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Can we expect to recruit future engineers among students who have never repaired a toy?

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Education has traditionally focused primarily on content and cognitive goals. While content knowledge is important, to enter to the labour market today, graduates must also develop manual skills and technical literacy. The paper deals with engineering and technology education in Slovenia. It portrays the problem of the decline in interest in technical studies, seeks reasons behind this and advances proposals for improving the situation. The main goal of our research is the wish to identify and explore potential epistemological obstacles to a better appreciation of STEM education among lower secondary school students, and to offer solutions to the problem. The results of the study showed that practical and hands-on activities are, to a large extent, lacking in lower secondary education in Slovenia. The findings call for redesigned curricula and reform of teacher education towards more practically oriented and inspiring teaching.

Keywords: hands-on activities; lower secondary school; science and engineering education; technology literacy

INTRODUCTION

One of the cornerstones of our civilization is technology. Recognition of technology, whether good or bad (Small & Jollands, 2006) is crucial for the future of our planet and human kind. On the other hand, this importance is not reflected in the general public interest in Science, Technology, Engineering, and Mathematics (STEM), or in choosing STEM domains as a career path (Archer et al., 2010; Osborne, Simon, & Collins, 2003; Prokop, Tuncer, & Chudá, 2007; Randler, Osti, & Hummel, 2012).

A declining interest in technology – engineering studies – has created a constant problem of filling the study places at many science/engineering/technology faculties and departments at Universities in Slovenia, and higher and secondary schools (Aberšek, 2004; Cerinšek, Hribar, Glodež, & Dolinšek, 2013; Kocijančič, 2011a). This decline can be attributed to three main reasons: the first is a general tendency towards loss of interest in STEM subjects; the second involves the de privileged position of engineering subjects in elementary and general secondary schools, and

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the third relates to how these subjects are taught (Šorgo & Špernjak, 2012). Lessons that are too abstract in nature and that exceed the students' intellectual level are a waste of time. Pisano (2011) pointed to the problem of teacher qualification, recommending that teachers upgrade their level of content understanding by acquiring knowledge of historical facts and epistemology of science. This would enable teachers to better understand the students' cognitive abilities and to adjust the learning process to the appropriate age level.

The problem of declining numbers of students studying engineering has also occurred both in the United States (U.S.) (Carr, Bennett, & Strobel, 2012) and in Western European countries in recent years, (Johnson & Jones, 2006).

Carr et al. (2012) conducted research on engineering education at all levels in the U.S.. Content analysis of educational standards in all 50 U.S. states found engineering listed in the standards of 41 states, and analysis of those standards resulted in Sneider and Rosens' (2009) list of "Big Ideas" for doing engineering in the pre-college classroom. The list of "Big Ideas" consists of nine ideas, divided into three sections:

Knowledge;

- Engineering design is an approach to solving problems or achieving goals;
- Technology is a fundamental attribute of human culture;
- Science and engineering differ in terms of goals, processes, and products.

Skills;

- Designing under constraint;
- Using tools and materials;
- Mathematical reasoning.

Habits of Mind;

- Systematic thinking;
- Desire to encourage and support effective teamwork;
- Concern for the societal and environmental impact of technology.

This problem has also been studied by the OECD (Bonga et al., 2006). The overall goals of the Global Science Forum activity were as follows:

- To analyse quantitative trends in enrolment in science and technology studies during recent years (and, in particular, to quantify the extent of any decline);
- To identify the underlying factors that affect students' choices;
- To explore solutions that can be implemented to influence such choices.

State of the literature

- It is difficult to believe that school can change the frequency of technology usage among students from homes where parents want to protect their children, building them a risk-free world.
- This is an additional reason for the importance of engineering-based science instruction, an approach supported by study results confirming that the use of engineering problems as a basis for conceptual science exploration does foster improved science learning for children.
- It is known from previous studies that young children have positive attitudes toward science and that this interest declines by the age of 14, by which time attitudes have been formed.

Contribution of this paper to the literature

- From the results we can conclude that tool usage outside of school is a better predictor of student intentions than either tool usage in school or their opinions about school work in technical/engineering subjects.
- Based on the usage frequency of various tools and performance of procedures, a large gap between home and school technics can be recognized.
- Opinions about technics in school and tool usage in school are poor predictors of students' future schooling. More influential is the usage of tools at home.

HISTORICAL ROOTS OF THE STEM PROBLEM

Many studies focus on attitudes and motivation for enrolment in STEM education, but only a few of them touch the historical roots of the problem (Pisano, 2011; Pisano & Busotti, 2012; Lövheim, 2014).

Lövheim (2014) presented the Swedish case from the second half of the 19th century, when they faced a severe decline in interest in STEM studies. To solve the problem, state and local authorities introduced various actions: positive propaganda, reconstruction of the school system so that the school itself placed the need for science and technology on display and thus create the attraction of science and technology, fix the percentage of individuals in the Science and Technology programs to more than half of the student population, not respecting of the individual's right to a free choice. The results of different actions were short-term. Enrollment in STEM studies increased to 20.2% immediately, but it decreased in just two years to 10%. In addition, a new problem appeared: many high school students dropped out after the first year of study because of the difficulty of the subjects. Sweden was forced to take new actions. The Swedish situation points to similarities with the U.S. example, however without the same pressure of Cold War politics.

Lövheim (2014) asserted the importance of creating pedagogical methods for changing students' approach to science and technology. For this purpose, a group of experts was created to research and gather information through surveys and questionnaires. They asked students how they felt about studying science, what they thought about their science teachers and also about their relation to parents and after-school activities. The results concluded that laboratory work was, to a large extent, absent from Swedish schools.

THE SLOVENIAN CASE

The problem of reduced interest in STEM studies has increased in Slovenia in recent years. To solve this problem it is necessary to examine the causes in detail and to find potential remedial actions. To facilitate understanding of the problem, which is slightly specific in Slovenia, the school system and the reforms that were carried out in Slovenia in the early 21st century are presented below.

School reform between 2001 and 2006 brought some important changes to education in the Slovenia. Compulsory elementary school was extended from 8 to 9 years (Ministry of Education, Science and Sport [MESS], 2009). These nine years were divided into three cycles (the first and second cycle constitute primary education, and the final 3 years, lower secondary education). Curricula were rewritten, and substantial changes were introduced, such as merging subjects or reduction in or extension of topics, reflected in changes to the lesson hours dedicated to various subjects. Additionally, the inclusion of elective subjects was one of the innovations. There were also some crucial changes related to engineering and technology (hereinafter technical topics) in education, whereby the engineering content was reduced by 33% (Kocijančič, 2011b; Kocijančič et al., 2011).

Topics related to engineering skills, which include handwork and the technical knowledge needed in everyday life, are now represented in the 1st to the 8th grade, but not in the final grade. In the first five grades (6 to 11 years), technical topics are incorporated into the subjects "Environmental Sciences" and "Science and Technology". A purely technical course, titled "Technics and Technology" is taught in the 6th (2 hours per week), 7th (1 hour per week) and 8th (1 hour per week) grades. In addition to the regular course "Technics and Technology", within the framework of school activities there are also "Technical Days". These normally take the form of project work, but according to school sources, these are often not optimally implemented. A detailed study of their implementation has not yet been made. These technical days should complement and build on the teaching in "Technics and Technology", but do not replace the regular course in 9th grade. As mentioned before, Technics and Technology is not taught in the 9th grade, an unfortunate gap that may influence future decisions regarding students' career paths and decisions in choosing an upper secondary school.

At the upper secondary level, problems are even more serious. Despite the demographic decline, enrollment in general secondary education programmes (high school) is rising and recently reached 42% of the student population; on the other hand, enrollment in vocational and professional programmes is declining faster than the rate of population decline. There is an extremely unfavorable trend in the field of 3-year vocational education. We cannot explain the declining interest in technical schools only in terms of the changes in elementary education. The numbers, however, tell the story: in the short term, vocational programme (2-year) enrolment declined by 71%, vocational programmes (3-year) enrolment by 60%, vocational-technical (3+2-year) enrolment by 23% and technical programmes (4-year) enrolment, by 19% (Kocijančič et al., 2011).

At the content level, engineering topics are absent from the syllabus of general upper secondary schools, even in the form of elective courses. The Science subjects (Biology, Chemistry and Physics) are oriented more toward understanding basic concepts of the disciplines than to technics, technology and engineering competences (Šorgo & Kocijančič, 2004). This means that within the general schools about 42% of the population (mostly those who have excelled in school) lacks any courses on technical topics. Although a handful of students decide to continue their studies in technical fields after leaving general high school, they are faced with a lack of basic technical knowledge, of general-technical thinking, behavior, skills and methodology for solving technical and technological problems (Kocijančič, 2011b).

Most European countries carried out the first major school reform around 1970 (Brunello, Fort, & Weber, 2009). The rapid development of science, along with lifestyle changes, calls for constant adaptation of the education system. Many authors (Alpaslan, Yalvac, & Loving, 2015; Pinar, 2013; Serin, 2015, Kapanadze, & Eilks, 2014) have analysed curriculum reforms from countries around the world. Dillon (2009) made an overview of curriculum reforms, from the scientific point of view. Turkey initiated a major primary school curriculum reform in 2003. Science was one of five subjects chosen for reform, and a new curriculum for grades 1-8 has been implemented. One of the major motivations for this curriculum improvement is to reach ideal international standards of education as implemented in Europe, North America and East Asia (Koc, Isiksal, & Bulut, 2007). Science is compulsory in Turkey from grade 4 (ages 9-10) through to grade 8 (ages 13- 14). The seven learning areas in the new science and technology curriculum are Physical Processes; Life and Living Beings; Matter and Change; The Earth and the Universe; Science Process Skills (SPS); Science-Technology-Society-Environment (STSE), and, Attitudes and Values (AV) (Tasar, & Atasoy, 2006). What is particularly interesting about this curriculum is the predicted outcomes of the Science-Technology-Society-Environment learning area.

There are some interesting parallels with what has been happening beyond Europe (Dillon, 2009). For example, in Canada, which has seen many initiatives aimed at promoting Science-Technology-Society (STS) education for many years, a nationwide framework (Council of Ministers of Education, Canada [CMEC], 1997) led to a series of provincially-based science curriculum revisions. The framework is based on a premise of science for all and scientific literacy is defined as "an evolving combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem-solving, and decision-making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them" (CMEC, 1997). The Canadian approach differs from that taken in England and Wales and in the Netherlands in that it is an attempt to add a dimension to the curriculum rather than to create a special course. However, the approach used is to mandate that students complete particular units which focus on problem solving and on decision making.

The approach taken in Australia (Goodrum, Hackling, & Rennie, 2000; Rennie, Goodrum, & Hackling, 2001) and the USA could be seen as more of an infusion in which frameworks and standards are intended to have an impact across the curriculum. Bybee (2013) pointed out the importance of STEM and proposed the STEM education reform for the American education system.

Technology/engineering education has much in common with Environmental education. One widely used definition of environmental education (UNESCO, 1976) is as follows:

> Environmental education is a process aimed at developing a world population that is aware of and concerned about the total environment and its associated problems, and which has the knowledge, attitudes, motivations, commitments, and skills to work individually and collectively toward solutions of current problems and the prevention of new ones.

This definition of environmental education can easily be transformed to a definition of technology/engineering education by replacing the word 'environmental' by the word 'technology/engineering'. This new definition goes as follows:

> Technology/engineering education is a process aimed at developing a world population that is aware of and concerned about technology overall and its associated issues, and which has the knowledge, attitudes, motivations, commitments, and skills to work individually and collectively toward solutions of current problems and the prevention of new ones.

Consequently, and in line with the aims of the proposed definition, technology/engineering education must fulfil three educational objectives:

- To educate about technology;
- To educate by means of technology;
- To educate for the sustainable use of technology.

A well supported finding is that many concepts of and much knowledge about technologies or processes in nature can be achieved through no direct physical contact with the technology or process itself, especially if Information and Communication Technology (ICT) is used (e.g. de Jong, Linn, & Zacharia, 2013; Han, 2013; Puhek, Perše, & Šorgo, 2012; Kubiatko, Usak, Yilmaz, & Tasar, 2010; Bilek, 2010). At this point, we must clarify that our study does not deal with the impact of the kind of educational technology (e. g., multimedia, overheads and video) commonly used in classroom teaching by teachers, but with classic technology/engineering (e. g., hand and electric tools), and with computer-supported hands-on technology, such as data acquisition systems and robotics (Rihtaršič & Kocijančič, 2012), with the exclusion of virtual technologies (e. g., simulations). We recognize virtual technologies as technologies where the whole process is performed within the frame of a computer or a network of computers, in contrast to a real laboratory, where ICT is used as a tool (Kocijančič & O'Sullivan, 2004). The boundary between real and virtual is sometimes very thin, as in augmented reality (Cuendet, Bonnard, Do-Lenh, & Dillenbourg, 2013) or in mixed reality (Lindgren & Johnson-Glenberg, 2013; Koštomaj & Boh, 2011), technologies which are not considered in our study.

The theoretical and empirical background on the importance of blending physical experience and verbal/visual teaching is supported by theories of embodied or grounded cognition. According to Barsalou (2008, p. 618), "Grounded cognition reflects the assumption that cognition is typically grounded in multiple ways, including simulations, situated action, and, on occasion, bodily states". Assuming that "conceptual knowledge is organised visually and that it is grounded in the perceptual system" (Kan, Barsalou, Solomon, Minor, & Thompson-Schill, 2003), we can expect a better quality of knowledge where explanations are supported by first-hand experience, especially at the procedural and conceptual levels and the acquisition of skills. In addition, hands-on activities can raise cognitive abilities because they are performed repeatedly in 3D space and especially if they include prediction of outcomes (Jaušovec & Jaušovec, 2012; Taylor & Hutton, 2013).

There is considerable evidence that children's play has changed dramatically in recent decades. Valentine & McKendrick (1997) found that in North-West England "Fewer children are playing outdoors and the location of most outdoor play is now closed centred on the home rather than the street." Child play and activities are important because "exercise could provide a simple means to maintain brain function and promote brain plasticity" (Cotman & Berchtold, 2002). By analogy, we can extend the findings from physical education and medicine to technology education, by the prediction that hands-on activity using a variety of tools and materials not only widens a toolbox of manipulative skills, but also influences cognition (Wysocki, McDonald, Fanto, & McEwen, 2013).

The main goal of our research is to identify and explore potential epistemological obstacles to better appreciation of STEM courses by primary and lower secondary school students, and to offer solutions to the problem. Our research at this point is not hypothesis-driven but exploratory, with three main aims:

- Taking into account the historical aspect of scientific-technical learning, to explore the frequency with which tool usage and hands-on activities were conducted at home, in school, and in other places outside of school. The impetus behind this objective was the recognition that pathway of knowledge is not a one way route – from school to "life" - but that informally acquired experience and knowledge can greatly influence school-work (Avery, 2013);
- To explore whether all students have the chance to work with the machines and hand tools prescribed by the curricula and syllabi of lower secondary schools;
- To explore opinions considered to be important for choosing students' future career path. In addition, comparisons based on personal status were pursued. The impetus behind this objective had its origin in the literature, where it is established that opinions and values, and not knowledge lie at the root of many decisions (e.g. Ajzen, 1991; Allum, Sturgis, Tabourazi, & Brunton-Smith, 2008).

Research questions, based on the above-listed aims, were defined as follows:

- How often do students use various tools and perform hands-on activities at home, in schools or in other places?
- What do students think about school work in technology oriented subjects in relation to their everyday life?
- Which selected factors influences on choosing students' future career path?
- Are there differences between usage frequencies, opinions and future plans that depend on students' personal characteristics?

METHODS

Sample and sampling

Data were collected by the University staff among the pupils who attended free science and engineering workshops organized by the Faculty of Natural Sciences and Mathematics at the University of Maribor during the 2012 school year. Our sample consisted of 578 lower secondary school students, 305 (52.8%) boys and

273 (47.2%) girls. The students were from elementary 9-year compulsory schools from big towns – more than 90,000 inhabitants (41; 7.1 %), small towns – from 10,000 to 90,000 inhabitants (474; 82.0%) and villages – less than 10,000 inhabitants (63; 10.9%), all in Slovenia. All students were at the lower secondary school level: 515 (89.1%) were in the 9th grade, 62 (10.7%) in the 8th grade and one (0.2%) in the 7th grade. In Slovenia, this means that they were, on average, between 14 and 15 years old. In the later statistical analyses, we worked with them as a single group.

A self-reported scale of their school grade was used. They rate themselves as excellent (202; 35%); very good (195; 33.8 %) good (149; 25.8%), and 31 (5.4%) as fair. We did not get information from one student.

Most of them lived in houses with gardens (348 (60.2%)), 137 (23.7%) in apartments, 62 (10.7%), on farms, and 31 (5.4%) in houses without gardens. Because the questionnaires were collected mostly among the suburban population from small towns, there are biases in the group numbers toward this type of school and living in a house with a garden, so we do not report these differences in the Results section.

Structure of the research instrument

For the purpose of this research, a questionnaire was assembled. It consists of four parts, as follows:

Demographics

The questions in this part covered socio-demographic information about the respondents.

Future plans for education

This part consists of one question. A list of upper secondary schools (see Table 3) was provided for them to choose from.

Hands-on activities scale

The intention of the 'hands-on activities scale' was to assess the frequency of tool usage and performance of several procedures connected to the use of technology. We listed 19 hands-on activities (see Table 1) which, from empirical experience, we expected that every student would have had a realistic chance to perform in school, at home or in another location like a campground, a learning centre, in the neighbourhood or with distant relatives. The list was compiled according to the Slovenian syllabi of subjects, covering the topics of science, technical education and home economics, with possible impact on future careers in STEM disciplines.

Reliability figures (Cronbach's alpha) for the hands-on activities scale and its subscales were as follows: School = 0.812; Home = 0.883; Others = 0.904; School + Home = 0.897; School + Home + Other = 0.936. All reliability figures can be recognized as appropriate (Field, 2009). Prior to the analysis, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (0.890) and Bartlett's test of sphericity (Approx. Chi-Square = 6133,0; df = 703; $p < 0.000$) were used to check data suitability for further analysis. The items, factor loadings and frequencies are listed in Appendix 1.

Opinions on school work in technology-oriented subjects for everyday life scale

The intention of the second instrument (see Table 2) was to assess opinions concerning technology in schools. It was constructed as a set of six statements, and the response format was a Likert scale, in a range from disagree (1) to agree (5). The reliability, reported as Cronbach's alpha, was 0.824, which can be recognized as satisfactory for this type of research.

Following initial checking (KMO = 0.846; X = 1148.790; df = 15; $p < 0.001$), exploratory factorial analysis revealed one factor explaining 53.8% of the variance and showing one dimension of the instrument. Factor loadings are reported in Table 2.

Statistical analyses

Prior to further analysis, data were checked for missing data and outliers. Cases with more than 10% missing data were deleted. Normality was checked by use of the Kolmogorov – Smirnoff test at a 0.05 significance level. Our data did not meet the assumption of normality, so nonparametric statistics was performed to compare between groups (Erceg-Hurn & Mirosevich, 2008). The effect size was calculated using the formula $r = Z/\sqrt{N}$, where Z = Kolmogorov-Smirnov Z and $\sqrt{N}$ = square root of the sample size (Field, 2009, p. 550).

Exploratory factorial analysis was performed. Principal component analysis with Varimax Rotation and Kaiser Normalization was chosen. Prior to the analysis, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity were used to check data suitability for further analysis. Owing to the abnormal distribution, the results from principal component analysis should be considered with caution (Basto & Pereira, 2012).

To find predictors for the selection of upper secondary school, multiple regression analysis was executed. To perform regression analyses for home and school tool use, we summed individual responses (never = 1; one to two times = 2; three or more times = 3) for each student for the nineteen items, listed in Table 1. We were following the logic that someone who had never worked with any tool or performed any activity would get a sum of 19 (19 x 1), and if all activities were performed more frequently than three times, the end sum would be 57 (19 × 3). The same procedure was used for the opinions, where someone who disagreed with all the opinions would end with a sum of 6 (6 x 1), and someone who agreed with all the items would get a sum of 30 (6 x 5). Because of the structure of the instrument, no negative coding was necessary. All statistical analyses were performed using SPSS® 21.0 software.

RESULTS

The results are presented as tables with immediate commentary on the main findings.

Frequency of tool usage and hands-on activities

From Table 1 (Frequency of tool usage and hands-on activities) it can be inferred that schools and homes are the places where most students have their first contact with tools. Other places for acquiring hands-on skills do not play a significant role in most cases. We can consider them more as places for mastering special skills for some students. The frequency of tool use varies but never reaches 100% for three or more types of usage at home or in school. The peak values at home are for hammering a nail (80.6%) and replacing a battery in a toy (88.4%) and in school 60.2% hammering a nail and sanding wood on a wood sanding machine (55.0%). The lowest values at home are for robot programming (71.6%) and deep draw forming plastic (80.4%). At school, 94.5% of students have never replaced a blown fuse, and 91.9% of them have never tried to use a sewing machine. In addition, it was possible to identify that, for example, as many as 66.2% of students have never tried to repair an electronic toy, either in school or at home, while 18.5% have never

Table 1. Frequencies and percentages of hands-on activities in school, at home and in other locations. (the answers with highest frequencies are in bold)

No	Hands-on activity	School Frequencies (N, %)			Home Frequencies (N, %)			Other Frequencies (N, %)		
		never	1-2 times	3 or more times	never	1-2 times	3 or more times	never	1-2 times	3 or more times
1	Sanding wood on a wood sanding machine	83	177	318	321	104	152	433	69	73
		14.4	30.6	55.0	55.5	18.0	26.3	75.3	11.9	12.7
2	Cooking on a gas cooker	255	131	190	94	61	422	254	135	185
		44.3	22.7	33.0	16.3	10.6	73.1	43.9	23.5	32.2
3	Repairing an electronic toy	447	83	48	232	172	173	418	92	67
		77.3	14.4	8.3	40.1	29.8	29.9	72.3	15.9	11.6
4	Deep draw forming plastics	294	185	95	465	60	46	510	45	16
		50.9	32.0	16.6	80.4	10.4	8.0	88.2	7.8	2.8
5	Robot programming	414	118	46	487	52	38	516	42	19
		71.6	20.4	8.0	84.3	9.0	6.6	89.3	7.3	3.3
6	Using a wood lathe machine	427	103	47	438	69	68	504	45	26
		73.9	17.8	8.1	75.8	11.9	11.8	87.2	7.8	4.5
7	Using a sewing machine	531	34	12	272	198	108	459	77	41
		91.9	5.9	2.1	47.1	34.3	18.7	79.4	13.3	7.1
8	Technical drawing with computer software	140	180	258	239	136	201	435	65	76
		24.2	31.1	44.6	41.3	23.5	34.8	75.3	11.2	13.1
9	Using a flat blade or cross screwdriver	144	142	292	103	81	393	287	88	202
		24.9	24.6	50.5	17.8	14.0	68.0	49.7	15.2	34.9
10	Using an Allen key	326	109	142	155	122	299	341	71	164
		56.4	18.9	24.6	26.8	21.1	51.7	59.0	12.3	28.4
11	Machine drilling	189	130	259	185	117	275	368	76	133
		32.7	22.5	44.8	32.0	20.2	47.6	63.7	13.1	23.0
12	Hammering nails	94	135	348	31	80	466	229	74	273
		16.3	23.4	60.2	5.4	13.8	80.6	39.6	12.8	47.2
13	Replacing a battery in an electronic toy	304	105	169	27	40	511	215	84	278
		52.6	18.2	29.2	4.7	6.9	88.4	37.2	14.5	48.1
14	Replacing a power switch or electrical outlet	503	36	38	373	108	97	482	50	45
		87	6.2	6.6	64.5	18.7	16.8	83.4	8.7	7.8
15	Replacing a blown fuse	546	20	11	378	108	92	500	40	38
		94.5	3.5	1.9	65.4	18.7	15.9	86.5	6.9	6.6
16	Replacing a burned-out bulb	499	50	28	122	138	318	392	101	85
		86.3	8.7	4.8	21.1	23.9	55.0	67.8	17.5	14.7
17	Replacing a bicycle/motorcycle tube	514	38	25	244	126	208	412	85	80
		88.9	6.6	4.3	42.2	21.8	36.0	71.3	14.7	13.8
18	Using a vibration saw or band saw	264	107	150	314	92	115	412	59	50
		45.7	18.5	26.0	54.3	15.9	19.9	71.3	10.2	8.7
19	Using a hand saw	177	157	244	133	134	311	341	75	162
		30.6	27.2	42.2	23.0	23.2	53.8	59.0	13.0	28.0

changed a burned-out bulb. At the extreme, it was possible to identify 1.9% of students who had never hammered in a nail and one tenth (10.8%) who had never used a gas cooker.

Statistically significant differences between genders exists in the frequency and distribution of all home activities except for cooking on a gas cooker ($U = 39844.5$; $z = - 1.053$; $p = 0.292$). In all cases, except for “using a sewing machine”, boys are more frequent performers than girls at statistically significant levels ($p < 0.05$). In school activities, differences are statistically significant for 11 of 19 items of hand-on activities. For all items, boys are more active than girls.

Differences among students for school use, based on self-reported average grades, appear in only one item: Using a flat blade or cross screwdriver ($\chi 2$ (N = 576; df = 3) = 11.299; $p < 0.01$). There is a trend for higher achievers to have used a screwdriver more frequently than their peers.

Differences at home, based on school success, were revealed in three items. In all of these, lower achievers were the most frequent performers: “Replacing a blown fuse” $\chi 2$ (N = 576; df = 3) = 15.692; $p<0.001$, “Replacing a bicycle/motorcycle tube” $\chi 2$ (N = 576; df = 3) = 17.639; $p<0.001$ and “Using a vibration saw or a band saw” $\chi 2$ (N = 576; df = 3) = 11.957; $p<0.008$. We cannot provide a satisfactory explanation for this finding, but we speculate that one reason for the differences could be the influence of socioeconomic status.

Exploratory factorial analysis of tool usage and hands-on activities

Additional information about performance was extracted by Exploratory Factor Analysis. Nine factors (Appendix 1) are extracted, explaining 55.5 of variance. Only the first three factors can be considered reliable according to their reliability measurement. The first factor is loaded by eight items (Cronbach's alpha = 0.847) and explains 12.1% of variance. We can name it “Not at home”. It consists of items where in six cases more than half the students report that they never perform the activity at home and in two items, about 40% of them. These two items are “Replacing a tube” (42.2%) and “Repairing an electronic toy” (40.1%). The second factor (Cronbach's alpha = 0.823) is a construct of seven items where about half or more of the students reported that they regularly perform these tasks at home. We can name the factor “Done at home”. The third factor (Cronbach's alpha = 0.791) consists of nine school items. Except that all of them are connected with school, we cannot find a sound explanation for this grouping:

- More than 40% of students reported four items to have been performed in school;
- On the other hand, more than 40% of students reported that three of the items had not been performed in school.

The reliability of the last six factors is below acceptable level; nevertheless, we report them with reservations. Alphas are reported in Appendix 1. The fourth factor consists of four items (Cronbach's alpha = 0.620) and can be named “Never in school” but includes tasks that can be performed by the majority at home (Replacing a burned-out bulb and Replacing a tube) or not at home (Replacing a power switch or electrical outlet and Replacing a blown fuse). The fifth factor (Cronbach's alpha = NA (not available)), named “robotics”, consists of the item robotic programming at both school and home. In both cases more than 70% of students reported a lack of this activity. The sixth factor consists of items that are not regularly performed in school but regularly at home. Such items are “Cooking on a gas cooker” and “Using a sewing machine”. The last three factors comprise only one or two items and are most probably only the inverted remains of higher orders factors.

Opinions on school work in technology-oriented subjects

Table 2 presents students’ opinions on engineering education. Less than half the students (44.5%) partly agree that the course “Technics and Technology” is interesting.

This result is in the same range as the number of students who wish to have an additional year of this course (42.5%), and those who feel that a teacher was able to inspire them (46.7%). On the other hand, 56.1% would prefer more practical activities, but only 29.9% are interested in technical occupations. Only one in ten

Table 2. Opinions on engineering education

Item	Factor loadings	Disagree	Partly disagree	Undecided	Partly agree	Agree	M	SD	GES
The course “Technics and Technology” in school was interesting.	0.83	77 13.3	104 18.0	140 24.2	113 19.6	144 24.9	3.25	1.359	- 0.24
I wish that we had the course “Technics and Technology” in the 9th grade.	0.81	217 27.5	55 9.5	59 10.2	68 11.8	177 30.7	2.88	1.715	- 0.27
I would like more practical activities in the course “Technics and Technology”.	0.76	92 15.9	67 11.6	95 16.4	101 17.5	223 38.6	3.51	1.487	- 0.29
I am interested in technical occupations.	0.71	202 34.9	99 17.1	104 18.0	66 11.4	107 18.5	2.61	1.510	- 0.52
The teacher of “Technics and Technology” was able to inspire us.	0.64	102 17.6	80 13.8	125 21.6	107 18.5	163 28.2	3.26	1.448	- 0.24
Engineering education is important for everyday life.	0.62	11 1.9	42 7.3	100 17.3	164 28.4	260 45.1	4.07	1.041	- 0.24

GES = gender effect size

(9.2%) believes that engineering education is unimportant, while on the other hand, there are 45.1% students who agree with the statement that engineering education is important for everyday life.

All differences between genders are statistically significant at a level of $p < 0.05$, and boys partly agree with statements more frequently than girls. Yet the effect size is small to medium (Table 2), except for the statement “I am interested in technical occupations”, where the effect size is large (Field, 2009, p.550). The mean for boys is 3.35 (SD = 1.43) and for girls M = 1.79 (SD = 1.51).

School grades statistically significantly affect only two opinions: “I am interested in technical occupations” $\chi 2$ (N = 576; df = 3) = 22.805; $p<0.001$ and “The course “Technics and Technology” in school was interesting” $\chi 2$ (N = 576; df = 3) = 11.754; $p<0.008$. In both cases, support for the statements is low (Table 2), but lower achievers show slightly more support for the statements. In the first case, the difference between the highest and lowest achieving groups expressed as effect size falls on the boundary between small and medium (r = 0.23), and in the second case is non-existent (r = 0.03).

Future plans about schooling

Plans for future schooling after completing elementary school are displayed in Table 3. The most desired outcome is general education, followed by professional and vocational schools.

Regression analyses were performed to find predictor variables for preferences in future schooling. The chosen predictor variables were school grades, gender, and the sum of home tool usage, the sum of school tool usage and the sum of opinions. The best and only statistically significant ($p < 0.001$) predictor was school grades, followed by gender and use of tools at home at a level of $p < 0.1$ level (Appendix 2).

Table 3. Plans about upper secondary school attendance after completing elementary school

School	Frequency	Percentage	Valid Percentage	Cumulative Percentage
Vocational school 2-3	73	12.6	12.7	12.7
Professional school (4-5 y)	217	37.5	37.7	50.3
General school	242	41.9	42.0	92.4
Others	7	1.2	1.2	93.6
Do not know	37	6.4	6.4	100.0
Total	576	99.7	100.0	
Missing System	2	0.3		
Total	578	100.0		

DISCUSSION

From the results, we can identify a large gap between school and home tool usage. Based on frequency of tool usage, and if we exclude from the comparison between school and home cases where students performed something only once or twice, rationalizing that one or two experiences cannot produce mastery of a skill, we can place these activities into four categories.

In the first category there are activities performed both in school and at home (e.g., use of a screwdriver or a hammer). The second category includes tools used mainly at home and not in school (e.g., a gas burner). In the third category we find tools used in school and not at home (e.g., Technical drawing with computer software), and the fourth group includes activities that most students do not perform either at home or in school (Replacing a blown fuse or robot programming). If the differences at home can be explained by some gender related factors and/or culture, our results from schools cannot be so easily understood. Because elementary 9-year school is compulsory and based on the same state approved syllabi, a greater proportion of tool usage should be equal for all students. We cannot blame the curriculum; for this gap in tool usage or procedures it must be individual teachers who make the difference. There also exists an option, which cannot be proved by our instruments, that when a tool is used in group work, the actual work is delegated to boys in the group. It was possible to draw the conclusion that engineering education at school does not support its use at home, and what is learned at home is not upgraded and used in school (Avery, 2013). Mastery of some procedures is not self-evident, and for every type of tool usage or procedure, it was possible to identify students who had never experienced it. It was recognized anecdotally that the use of a Bunsen burner in university courses was the first chance for some university students to light a match and ignite gas.

When searching for possible changes, it is unnecessary to try to raise the levels of perceived importance given to technology because these are already high. In our study, less than 10% of students partly disagree with the statement that "Engineering education is important for everyday life", but only about half of them regret the lack of a technical course in their final grade.

The problem of teaching "Technics and Technology" is probably similar to the problem recognized by Millar & Osborne (1998): that the perceived goal of science education lies more in the production of new scientists than in the creation of science-literate future non-scientists. Because the curricula of technical/engineering courses are designed by engineers, they most probably see students as future engineers and not as informed consumers of technology, and in that way they lose potential students. Osborne (2007) lists seven fallacies of Science teaching, which can easily be transferred to technical/engineering education. The three key fallacies are as follows: 1. the foundational fallacy; 2. the fallacy of coverage; 3. the fallacy of detached or value-free science.

When trying to predict the impact of school on planned future schooling, it can be recognized that the major factor is grades achieved in school; grades serve to direct higher achieving students into general secondary education (Appendix 2). Our numbers are in line with general trends in Slovenia in recent years. According to the official data (Government of Slovenia: Government Communication Office), 98% of primary school leavers decide to continue their education immediately after primary education, and about 40% of students continue their education in general schools. By electing this pathway, they delay their decisions about choosing their career path for four years. In these additional four years, attitudes are finally formed, without the influence of technology-oriented subjects but including the strong influence of peers and relatives (Robnett & Leaper, 2013). In line with these findings are the results of our regression analysis, which revealed that "Opinions on engineering education in school and tool usage at school" are poor predictors of their future schooling choices. More influential are gender and tool usage at home. These findings call for a radical transformation of school technical/engineering courses in such a way as to render these courses more interesting to students, as well as more practical and inspiring, with a myriad of different teaching methods and building on the experiences and positive attitudes from elementary school (Hus & Ivanuš Grmek, 2011).

CONCLUSION

Based on our study, a list of proposals can be constructed to improve recent curricula and syllabi of lower secondary schools, with the aim of improving technical education and inspiring students to choose STEM in their career development.

We can conclude from the study of students' opinions on technical/engineering education, that the majority evaluates it as important, but they would prefer more practical activities. These findings call for a radical transformation of school technical/engineering courses in such a way as to render these courses more interesting to students, as well as more practical and inspiring.

The research identified that there are some activities which are performed almost exclusively in school, and others performed mostly at home. On the other hand, there are some students who have never performed any individual activity, either in school or at home. A stronger connection between school work and home activities should be established, targeting complementarity, which would mean that upon formal completion of lower secondary school every student would have hands-on experience with a range of tools.

Because it is difficult to believe that schools will be able to change the frequency of technology use in homes where parents want to protect their children (Valentine & McKendrick, 1997; Pacilli, Giovannelli, Prezza, & Augimeri, 2013) and offer them a risk-free world, one future task could be to identify 'a survival kit' of technology usage that must be learned in school to be used at home as a lifelong skill.

We cannot be sure what technologies will be in use in the future, but we can be sure that technical/engineering education must be an engaging experience for students (Osborne et al., 2003) and one with the potential to raise interest in STEM among citizens. The reasons for raising interest in engineering education cannot be based only on utilitarian fears of the shrinking supply of engineers but in providing better and more effective technical/engineering education for all.

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Appendix 1

Rotated component matrix and factor loadings for different kinds of tool usage and procedures.
Legend:
(H) – activity made at home
(S) - activity made in the school

Rotated Component Matrix[a]

	Component								
	1	2	3	4	5	6	7	8	9
Percentage of variance	12.1	9.1	8.9	5.6	4.7	4.6	3.9	3.3	3.1
Cronbach's alpha	0.85	0.82	0.79	0.62	NA	0.48			
Using a wood lathe machine (H)	.71								
Using a vibration saw or band saw (H)	.71								
Replacing a bicycle/motorcycle tube (H)	.67								
Replacing a power switch or electrical outlet (H)	.66								
Sanding wood on a wood sanding machine (H)	.65								
Replacing a blown fuse (H)	.62								
Repairing an electronic toy (H)	.54								
Deep draw forming plastic (H)	.49								
Using a flat blade or cross screwdriver (H)		.73							
Hammering nails (H)		.72							
Using an Allen key (H)		.63							
Using a hand saw (H)		.60							
Machine drilling (H)		.59							
Replacing a battery in an electronic toy (H)		.56							
Replacing a burned out bulb (H)		.47							
Machine drilling (S)			.67						
Using a flat blade or cross screwdriver (S)			.66						
Sanding wood on a wood sanding machine (S)			.65						
Using a vibration saw or band saw (S)			.63						
Deep draw forming plastics (S)			.58						
Hammering nails (S)			.55						
Using an Allen key (S)			.51						
Replacing a blown fuse (S)				.74					
Replacing a burned-out bulb (S)				.69					
Replacing a power switch or electrical outlet (S)				.58					
Replacing a bicycle/motorcycle tube (S)				.50					
Robot programming (S)					.79				
Robot programming (H)					.59				
Cooking on a gas cooker (S)						.60			
Replacing a battery in an electronic toy (S)						.56			
Replacing a battery in an electronic toy (S)						.50			
Using a sewing machine (S)						.44			
Using a sewing machine (H)							.73		
Cooking on a gas cooker (H)							.64		
Technical drawing with computer software (S)								.87	
Technical drawing with computer software (H)								.51	
Using a hand saw (S)									.52

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 9 iterations.

Appendix 2

Regression coefficients of predictors on plans about schooling.

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	1.091	.336		3.250	.001
School grade	.467	.040	.443	11.623	.000
gender	-.146	.084	-.076	-1.735	.083
Tool usage at home	-.010	.006	-.087	-1.673	.095
Opinions on engineering education in school	.005	.007	.030	.658	.510
Tool usage at school	.002	.007	.014	.312	.755

a. Dependent Variable: plans about schooling