found Hamiltonian circle in the initial gird - a solution of the puzzle (Fig. 6).

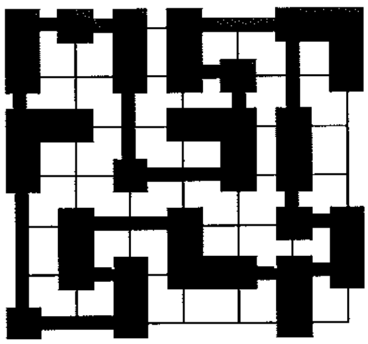

Fig. 6 solution of the puzzle

The puzzle is chosen from the Czech semi-monthly magazine "Hádanka a Křížovka" (Riddle and Crossword puzzle in English). It allows a deeper analysis when trying to find a Hamiltonian circle having further special properties which further improves understanding of the subject matter.

Another example of puzzles seeking Hamiltonian circle having further special properties is introduced in the following section.

C. *Enjoyable tasks inspired by another subject*

With regard to the fact that our students of Computer Science study both, Graph Theory and English language, we have prepared various puzzles combining the acquired knowledge from both study-areas and thereby we indicate further application possibilities of the discussed concept. Let us present very simple one.

English sentence on a Hamiltonian graph

In the following graph (Fig. 7) find a sequence of vertices that creates a Hamiltonian path and at the same time a correct English sentence.

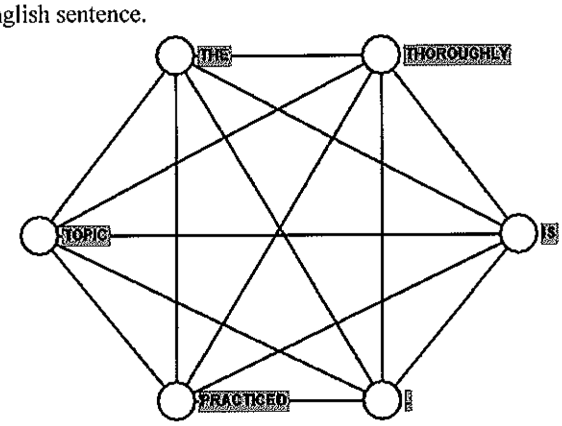

Fig. 7 given graph with English words

Obviously, the given graph is complete graph. Hence, each sequence of all vertices creates a Hamiltonian path. However, although there are 6! = 720 various Hamiltonian paths in the given complete graph, the solution of the task is simple. It is the sequence "THE TOPIC IS THOROUGHLY PRACTICED.".

To enhance awareness of the given concept properties, in relation to this example, it is appropriate to discuss not only number of all Hamiltonian paths in a complete graph but also the number of its Hamiltonian circles, i.e. (n-1)! if we distinguish their orientation and ((n-1)/2)! if we do not distinguish their orientation.

D. Enjoyable tasks based on practical situation

One of our basic teaching principles that we have been applying in our teaching for many years is thorough practicing of the explained topic on various examples, discuss students' own examples describing the topic and encourage them to solve similar examples.

The following task laying on the intersection of a practical example and entertaining example is excellent connection of two topics, Hamiltonian graphs and bipartite graphs. It also helps to enhance student's ability to form images in mind.

Arrangement of guests around the table

Imagine that you would like to invite to your house seven guests, represented by letters *a, b, c, d, e, f, g* with whom you (denoted *h*) are going to dine at a round table. Among the guests, however, are also those who would appreciate if you do not sit them next to certain people, above all the guests *c* and *g*, who have problem almost with all of the invited persons. The overview of the people who "are not on friendly relations" is as follows

c ... a, d, e, f, g

g ... b, c, d, e, f

a ... b

Will you find such guests seating arrangement at the table that everyone is feeling well?

To solve the puzzle, we proceed in the following steps.

1. Finding a graph-representation of the given task:
   a. We create a graph *G* with vertices representing people *a, b, c, d, e, f, g, h* and edges corresponding with their relation "not on friendly relation" (Fig. 8).
   b. We create complement to the graph *G* that represents relation "on friendly relation" (Fig. 9).

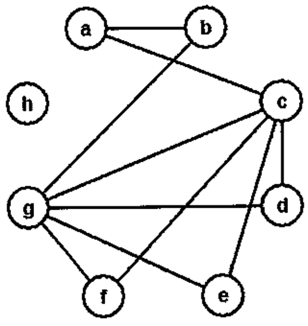

Fig. 8 graph *G*

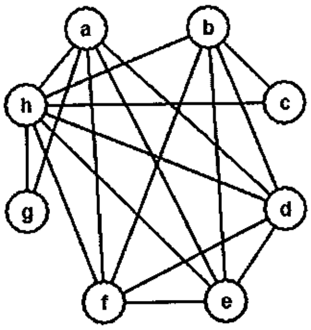

Fig. 9 complement to the graph *G*

2. Solving the problem expressed by the graph:
   - We seek a Hamiltonian circle in the complement of *G*.
   - If there is a Hamiltonian circle the task is successfully solved – a found Hamiltonian circle represents result

One of possible solutions of our task (a guests seating arrangement at a round table) is *h, g, a, d, f, e, b, c, h*. (see Fig. 10 – green edges).

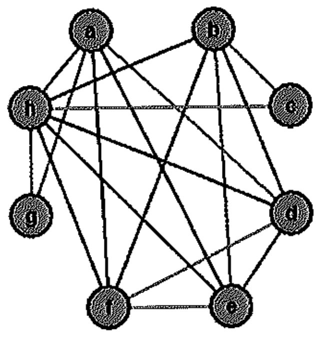

Fig. 10 a solution of the task

In relation to this example, it is desirable to discuss another task, namely:

Arrangement of guests to two tables

Imagine that you would like to invite to your house seven guests, represented by letters *a, b, c, d, e, f, g* with whom you (denoted *h*) are going to dine at two tables. Among the guests, however, are those who would appreciate if they are not sitting next to certain people at the same table, above all the guests *c* and *g*, who are troubled by almost all of the invited people. The overview of the people who "are not on friendly relations" is as follows

c ... a, d, e, f, g

g ... b, c, d, e, f

a ... b

Will you find such guests seating arrangement at the given two tables that everyone is feeling well?

Although the assignment of this task is very similar to the previous one, we solve it using the concept application of bipartite graph. Instead a Hamiltonian circle we need to determine if the graph representing "not on friendly relation" is or is not bipartite. *Solution* of this task "There is no guests seating arrangement at the two given tables that everyone is feeling well." is obvious. It is evident from the graph G, Fig. 8, regarding the known theorem "graph G is bipartite if and only if graph G does not contain a circle of odd length".

V. Discussion

Algorithmic complexity is often viewed as a difficult part of IT education.

Let us add to the topic discussion concerning a puzzle "Pilgrimage" found on the Internet in the following form.

The puzzle Pilgrimage

A traveller wants to travel from a castle A to castle B. The traveller has a map with the two castles and cities between the castles. The cities are structured in n layers according to their distance to the castles. Given an arbitrary layer k, all cities in k have a direct path to every city in neighbouring layers (k-1) and (k+1). Cities in the first and last layer are connected directly to castle A and B respectively. Each city on the map belongs to one of the castles, A or B. Some pairs of the cities are in war and when the traveller visits a city that is in war with some previously visited city, he will be imprisoned and won't reach his goal. Thankfully, political power of the castles ensures that cities belonging to the same castle are never in war. The traveller has a list of cities that are in war, allowing him to find a safe path (if such exists). Because of a large number of cities on the map, it's not possible to check all possible paths, as there are exponentially many of them. Devise a fast (**polynomial time**) algorithm to find a safe path between the two castles.

The puzzle "Pilgrimage" corresponds with known NP-complete problem of finding paths avoiding forbidden pairs of vertices which originates in graph theory. This problem is known to be NP-complete in general, but some restricted versions lay in P.

The puzzle "Pilgrimage" can be described as the following restricted version of the problem [18]:

Given a graph $G^* = (V, E)$, so called *free-path-problem graph*, with two fixed vertices $s, t \in V$, vertex s is called the source vertex and vertex t is called the sink vertex. All vertices are divided into layers i, $i = 1, \ldots, n$, in a way that vertices of each layer i are fully connected to vertices of their surrounding layers $i-1$, $i+1$, $i = 2, \ldots, n-1$, whereas the source vertex s is the only vertex belonging to the first layer and the sink vertex t is the only vertex belonging to the last layer n. Additionally, the vertices are divided into two non-empty disjoint sets A and B. We define a set of pairs of vertices $S \subset (A \times B)$. The pairs in the set S are called forbidden pairs and the paths containing at most one vertex from each pair in S are called *free paths*. The goal is to find a free path from s to t, or to recognize that no such path exists.

The source and sink vertices can be assigned arbitrarily to A or B and they cannot form a forbidden pair – there would trivially be no *free path* in G^* if the source and sink formed a forbidden pair. Figure 11 displays the vertices from A in white and vertices from B in grey.

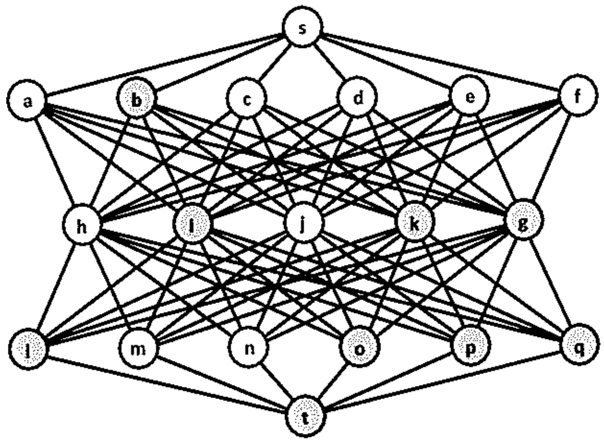

Fig. 11 an example of a free-path-problem graph with the source vertex s and the sink vertex t

However, contrary to the intuition that the puzzle "Pilgrimage" is solvable by a polynomial algorithm (see the task formulation), we can prove (see in press [18]) that even this special case is NP-complete and thus a fast algorithm is unlikely to exist.

The puzzle serves as an excellent educational example when explaining NP-complete problems. Its formulation is interesting and attractive for students and the NP-completeness proof is straightforward enough to further improve student motivation to the matter.

VI. Conclusion and Future Work

Technology related to teaching/learning plays a vital role in 21st century education [19]. The needs to serve the learners become urgent to make learning activities more motivating, funny and engaging for the students who are continuously surrounded with every form of new technology [20].

In the paper we discussed the role of entertaining tasks used as suitable complement of educational materials developing algorithmic thinking and mathematical competences and enhancing student's aptitude to solve everyday life practical situations. We also discussed a particular learning style preferences model, namely Felder's model directed on four dichotomous learning style dimensions, and we also emphasized an importance to enhance student's ability to function both ways.

Future work is focused on search for more entertaining tasks to each explained subject topic, which deals with graph theory and combinatorial optimization. We will focus mainly on the preparation of the tasks that require within the solution process the application of not only one, but more graph-concepts and graph-algorithms. To them we will add tasks that have similar wording, but a different approach to a solution process - as demonstrated in the example tasks described as *Arrangement of guests around the table* and *Arrangement of guests to two tables*.

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Spatial Skills of Preschool Children supported by Game Application

Simona Pekarkova, Eva Milkova

Abstract—In recent years, there has been an increasing interest in technology and its use in education. Many studies on mathematical and early mathematical competencies have been conducted in order to help establish the new field in education, pedagogy and also in science. The attitude towards how to define mathematics and how to teach mathematical competencies has been changing immensely during the last decade. Mathematical skills and spatial skills correlate with success in many areas. Comprehensive mathematics curricula targeted at preschool-aged children define knowledge in the new framework of early mathematical competencies. ICT might bring some critical benefits to early childhood education and to development of particular human cognitive abilities and skills. In the paper we focus on a research analyzing the benefits and impact of an educative multimedia application, a story-based game with contents related to visual differentiation and spatial skills, on preschool aged children's spatial skills.

Keywords—Mathematical competencies, multimedia application, preschool aged children, spatial skills.

I. Introduction

THERE has always been a lack of attention in the field of spatial skills in education. Nevertheless, within last decades spatial skills have gained increasing acknowledgement as an important aspect of intellectual ability. Researches bring sufficient evidence that spatial skills are foundation for mathematical skills and their influence in human life is remarkable. Positive correlations were found between spatial skills and mathematical achievement. Moreover, spatial skills are malleable and can be supported.

It is also evident that spatial skills are already presented by small children being strong predictor for later achievements in mathematics. Thus, the importance of spatial skills as a gateway to better mathematical skills has had an increasing trend during the last decade.

Furthermore, these skills are also necessary for success in the science, technology and engineering domains. A lot of research started to focus on a new attitude to spatial skills and training which can help children not to be left behind. In this context ICT are also considered to provide new learning opportunities.

Approach to teaching mathematical skills has changed dramatically in the last decade. Newly promoted competency model involves more complex area than only acquiring of math skills and numerical rules. As mentioned above mathematical skills are strongly affected by spatial skills. ICT can bring benefits to the development of new mathematical concept- mathematical competences, where well developed spatial skills also belong.

On the other hand, the use of ICT and educational applications might present certain risks in education of preschool children where the role of ICT educational tools might be exaggerated. Therefore, we want to analyze relationship and correlations between specific variables and their impact on overall mathematical competences.

II. Current State of the Field

Recent research is bringing new evidences about interconnections between domains of human thinking. New interdisciplinary research indicates relations among education, neuroscience, psychology and neurophysiology. The movement from the previous attitude, which considered mathematics mostly as counting and capability to operate with numbers is disappearing, and new concept of mathematical skills and competences is coming with changes in the life of society.

Mathematical skills and spatial skills correlate with success in many areas: chemistry, engineering, science, geology and etc. Many new science, technology, engineering and math (STEM) related positions have been emerging last years and employees and workers have to face new demands of these new job positions which require more technical and mathematical capability than the previous ones. Young children's mathematical development and proficiency has become an important predictor of later labor market success [1], [2].

An increasing number of research demonstrates that other abilities not traditionally viewed as "mathematics skills," such as spatial skills and executive function skills, make significant contributions to young learners' overall mathematics performance [3]–[5]. Empirical work states that children's early competencies set the course for their later achievement, the mathematical competencies which children demonstrate at school entry are considered as the strongest predictors of their

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later school achievement [6]. Researchers bring evidences that spatial skills are essential base for later developing of mathematical skills [5], [7]–[8]. Research findings also bring the results that information and communication technologies (ICT) have the propensity to increase children's motivation, interest and engagement in literacy and learning [9]. The use of technology is more interdisciplinary approach which can allow teachers to act primarily as coaches while children motivate themselves to grow as learners [10].

A. Malleability of Spatial Skills

Based on previous research there is evidence of malleability of spatial intelligence. The evidence of malleability is quite encouraging and the research focused on this issue has repeatedly confirmed similar outcomes in terms of possibility to enhance and support this cognitive factor by training and specific tasks [11]–[14].

Different instructional programs, concrete materials, manipulatives, visual treatments, sketching activities, technologies, computer aided-design courses, and toys are considered to be effective tools for improving individuals' spatial skills [15]–[17].

For instance, Sorby [18] provided a review of pre-college activities in which students with well-developed spatial skills were interested. Based on researches, which he had compared and analyzed, he concluded that follow activities to develop spatial skill are: 1) playing with construction toys as a young child, 2) participating in classes such as shop, drafting or mechanics as a middle school or secondary student, 3) plying 3-D computer games, 4) participating in some type of sports, 5) having well developer mathematical skills. He described strategies that educators should adopt to develop these skills in their engineering undergraduate students such as sketching, drawing 3-D objects and using hand-held models.

He claimed, that only one semester of a spatial training course improved spatial skills, and gained exceeded up to +15 IQ points.

Uttal [8] conducted an exhaustive search in 2545 relevant studies on spatial training. He reconfirmed Sorby's results. It was shown that overall effect size of training was mostly +7 IQ points. This result is still significant to be taken in account because this is considered a moderate effect size and indicates that spatial skills are malleable.

A lot of different training methods (e.g., playing video games, practicing spatial tests, or taking an engineering graphics courses) improved spatial skills. Variety of training methods can substantially improve spatial skills. To summarize, the available evidence indicates that spatial skills can be improved, and they have impact on performances in STEM learning. [19]– [20].

There are several studies concerning the development of spatial skills over different ages. For instance, in above mentioned research Sorby was conducting study in which he involved adults. Most of other studies also involved adults, secondary school or university students. Only small body of studies focused on younger children from 6 to 10 years old [21]. Studies involving preschool children are still very rare and mostly focused on finding what sub-factor of spatial ability appears in infants [17]. Therefore, we concentrate on investigating malleability of spatial skills through the use of ICT in preschool age in our research.

B. Links between spatial and mathematical skills

Spatial skills are critical for mathematical performance as previous researches show. Authors state in [7] that *The relation between the spatial ability and mathematics is so well established that it no longer makes sense to ask whether they are related.* According to a factor analysis by [22] the significant spatial predictor of mathematical ability changes during kindergarten, 3rd, and 6th grades. There might be an explanation that acquisition of different mathematical skills across grades relies on different types of spatial expertise. Golinkoff states in [23] that strengthening of spatial-mathematical links with age is consistent with a causal chain of events whereby spatial skills provide a foundation for mathematical learning. *The relation between spatial and mathematical skills may appear to strengthen over time because children with good spatial skills use them as they acquire new and more advanced mathematical skills.* [23]

C. Spatial skills links to achievement in STEM

Spatial skills are necessary for success in the science, technology, engineering and math domains. Recent research indicates that spatial skills play a unique role in predicting which students pursue STEM-related careers. Wai, Lubinski and Benbow [24] found on a large nationally representative sample (n ~ 400,000) that spatial skills assessed in high school predicted which students would enter a STEM career 11 years later.

Although some educational systems already started to focus on development of spatial skills deliberately, there is still a lack of such activities. Some researchers call for more active attitude and faster implementation of different supporting means of spatial skills in the classrooms. There is still a lack of specific knowledge of how spatial thinking may be best infused across curricula and how to optimally incorporate new technologies in order to enhance better results of children [17].

III. RESEARCH STUDY

A. Problem Statement

The paper reports the pilot study of our research investigating influence of new technology, specifically use of tablets with particularly developed educational game application ADAM, on children's spatial skills development. The research is part of a doctoral study research focusing on cultivation of early mathematical competencies with the use of digital technology.

B. ADAM application

Game Application was developed in Unity environment. It can be run on touched screen devices, tablets, PC and interactive boards. The ADAM game application is designed as the comprehensive story in which a child participates by playing to fulfill the main tasks. The game is divided into 17 tasks which contain wide variations of subtasks. Each task has subtasks which are divided into low, medium, and high level based on set up criteria of difficulty. There are principles of adequate challenge that help a child to be motivated for trying out the challenging or difficult tasks. For instance, the comprehensive story has a narrative guide which gives instructions, the results and provides a child with the feedback to the chosen solution. Furthermore, different subtasks of each task with gradually increasing difficulty level are shown to a child by every playing session. The difficulty level of subtasks is than automatically adjusted according to child's previous results in playing.

The ADAM application enables to collect data of child's achievement in every task, namely data following the quality of responses, time spent on a task solving and working speed.

There are particular parameters influencing level of spatial skills included in the application. The parameters such as spatial orientation and position are incorporated in specific tasks. Also parameters of pattern comparing, pattern exploration and parameter of composing and decomposing of geometric shapes are involved. The last parameter embedded in specific tasks is transformation (reflecting, translating and rotating of subject).

The principles of effective and affective learning are also used and were incorporated in ADAM application. According to the results of children the game shows child a subtask of adequate level. There is a score logarithm set up which either goes for more difficult level or decreases the level if a child fails a few times. There is a principle of adequate challenge that should help keep a child being motivated for trying demanding task.

Very clear evidence about children's spatial language and their relations to their spatial skills and thus mathematical skills have been provided in recent researches [25]-[26]. According to this fact, the whole story has a narrative guide which gives a child instruction using terms which are connected with spatial skills and with early mathematical skills (seriation of orders, directions, prepositions, terms like bigger, smaller, equal, nothing, order, compare etc.), says the feedback to each task. In the case a child fails, the correct solution (with the help of animations) is provided to him.

C. *Purpose of the Study*

The main objective of our research has been to find out to what extent the game application ADAM has impact on the level of spatial skills. Differences in performance in particular domains between boys and girls were also subject of our interest.

D. *Objectives of the Study*

The objectives of the study are as follows:

- To assess the current level of spatial skills.
- To find out to what extent the game application ADAM has impact on level of spatial skills.

IV. PILOT STUDY

A. *Participants in pilot study*

Preschool children from a kindergarten in the Czech Republic were participants in the pilot research. 39 children were included into the target group and they were in age from four until six years. The pilot group consisted of one experimental (No 19) and one control group (No 20).

B. *Research Methodology*

Assessments of spatial skills in the pilot study were conducted with the help of the standardized psychological SON-R 2,5-7 test suitable for measuring general intelligence in children between the ages of 2.5 to 7 years.

Three subtests, Mosaics, Puzzles, Patterns, of the test battery SON-R 2,5-7 were chosen.

All these subtests belong to the subtests which reflect the level of spatial relations and spatial skills. They measure abstract and concrete reasoning, spatial skills and visual perception. (Remark: The sub-tests of the SON-R 2,5-7 test are grouped into two types: reasoning tests such as Categories, Analogies and Situations and spatial performance tests such as Mosaics, Puzzles and Patterns. Perceptual, spatial and reasoning skills play role in all sub-tests. The performance sub-tests can be found in a similar form in other intelligence tests although in other tests these require verbal directions.)

In the time between pretest and posttest the developed game application ADAM as a treatment tool was used.

C. *Data collection*

Quantitative data were collected two times. The first collection of data was conducted in the pretest and level of spatial skills was measured in preschool children. The second collection was conducted four months after the children had been using game application. The same test battery was used as in the pretest. Both pretest and posttest data were collected during personal visits of the researcher.

Before the research and collection of data started the general parental consent for children who took part in the research, was collected. The parents were informed about the etic rules of planned research. The introduction workshop was prepared for head teacher and teachers in order to familiarize them with the ADAM tool. Twenty tablets, chargers and headphones were provided to the kindergarten.

Before the treatment phase started, the classroom environment was prepared, and teachers underwent the training. The training consisted of information about the application and its content. Teachers were instructed how to use and how to manipulate devices. The schedule of playing sessions was discussed and clarified with teachers. The teachers provided the name list of children. After randomization of the sample, each child was given their own profile in the tablet under their name and always played under given profile. It enabled researchers to evaluate the particular results in playing and performances in the game. Each child had approximately 25 play sessions in total. The experimental group used ADAM application in the time which suited to the common schedule of the classroom.

V. Results and Discussion

Focus group of the pilot study consisted of 39 children aged from 4 to 6, selected from the same class of a chosen kindergarten. Children were assigned randomly to experimental and control groups. This study was conducted as an experiment with pretest, application treatment, and posttest model.

A one-way analysis of covariance (ANCOVA) was conducted for this study. The dependent variable was the children' achievement scores in posttest and the covariate was the children' achievements scores in pretest of chosen relevant tasks of standardized battery test SON-R (Mosaics, Puzzles and Patterns).

A preliminary analysis evaluating the homogeneity-of-regression assumption indicated that the relationship between the covariate and the dependent variable did not differ significantly. The results received from experimental and control group showed that experimental group playing with game based application achieved higher scores and performed higher in the posttest.

By the first spatial task (Mosaics) the p-value (0.002) of above ANCOVA is lower than assumed 0.05 which indicates that mosaic scores of children are having significant difference between scores of control and experimental group students in both pretest and posttest results. 31.7% ($\omega2 = 0.317$) of the total variance was accounted, which can be considered moderate effect size.

By the second chosen task (Puzzles) the p-value (0.002) again falls under the assumed significance 0.05. According to this acquired result, it's clearly evident that there is significant difference that exists between the scores of both control and experimental groups in Puzzles task. 34.6% ($\omega2 = 0.346$) of the total variance was observed, that can be considered also as moderate effect size.

In Pattern task, third variable, the p-value (0.001) is lower than assumed significance 0.05. Therefore it is concluded that scores of students, of both experimental and control groups differ significantly. 50.4% ($\omega2 = 0.504$) of the total variance was calculated. We consider such a result as large effect size because it's higher then moderate effect size value.

The experimental group achieved better results in posttest phase in all three subtests of measurement tool and scored significantly better. ADAM game application proved to influence the level of children's spatial skills.

VI. Conclusion

Focus on the usage of technologies in school education has increased in the last years. [27] - [29]. There is a growing need to use smart and educational applications for the development of cognitive skills [30], [31]. There is a growing need to find appropriate technological resources in pre-school education. However, ICT is being promoted in pre-school education rather rarely, as there is a lack of professional work to assess the impact, benefits and also withdraws of ICT in pre-school children.

In order to analyze the impact of ICT in the chosen area of cognition and spatial skills, the educative application ADAM was created. ADAM application is conceived as a game based on psychological and special pedagogical knowledge as well as on the needs of preschool children.

The pilot study was carried out at a kindergarten for 4 months with 39 children. The comparison of the experimental and control results between pretest and posttest indicated improvement in spatial skills of the children in the experimental group.

Last month the main research carried out at one chosen kindergarten with 70 children started. It will include not only data collection concerning spatial skills, but also data about visual perception and motivation. All these aspects belong to the newly defined concept of mathematical competences.

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VISUALIZATION AS A CONVENIENT TOOL TO SUPPORT THE TEACHING OF MATHEMATICAL PROOFS

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Abstract

Subjects dealing with graph theory and combinatorial optimization belong among the basic subjects of informatics study. Their aim is above all to develop and deepen students' capacity for logical and algorithmic thinking. Mathematical proofs that are inseparable part of these subjects do not belong to popular topics among students due to the difficulty to understand this field of mathematics. Within educational process we are searching for various tools to help students deal with this area of mathematics. Suitable visualization could become a very convenient instrument used to enhance understanding of theorems and their proofs. Using visualization and deep analysis of the topic together with discussion on mutual relationships between solutions to problems allows the teacher to enhance student's logical thinking and support their understanding to more complex proofs. In the paper we provide a justification for the importance of the mathematical proofs for students of informatics at first. Secondly, we introduce a research study examining an impact of visual applications on understanding of mathematical proofs; we implemented presentations instructed within the Discreet mathematics course, which are used to visualize proofs of mathematical theorems in the area of the graph theory, and we analysed students' approaches to proofs visualization and proofing in general.

Keywords: Proof, visualization, graph theory, multimedia application, teaching

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1. Introduction

Evidence or proof - a term that is often used both in everyday life and in many fields of science.

1.1. Proofs in mathematics

Proof was, is and will be one of the concepts that characterize mathematics. We can state that the concept of rigorous mathematical proof significantly singles mathematics out from the spectrum of other scientific disciplines. Mathematical proof, unlike evidence in other areas, is fundamentally unquestionable (Garnier and Taylor, 1996).

1.2. Proofs in informatics

There is a clear correlation between the proof of the mathematical theorem and the formulation of the algorithm. In mathematics, it is important to speak accurately and to be assured of the statement; on the other hand, in informatics it is important to learn how to design algorithms and to be absolutely sure of their correctness. Mathematical proof is the basis for proving the correctness of the algorithm. According to Hlinený (2010), the most frequently used proofing tool in informatics is mathematical induction.

2. Problem Statement

Although proofs in informatics are important, plenty of students consider them to be too sophisticated and even unnecessary. The most common reasons why students do not like proofs is that they do not understand them and thus they are not motivated to implement them. University students are expected to be interested in the chosen subject, to be eager to learn as much as possible about it and to understand the subject matter well. Simply memorizing theorems is wrong, as the consequence is that students do not know what the prerequisite of the theorem is, what is its statement and overall meaning, what is the theorem intended for, and how to use it further. Therefore, it is essential to constantly seek ways how to make the teaching of mathematical proofs more transparent and comprehensible.

Very often, better understanding of what needs to be proofed is brought by itemizing and visualization of the definitions and terms included in the theorem, the apt graphics of the implications, and correlations, i.e. the visualization of the proofs. Appropriate visualization or animation of theorem proofs could help students to reach better and deeper understanding.

2.1. Graph theory at the University of Hradec Králové

Basics of the graph theory and combinatorial optimization form the main content of Discrete Mathematics (DIMA) intended for students of informatics fields of study at our faculty. Great emphasis is placed on the understanding of the mathematical theorems and their proofs. In order to promote the effectiveness of the proof teaching, various presentations, described below, have been developed for the DIMA subject.

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2.2. Proofs visualization

The proof visualization, or in other words "proof without words", appeared already in the deep past. The ancient Greeks of Aegina Island used in the 6th Century BC silver coins, on the back of which there was a geometric proof without the words of the square of a binary a + b: (a + b) 2 = a2 + 2ab + b2 (Jones, 2011), See Figure 1.

Figure 01. Silver coin from the 6th century BC (Jones, 2011)

At present, plenty of scientific results have been published regarding the research in the field of mathematical proof visualization:

In 2007, Hanna and Sidoli (Hanna, Sidoli, 2007) presented a brief overview of the possibilities of using visualizations that were the subject of discussion in the literature of mathematical philosophy. They dealt with the question - to what extent can visualizations be used as proofs. They concluded that we were far from consensus in all possible roles of visualization in mathematics, mathematical education, and above all its role in the proofs.

Marrades and Gutiérez studied whether dynamic geometry can facilitate students' transition from experimental activity with mathematical objects to formal deductive proof. They detected that implementation of dynamic geometry into teaching helps students understand the abstraction of the reasoning of discovered correlations, and that students need more time for experimental activities in the application environment before they can move to hypothesis proofing (Marrades, Gutiérez, 2000).

Another studies can be found in (Kilic, 2013), (Štrausová, 2012), (Robová, 2013), (Autexier et al. 2012), (Knill and Slavkovsky, 2013), (Ugurel et al. 2016).

3. Research Questions

How can mathematical proof teaching be enhanced? Can visualization help in graph theory proof teaching?

4. Purpose of the Study

The aim of this study was twofold: to explore available visualization tools at the University of Hradec Králové, suitable as a supplement to the explanation of the proofs of mathematical theorems

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taught in the theory of graphs, and to analyse students' projects and their views on proof visualization and proofing in general.

5. Research Methods

This study is part of a quasi-experiment in which the effect of visual representation of proofs on its comprehensibility is explored.

5.1. Research Sample

The object of our research are students who attended the DIMA course in the academic years 2015/16 and 2016/17 at the University of Hradec Králové. Both, the control and experimental groups consisted of 67 students. The teaching of proofs of the control group was realised in a standard form, that is, the teaching of proofs by means of propositional logic. In the proof instruction of the experimental group were used the visual representations of proofs.

5.2. Research tools

The main research tool of this study was the analysis of tools available at the University of Hradec Králové used to support the teaching of proofs in the subject DIMA and the analysis of students' projects as well as their views on visualization and proofing. Additional tools included observation and analyses of students' views on proofing and visualization, and a questionnaire.

5.3. Procedure

The research was conducted in the real learning settings. After completing the DIMA course, the participants of this study were to conduct a credit project, in which they instructed to create a visualization of a selected mathematical statement from the field of graph theory. They were also asked to write an essay about their work and attitudes to proofs and visualization.

6. Findings

Based on the questionnaire results, filled in by 67 respondents in the academic year 2015/2016,in which the respondents were asked what they think would help them better understand the proof instruction (note: 20% of respondents requested visualization), PowerPoint presentations were created to support the teaching of theorems and proofs in the DIMA subject. The presentations, which provide step-by-step proof of the statement, were gradually created and supplemented by dynamic sections, such as animations or videos that would bring better understanding of the subject matter. Some presentations have been created with the support of the GrAlg multimedia application, which has been used for several years in the subject of graph theory (Milkova and Sevcikova, 2016). GrAlg is used for visualization of terms, correlations and graph algorithms (for more information about the program GrAlg see (Ševčíková & Milková, 2016).

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In Figure 2 are presented Power Point screens visualizing a proof (note: This is a selection of screens – completed animations; the entire visualization contains more than 400 screens.) to the following statements (Basic Property of Trees): Let *T*=(*V*,*E*) be a tree. Each tree *T* with at least 2 vertices contains at least 2 end-vertices.

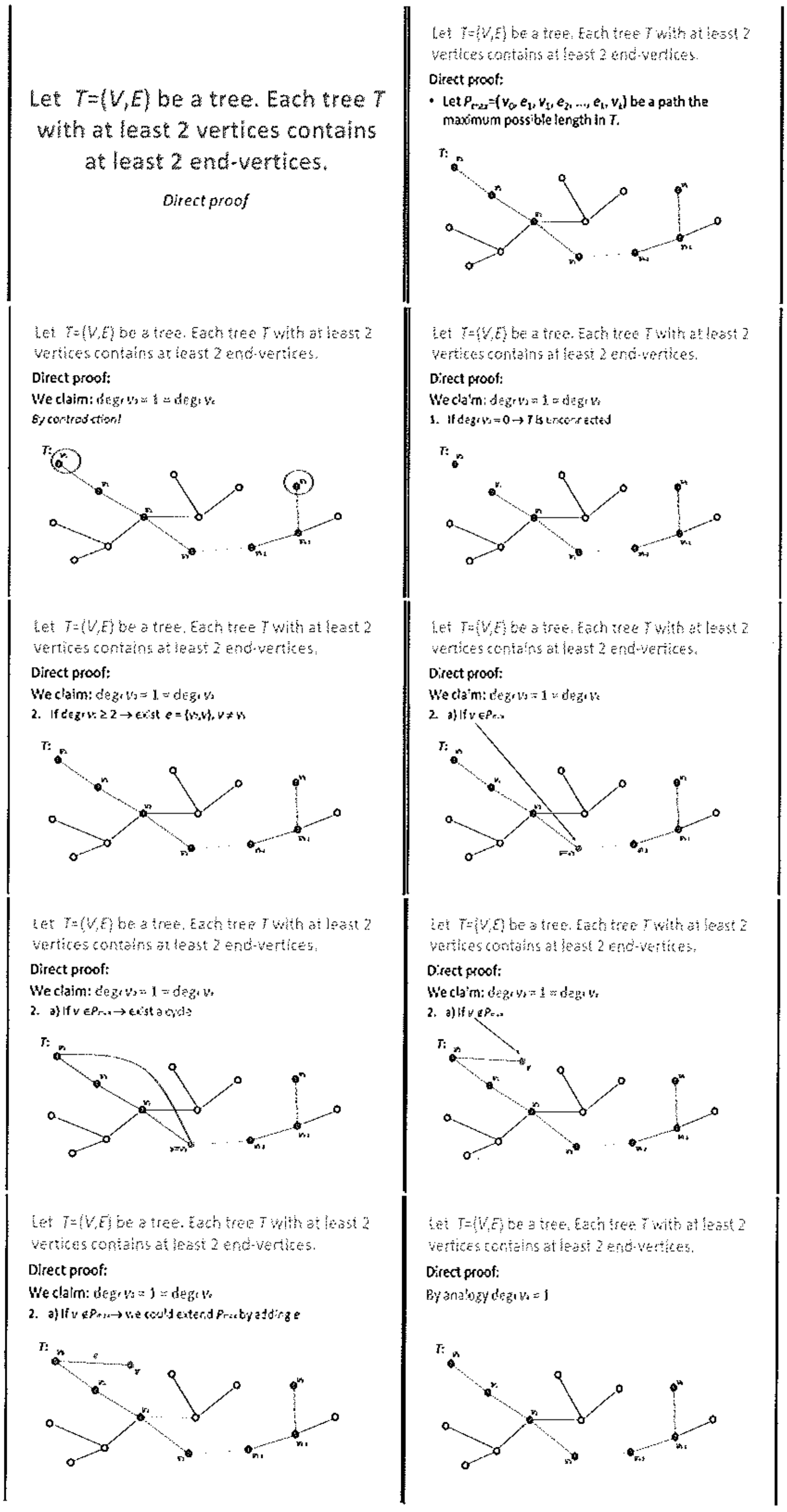

Figure 02. Visual Proof

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In the academic year 2016/2017, 67 students, in the instruction of whom the teaching was already conducted with the presented proofs, were interviewed by the form of the questionnaire. 17% of students would prefer more multimedia tools in the instruction. In order to support the effectiveness of the proof teaching in the DIMA course, a specific GraPro multimedia application was developed. The GraPro Multimedia Tool was created in a source code editor called Visual Studio Code from Microsoft (Šťastná). In 2017, the application was tested by 10 students who provided valuable inputs to GraPro development, for example, easier operating or better understanding for students. At the end, students filled out a questionnaire in which they were asked about the tool benefits. Based on the results of the questionnaire, the benefits for students can be presented as follows:

- easy operation and clarity,
- interactive environment and animation,
- possibility of individual movement in time,
- quality performance of visualization.

From next year this app will be used as a complement to existing instruction to improve imagination and overall understanding of challenging topics.

6.1. Conclusions from the credit projects

At the end of the DIMA course students were divided into groups (1-5 members) and each group worked out a final project, the task of which was visualization of the selected statement. In both groups, control and experimental, 29 projects were created. The visualization was meant to be introduced and presented to the group of fellow students so that they were able to understand the proof. Based on the presentation and visualization performance, the projects were rated according to the following parameters: Proof correct, Proof with minor errors, Proof misunderstood, Proof wrong. The results can be seen in Table 1.

Table 01. Results of the control group projects

	Proof correct	Proof with minor errors	Proof misunderstood	Proof wrong
Control group	17% (5)	28% (8)	24% (7)	31% (9)
Experimental group	59% (17)	21% (6)	3% (1)	17% (5)

An interesting observation was what types of proofs were used by the students. In the control group, in which the teaching was conducted in the standard way, i.e. the proof was recorded by means of the propositional logic and the students worked with teaching texts where proofs were printed, the students did not favour any type of evidence. In their essays they pointed out that the main criterion for choosing a particular proof was the simplicity. The implication from the presented proofs is that even though the students chose in their opinion "simple" proof , they often did not understand it and for this reason they were unable to create an appropriate visualization, based on which they would provide the explanation of the proof. In the experimental group, where instruction was supplemented by

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visualizations, and students did not work with the teaching texts of proofs, recorded by means of propositional logic, the students preferred proof by contradiction, and in their essays they suggested that this type of proof seemed easier, they knew exactly how to proceed and logically deduced parts of the proofs until they reached the conclusion. The proof of mathematical induction, even though it is the most common proofing tool in informatics, was misunderstood by the students, which was also supported by the fact that it was used only once in the control group and not even once in the experimental group . The results of the used types of proofs can be seen in the graph in Fig. 3 (Control group: Direct proof - 38%, Indirect proof - 17%, Proof by contradiction - 41%, Proof by mathematical induction - 4%; Experimental group: Direct proof - 31%, Indirect proof - 7%, Proof by contradiction - 62%, Proof by mathematical introduction - 0%).

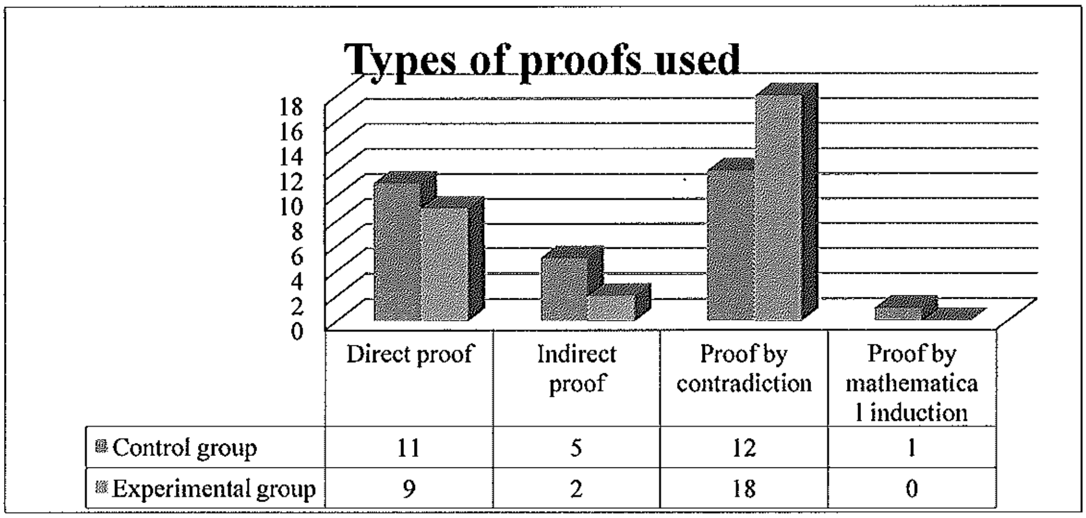

Figure 03. Types of proofs used by the students

The important facts and observations that were obtained from the students' essays analysis are listed below:

- Some students have a negative relationship to proofing. For some, this relationship has already been built up at secondary school. And even after completing the course, they do not realize the importance of proofing:
  - „I had the feeling that proofing is just one of the ways to complicate the already difficult situation of students. “
  - „There is no motivation, no desire to solve the proofs. In the proof, you have to think something out, logically deduce and then write it using the inverted E and the crossed out V, and it's crazy for me.“
  - „I take the proofs with some degree of exaggeration as "the necessary evil" or "the self-purpose" issue. “
- Despite a negative attitude towards proofs, some students are aware of proofs′ importance in the field of informatics, e.g.

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- „Statement proofing is to me an important part of the analyst's thinking because there should be created some analysis of the problem, which must be justified by the refutation of the statement negation. This ability definitely has a positive impact on correct and logical reasoning. "
- „I only realized the importance and the essence of proofing when I started studying the online course "Design and Analysis of Algorithms" recommended to us by the teacher at the end of the Programming I. course. Only then did I understood why the proofs are important and how they relate to the algorithms, which we will be creating in the future. For an algorithm designer, it is undoubtedly important to be sure that the algorithm is bulk (e.g., the output of the sorting algorithm QuickSort will always be a sorted list, regardless of the length of the original list) or that it really has the computational complexity we believe it has."
- „Definitely from a logical point of view, I would appreciate it as a positive experience. "

▪ Visualisation is generally perceived positively. Students realize that it helps them in the process of understanding. In making visualizations, some students realized what is important to illustrate and what is essential:
  - „Visualization brings enough light into the issue. "
  - „Appropriately chosen visualization of proof may be essential. "
  - „Making visualization is good for the creator of the presentation. In the case of any confusion, the context can be better grabbed and understood. "
  - „Such tools are exactly what helps me personally understand things. "

▪ The main problem of the students was that they did not know how to start and which type of proof to choose. They realized that proof creating is not an easy thing, there is no precise procedure, a guide that tells you what kind of proof to choose, and that a lot of proofs should be done to develop the feeling and intuition for the proof creation.

▪ A lot of students approached the project positively, as it motivated them to study proofing in details:
  - „Without that, I would really just passed the proofs quickly."

In general, students were amused by the visualization and they created interesting, attractive or original visualizations that would not only help fellow students to understand the proof, but thanks to the originality students memorized the proof procedure and were able to apply it.

7. Conclusion

The results of our research confirmed the effectiveness of the used strategy applied during the instruction in the experimental group, i.e. the use of visualization. Most teachers agree that using visualization in learning process should facilitate learning. We can find further studies about visual presentation and its efficiency in plenty of scientific articles, e.g. (Kostromina & Gnedykh, 2015): (Kosslyn, 1980) and (Shepard and Cooper, 1982). These authors confirmed the argument that images are better memorable than words. The Domik's study (Domik, 1994) showed that the use of visualization in

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teaching assumes an active, investigative and motivating environment that provides an intuitive understanding of complex processes.

Visualization plays an important role in mathematical proofs instruction. Students' involvement in visualization leads to a better understanding of the proof itself and encourages students to use their potential. Based on our current research and our own experience, we recommend using of visualization as an appropriate tool for mathematical proofs instruction.

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AFFECTIVE DOMAINS, INTRINSIC MOTIVATION AND GAME-BASED APPLICATION IN EARLY CHILDHOOD EDUCATION

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Abstract

Game based application and gamification is an approach for motivating and engaging participants using game-like design elements. Integrating game-like design elements in educational application and educational context have the potential to increase children′ intrinsic motivation and other related affective domains such as persistence, goal orientation and enjoyment. Some empirical studies provided proofs that gamification and system of rewards could influence children's motivation and level of cooperation. There is a lack of empirical research focusing on effectiveness and possibilities of development of intrinsic motivation and related affective domains with the help of ICT used in kindergartens and early childhood education.
The purpose of this research is to examine the influence of an educational game and its impact on chosen affective domains. 45 children from 3 kindergartens used original designed game application for two months. The used questionnaire "Game application's influence on affective domains by preschool children" consisting of 18 questions was created by collecting responses from 18 kindergarten teachers. For analysing and categorizing Likert scale was used. This study showed a positive impact of game based application on chosen affective domains (namely intrinsic motivation, persistence, goal orientation and joy/pleasure) without using wide spread reward system like badges, hints, praises etc. typical for extrinsic motivation.

This study is considered as a base for the next research which will be aimed on 7 affective domains and specific features of educational game applications which support motivation and other domains in the most effective way.

Keywords: Intrinsic motivation, affective domains, ICT, ECE, game based application

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1. Introduction

Motivation is a crucial drive by which learning behaviour can be stimulated. According to Bandura's social cognitive theory (Bandura, 1997), motivation is "goal-directed behaviour. People engage in motivated behaviour when they expect to succeed at a task and when they believe that the outcome of that success will be useful" (Bandura, 1997).

Some authors (Deci and Ryan, 2000, Berschenke, 2013) stressed the role of intrinsic motivation and demonstrated that participating in intrinsically motivated activities leads to greater learning, performance, persistence, creativity, self-esteem, vitality, and general well-being. Schunk et al. (2008) states that index of motivation can be seen as persistence which is defined as time spent on a task before quitting. Persistence is related to greater learning and achievement.

Other theories (Dweck & Leggett, 1988, Dweck, 2002) emphasised the role of goal orientation that links attributions which people make for success and failure to the goals that they adopt toward task. They defined learning orientation, with which the students show more positive affect, more interest, higher cognitive engagement, greater effort and more persistence. The second attitude explains performance-oriented students are those who place emphasis on getting good grades, rewards, beating other students and demonstrating high ability.

Motivation literally means the desire to do things and it's the crucial element in setting and attaining goals. The researches give evidence that level of motivation and self-control can be influenced (Berschenke, 2013, Dichev& Dicheva, 2017). Game applications use a lot of elements of gamification (game-like elements in non-game context). The main goal of gamification is to motivate participants and encourage expected behaviors in a meaningful way (Deterding, et al., 2011; Dichev & Dicheva, 2017; Shi, 2014). Current researches on gamification, in educational context, describe how badges affect learners of different skill levels (Abramovich, Schunn, & Higashi, 2013), how badges influence and how leaderboard can impact learning and motivation (Christy & Fox, 2014).

We suppose that suitable game applications equipped with specific characteristics and gamification usage has crucial potential to empower learners with a more engaging learning experience, higher motivation and better performance and achievements needed.

2. Problem Statement

We concentrate on stimulating and sustaining of children's motivation and the opportunities for optimising learning outcomes in particular areas.

It is not clear whether preschool children, in order to be well motivated, need to get the system of extrinsic rewards which is common and wide spread or if there are other options how to motivate children and how and to what extent to support intrinsic motivation and other related affective domains with help of ICT.

Unfortunately, there seems to be a lack of empirical studies on evaluating the efficiency of game application on intrinsic motivations and other affective domains.

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There are rare studies which would compare motivation approaches that are connected not only with extrinsic motivation (like badges, points) but also with features that can increase the level of intrinsic motivation.

3. Research Questions

1. Is this proposed design of an educational game application without typical extrinsic motivation elements effective for preschool children?
2. Are preschool children interested in playing without getting a typical reward?
3. Does the use of means of information and communication technology (ICT) have negative impact on daily work in kindergarten class?
4. Are teachers interested in using game-based learning application in education of preschool children?

4. Purpose of the Study

The purpose of our study is analysing and verifying of effectiveness of the educational game application on some affective domains of preschool children.

The study wants to verify and if a designed model of game app without elements which boost extrinsic motivation (such as badges, points, and leader board) is enough interesting for children. Further, we focus on it if a game based on a story, narration and feedback has a positive impact on motivation and some other affective domains that are crucial for further learning and education of preschool children. New approaches as affective learning, micro learning and adaptive learning have been raised recently in the field of education and have been incorporated in the educational game application used in this research.

5. Research Methods

5.1. Participants in pilot study

Preschool children from 3 kindergartens in the Czech Republic were participants in this research. 45 children were included into the target group and they were in age from 4 until 7 years.

The kindergartens which took part in the study educate children without special educational needs (SEN) and the children with some SEN as well. 4 children had visual special needs, 5 had speech special educational needs and 5 of children had a symptoms of ADHD. Teachers and parents agreed with carrying out of the pilot research in particular kindergarten.

5.2. Description of the game based applications - "I'm going to school!"

The game application "I´m going to school" was used in this research. This tool (designed and developed by S. Pekarkova, T. Sykora, 2015) is the educational game application whose structure and included features are specific from different aspects.

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The structure of the application is divided into *small units* focusing on specific topics (e.g. recognizing of the right place of subject, recognizing of some visual patterns or solving pre- mathematical tasks at different levels of difficulty etc.). Thus the content consists of tasks of six main *cognitive domains* for preschool children such as visual discrimination, spatial ability, temporal ability, language and speech, mathematical skills, hearing and auditory discrimination. The game application consists of planned short episodes that represent a *complete story* together. The other important point to be stressed is that the educational application has a *narrated guide* (Mr. Mouse Adam) who explains instructions to a player and shows and explains each new task. After each single task is being completed the guide provides *clear feedback* on the correctness. The educational application estimates a suitable *level of difficulty* based on the previous player's results (either too hard or too easy level could demotivate the player). The game will start next playing at an adequate level, which corresponds with the children's current capabilities. Thus a child can solve tasks without repeating failure. The application collects and *assesses data* about the level achieved in every task and can also provide useful information for parents and for kindergarten teachers about the area in which a child has some weaknesses and would need more professional support.

The application for preschool children has been tailored appropriately to the age (4-7 years) by using suitable graphics, animations and illustrations or a talking guide, using pauses in the game with mini stories where the child can relax and play freely with some new added details.

The characteristics of **game-based learning** were adopted when designing the educational application. The story in the application is important to engage the children into the active discovering and learning. The children can adjust their achievements according to immediate feedback in response to their mistakes. Thanks to the task content which has gradually rising difficulty, the learning pace is tailored to each individual child.

5.3. The Questionnaire "Influence of game application on affective domains by preschool children" for teachers

The Questionnaire for teachers contains 23 questions. These questions for teachers are aimed to evaluate particular behaviour by preschool children when playing the game application. The selected questions are based on previous interviews and workshops with 18 kindergarten teachers who originally raised many different questions and pointed out areas of their interests when speaking about affective domains in context of playing an educational game application. After analysing teacher's responses, similar statements and questions were selected and further categorized into 4 basic affective domains – pleasure/joy, motivation, persistence, goal orientation. These domains are defined as particular areas of Approaches to learning as well.

All items in questions are based on 6-point Likert scale. A 6-point Likert scale questions were used to measure respondent's agreement with the statements. The teachers needed to choose one from 6 descriptive options in every question for each child included into the research. The values of different levels of each domain has been defined as follow: 1- no evidence of specific behaviour, 2- poor level, 3- level of below average, 4-average, 5-over average, 6- very high level).

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6. Findings

We present the results with the help of percentage which represent outcomes from all questions from particular domain.

- The educational game-based application with particular features (narrated guide, feedback, story etc.) showed that 63.5% of children group was motivated better and their motivation was higher and permanent for a longer period in comparison with standard work when using worksheets or other materials.
- According to the teacher's answers the application supported 75% of all children while working on tasks with higher difficulty. The children did not give up harder tasks while working with the educational game application. A very important outcome is that the children with special educational needs are included in this percentage result.
- During play sessions 63.5% of all children showed higher interest and longer persistence to search for right solution and finish their tasks in comparison with work on worksheets which are common part of school preparation for preschool children.
- According to the teachers´ answers the most motivated aspect (59.4%) was enjoyment from playing the game. The second most important motivation aspect (22.6%) was the effort to finish the game. Although the children did not get any badges, hints and other extrinsic incentives they enjoyed the game and wanted to go it through to the end.
- According the teachers most of the children (43.8%) expressed their desire to play the game because "it is a fun". The second main reason (3.4%) of child´s motivation was "they want to play with Mr. Mouse". It might be perceived they created some identification with Mr. Mouse and wanted to help him in his story. The third significant reason was children´ own perception "they are learning and feeling happy about it".
- More than 31% children were keen on doing the tasks in which they have evident weaknesses and failed at the beginning a few times. Furthermore, the motivation was gradually increasing by 16.1% of children during play sessions. The answers of the teachers showed that 19.4 % of children played only those tasks in which they perceived to be successful.
- According to teachers' observation more than 84% children showed higher ability to focus on chosen tasks in game application. They also wanted to complete and finish their work even it seemed to be time-consuming for them. In this result the children with ADHD syn. are included also and the teachers commented that these children finished their works surprisingly well very often.
- The analyzed answers also presented the current perception of ideal "time duration of using tablets in kindergarten". The teachers let the children play mostly once in one week (45%), and 32% of children played twice a week. The time period for using the application in learning process all teachers spontaneously confirmed as optimal was 20 minutes for one playing session.

- From the view of school readiness it is interesting to discover which tasks the children preferred to play and to which the children came back more frequently- the tasks for visual discrimination, mathematics skills and for spatial skills.

7. Conclusion

The analysed data helped to answer whether young children need to be motivated mainly with elements of extrinsic motivation or if they can be effectively motivated with elements which are typical for intrinsic motivation. We concluded that generally used rewards (hints, badges, points) are not a critical point for game-based learning of young children. Most of children played the tasks at difficult level without losing their motivation and joy even if they did not receive common extrinsic benefits. Many children did not stop playing some tasks even if they did not succeed after several attempts. *"Between the tasks which children liked and their success in solving of these tasks there wasn't the relation of direct proportionality. For example in spite of many fails on searching for right solving the children most favourite task were Planets (mathematical ability)."*

The children did not avoid to play tasks from specific cognitive fields in which they perceived some weaknesses. The results in chosen affective domains (intrinsic motivation, persistence, enjoyment and goal- orientation) showed improvement in skills of children without SEN and in the children with SEN as well. These results show very high potentials of ICT tool how to improve specific skills and minimize particular difficulties in some cognitive areas of pre-schoolers before attending the school.

The educational game had positive impact on learning orientation instead of performance orientation which emphasis rewards and getting "good grades" (Dweck, 2002). Most of the children did not perceive they failed to find a solution but continued to play and discover another solution. This positive attitude might become stronger because no extrinsic motivation in game was used and therefore absence of repeating signs of failure was there.

A clear outcome is that the teachers are interested in new technology and they do not deny its use in education as something that does not belong to kindergartens.

Our further research will be oriented on comparison of the game application using the specific features (narrated guide, narrated instruction, meaningful story, feedback etc.) with the game application without them in order to analyse which components and characteristics are crucial for motivation and learning of preschool children.

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