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SIGNS OF A CATASTROPHE: PREDICTED SHORTAGE OF TEACHERS OF LOWER SECONDARY SCIENCE AND TECHNICS AND TECHNOLOGY IN SLOVENIA

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Abstract/Izvleček The paper provides evidence as a baseline for action to prevent the educational catastrophe that would result from the predicted shortage of STEM teachers in lower secondary schools in Slovenia. Based on the data, obtained from the relevant institutions, we can predict that, without a change in educational policy towards encouraging students to choose the teaching of STEM subjects as a career, the number of STEM teachers will fall below all acceptable levels.

Katastrofa na vidiku: predvideno je veliko pomanjkanje učiteljev naravoslovnih in tehničnih predmetov v slovenskih osnovnih šolah Prispevek predstavlja dokaze kot izhodišče za ukrepe, ki preprečujejo katastrofo v izobraževanju z napovedanim pomanjkanjem učiteljev naravoslovnih predmetov in Tehnike in tehnologije (TIT) osnovnih šol v Sloveniji. Na podlagi podatkov, pridobljenih na ustreznih institucijah, lahko predvidimo, da bo, brez spremembe izobraževalne politike, število učiteljev naravoslovnih predmetov in TIT padlo pod vse sprejemljive ravni. Edina rešitev, ki ohranja kakovost naravoslovnega in tehniškega izobraževanja, je povečanje števila študentov na omenjenih pedagoških študijskih programih. Predlagana rešitev potrebuje resno vladno podporo v obliki kadrovskih štipendij.

Keywords:
STEM teacher shortage, lower secondary schools, the economics of education

Ključne besede:
pomanjkanje učiteljev STEM, predmetna stopnja osnovne šole, izobraževalna politika

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Introduction

There is probably no need to argue the importance for any society of having citizens well educated in Science, Technology, Engineering, and Mathematics (hereafter STEM) and proficient in Information and Communication Technology (ICT). Therefore, if societies need such profiles, they need to attract enough students to enrol in study and qualification programmes leading to the desired professions. Moreover, as has often been recognized, the main challenge does not lie in building brick and mortar buildings or buying equipment; the problem lies in the provision of qualified employees to work inside those buildings and work with the equipment installed. To paraphrase what has been written, if societies need STEM-educated citizens, then they should make all necessary effort to create enough well-educated teachers to provide this instruction at all educational levels. Small countries like Slovenia face three interconnected problems regarding STEM education (Ploj Virtič et al. 2017):

1. How to attract enough students to enter STEM studies, especially at higher educational levels;
2. How to attract enough students to enter programmes for pre-service STEM teachers;
3. How to prevent brain drain.

The present paper addresses only the problem of attracting a sufficient number of students who want to become STEM teachers.

The arguments about the importance of including science in curricula were elaborated by Millar (2002), and these arguments can be applied to all STEM disciplines, as well. We would like to emphasize the intrinsic and instrumental arguments as provided by Millar (p.115), so we have chosen to cite these verbatim:

»(1) Intrinsic justification
Scientific knowledge is a cultural product of great intellectual power and beauty. Humans have a curiosity about the natural world which scientific knowledge can help to satisfy. Many people have found the pursuit of science personally satisfying and rewarding.
(2) Instrumental justification
Scientific knowledge is necessary to:

- *make informed practical decisions about everyday matters;*

- *participate in decision-making on issues which have a scientifically technological component;*
- *work in jobs which involve science and technology (at various levels)«.*

Because of the complexity stemming from the nature of science and scientific reasoning, STEM education at the primary and secondary school levels cannot be left to self-educated dilettantes. Good teaching requires teachers able to combine knowledge and pedagogy in Pedagogical Content Knowledge (PCK) (Shulman, 1986) and to utilize their PCK and its associated Technological Pedagogical Content Knowledge (TPCK) (Koehler & Mishra, 2006). To summarize, one of the most important key ingredients in the educational system is a well-educated STEM teacher. This is especially important in a period of rapid change when new knowledge is not only added to the existing corpus but is replacing old paradigms, new technologies are replaced even before they have been fully explored, and the teacher must be prepared for and flexible in adapting to these changes.
The aim of the study is to provide evidence as a baseline for taking action to prevent the educational catastrophe resulting from the predicted shortage of STEM teachers in lower secondary schools in Slovenia.

Overview of the teacher shortage problem in Europe
The shortage of teachers, especially those for STEM and ICT, is a well-known global problem recognized by many. In the documents of prominent international organizations such as the OECD, one can recognize warnings, such as: "In 15 out of 19 OECD countries, most primary teachers are at least 40 years old, and in Germany, Italy and Sweden, more than one third of teachers are older than 50 years" (OECD 2003 pp. 403), and nobody can say that there has been insufficient information to act to solve this problem. According to the 2003 edition of the OECD's Education at a Glance, teacher shortages may become a policy challenge for many OECD countries in the years to come, as student enrolment levels rise, while older teachers retire and not enough younger people join the profession. However, it seems that there is a lack of will among decision-makers to make a change because the problem has only worsened.

The Eurydice study Key Data on Education in Europe 2012 (Eurydice, 2012) states that, given the serious shortage of qualified teachers for core subjects, an average of 15% of 15-year old students were taught in schools where teaching was hindered to some extent by a lack of qualified science and mathematics teachers. This finding is alarming, since the teacher is one of the key factors influencing the selection of engineering and mathematics for further study (Dick, & Rallis, 1991). Therefore, it is necessary to make sure that STEM is taught by good teachers who will impress young people in STEM classes with their approach and way of teaching because "findings indicate that, overall, youth who are activated towards science learning are more likely to have affinity towards STEM careers, certainty about their future career goals, and have identified a specific STEM career goal" (Dorph et al., 2018, p. 1034). Years later, the European Centre for Development of Vocational Training (Cedefop, 2016) published their findings on the most in-demand occupations in Europe. They wrote (p. 1), "Across the European Union (EU), MPOs (Mismatch priority occupations are those for which a critical shortage, or surplus, has important implications for the national economy and for education and training) for which there are skill shortages are a mix of regulated and non-regulated professional and associate professional occupations at higher skill levels. The top five skills are ICT professionals; medical doctors; science, technology, engineering and mathematics (STEM) professionals; nurses and midwives; and teachers". To be honest, the shortage of STEM teachers did not affect all countries equally, and some countries did not share the problem (OECD 2003). On the other hand, in some countries, Slovenia included, there can be a surplus of teachers in one subject and a simultaneous shortage of teachers in another subject, a problem that must be resolved by each country separately. The reasons for the shortage are different in each country included in the study, but the most common reasons are the negative public image and low salaries, compared to similarly educated professionals, and at higher levels of education, that the study programs are lengthy and highly selective (Ploj Virtič et al. 2017).

In their Joint Report, the European Commision (2015) pointed out several challenges that national policy will have to address. One of these was a serious shortage of teachers, owing to the ageing population, geographical factors, or social background.

However, the response of the authorities in those countries that have a shortage of STEM teachers was not to pump resources into encouraging youth to think about entering teaching careers, but to use existing reserves to upskill existing employees. In extreme cases, teachers of literally any subject could teach subjects in which they were unqualified (Act of Amendments of Organisation and Financing of Education Act, 2003). Identifying the problem is not the same as solving it. One of the main findings from the Eurydice (2018) report, Teaching Careers in Europe: Access, Progression and Support, is that the most common challenges concerning teacher demand and supply in Europe involve teacher shortages and ageing teacher populations. They also report that the planning of teacher supply and demand is usually carried out annually. Most education systems in EU countries (26 countries) have some form of planning, but only seven have long-term planning (Eurydice, 2018). The Eurydice report is consistent with the OECD report, Education at a Glance 2017 (OECD, 2017), in which similar claims are made. In most EU countries, the teaching profession is less and less appealing for young people, owing to its low salaries compared to similarly educated professionals, highly selective and lengthy study programs and the phenomenon of children and learning environments that have become more demanding. To summarize, the problems are well known, and solutions have been proposed; however, action to solve these problems is still missing.

Education in Slovenia

For a better understanding of the problem, the Slovenian pre-tertiary school system, its duration, and the required education for teaching each level, are presented in Table 1. Nine-year elementary school is compulsory for all citizens of Slovenia.

Table 1: Slovenian pre-tertiary school system, including duration and education required for teaching each level.

Level of school	**Duration**	**Type of school**	**Education required for teaching**
Secondary school: starting at age 15	3 or 4 years	Upper secondary school (general or vocational)	Subject teachers
Elementary school: starting at age 6	4 years	Lower secondary school	Subject teachers, usually teaching two subjects (math, physics, chemistry, history, technics & technology, and sport)
	5 years	Primary school	Primary teachers (one teacher covers all subjects)

Requirements for teaching in Slovenian primary and secondary schools

Recently, the entrance criteria for enrolling in teaching in Slovenian public school have been set at a Master's level programme, including at least 60 ECTS (European Credit Transfer and Accumulation System) points in pedagogical subjects and teaching practice in school.

The next option is to finish a Master's level programme in basic science or engineering with an additional one-year course with 60 ECTS in pedagogical subjects. This option is most often used by teachers of subjects in the mathematics, ICT, science and technical-engineering disciplines at upper secondary schools who, because of a shortage of qualified teachers, were employed at schools and given the chance to acquire teacher qualification. For some teachers, mostly at vocational schools, this is the only option because such an educational programme is not offered (e.g. for teaching veterinary subjects at secondary school).

Professional teacher education is offered by the following institutions:

a) Faculties of Education – these offer a one-stream programme for elementary teachers and two-stream programmes for subject teachers, with later primary occupation in primary schools.
b) Professional one- or two-stream pedagogical programmes offered by faculties where the primary programmes are scientific (e.g. Biology, Physics, Chemistry, Mathematics), pedagogical programmes offered at the Faculties of Arts.

A case study of the Slovenia STEM teacher shortage

Slovenia is one of the few EU countries that lacks any form of planning for the teaching profession at any level of education (Eurydice, 2018). This finding should be surprising, given the numerous governmental institutions dealing with the education of a relatively small student population and the low number of institutions that educate future STEM teachers. Moreover, in Slovenia, there are only about 450 nine-year public compulsory elementary schools and fewer than 200 upper secondary schools, in addition to a small number of private schools.

On the other hand, Slovenia's demand for the required minimum level of teacher education is among the highest in Europe (Eurydice, 2012).

Even more, a report on Slovenian national policy indicates an oversupply of teachers: "In Slovenia, the demand for teachers has fallen in recent years due to a population decrease, the economic crisis and austerity measures. A measure to tackle the oversupply of teachers is the project First Employment in Education which aims to support the employment of young first-time job-seeking teachers or counselling specialists. Estimated funds in 2017 amount to approximately 1.5 million EUR" (Eurydice, 2018, pp. 30). This statement may be true for primary school teachers and teachers of some streams, but cannot be generalized to STEM teachers, especially teachers of Physics and Technics and Technology (hereafter TaT). But even if there was some surplus at the time of the report, signs of warning come from the OECD (2017), in which the Slovenian data is as follows:

- At the primary level, 6% of teachers are younger than 30; 63% are between 30 and 49, and 32% of teachers are older than 50. The average ratio for the OECD is 12–52–40.
- At the lower secondary level, 4% of teachers are younger than 30; 59% are between 30 and 49, while 37% are 50 or older. The average ratio for the OECD is 10–54–36.
- At the upper secondary level, 3% of teachers are younger than 30; 59% are between 30 and 49, and 38% are 50 or older. The average ratio for the OECD is 7–52–40.

Nor do the Eurydice data reflect data from the two faculties that educate future primary school STEM teachers in Slovenia: the Faculty of Education, University of Ljubljana and the Faculty of Natural Sciences and Mathematics, University of Maribor (Ploj Virtič et. al., 2017). These two faculties are responsible for educating more than 95% of all new teachers, and both have problems with enrolment of students in their prospective STEM teacher programmes.

General Background of Research

Slovenia's challenges in education are identical to those of most EU countries. The shortage, on the one hand, and the oversupply of teachers, on the other, may have different causes. At any rate, detailed planning of teacher education at the Slovenian national policy level could improve the situation.

The educational system in Slovenia has undergone some major structural changes over the last 20 years. These consist of structural changes in primary education in 2003, which extended it from eight to nine years, and the transformation of university study programs according to the Bologna reform in 2007 (Žužek Leskovšek, 2018). These changes raised the demand for new teachers at the primary level of education and caused the development of new study programs at university levels, all of which had an impact on the financial aspects of education. For this reason, the Slovenian government changed the Organization and Financing of Education Act (Organization and Financing of Education Act, 1996) in 2003, allowing teachers to teach subjects for which they do not have formal education up to 40% of their working time. This act was meant to be temporary and to help overcome the teacher shortage due to the structural changes. The act remained active until 2015, when the percentage was gradually lowered to 20% in 2017 and to 0% currently. The lowering of that percentage happened because of constant warnings by the professional public, organizations, and university educators. They raised the concern that this act was in violation of ILO/UNESCO guidelines (ILO/UNESCO, 1996) and the Act of Rules on the level of education of teachers and other professionals in the educational programs of primary schools (Rules on the level of education of teachers and other professionals in educational programmes of primary schools, 2011), as well.

During this time, the economic crisis began in Slovenia, which resulted in additional government fiscal restraint. Another huge impact on the educational system resulted from the Fiscal balancing act (Fiscal Balance Act, 2012). Teachers are public employees, and the Fiscal balancing act halted the employment of new teachers between 2012 and 2016. It also lowered teachers' salaries by approximately 8% until 2018 and had a devastating impact on the public image of teachers (Fiscal Balance Act, 2012). The lack of employment of new teachers meant that teachers were teaching more and more subjects in which they did not have formal education. We believe all these factors contributed to a significant drop in the enrolment of students at faculties that produce lower secondary STEM teachers.

The conflict between the misleading information about teacher oversupply and teacher shortage was investigated, and a solution was sought in detailed planning for at least STEM teachers, because this shortage affected the school system the most.

Research methods and procedures

The aim of the research was to gather data from public sources to build predictive models of the potential shortage of teachers in various subjects of STEM education in lower secondary schools, especially for TaT teachers. Data were obtained from the Statistical office of the Republic of Slovenia (SURS, 2019), the Ministry of Education, Science and Sport (Ministry of Education, Science and Sport, 2020), the Employment Service of Slovenia (Employment Service of Slovenia, 2020) and from two faculties: University of Ljubljana, Faculty of Education and the University of Maribor, Faculty of Natural Science and Mathematics.

Based on desk-top research, we assembled the research questions as follows:

- To what extent, if at all, does fluctuation in the numbers of 1st-grade pupils over time suggest that there will be a teacher shortage?
- To what extent, if at all, does the fluctuation in future teacher retirement in STEM and Technics and Technology (TaT) suggest that there will be a teacher shortage?
- To what extent, if at all, does the fluctuation in the number of new students in STEM pedagogical study programs over time suggest that there will be a teacher shortage?
- To what extent, if at all, does the fluctuation in the number of newly graduated STEM teachers over time suggest that there will be a teacher shortage?

Findings

Data acquired from the Statistical Office shows increased enrollment among first-grade pupils over time (Figure 1). The increase in the first-grade pupil population between 2011 and 2018 is almost 10%.

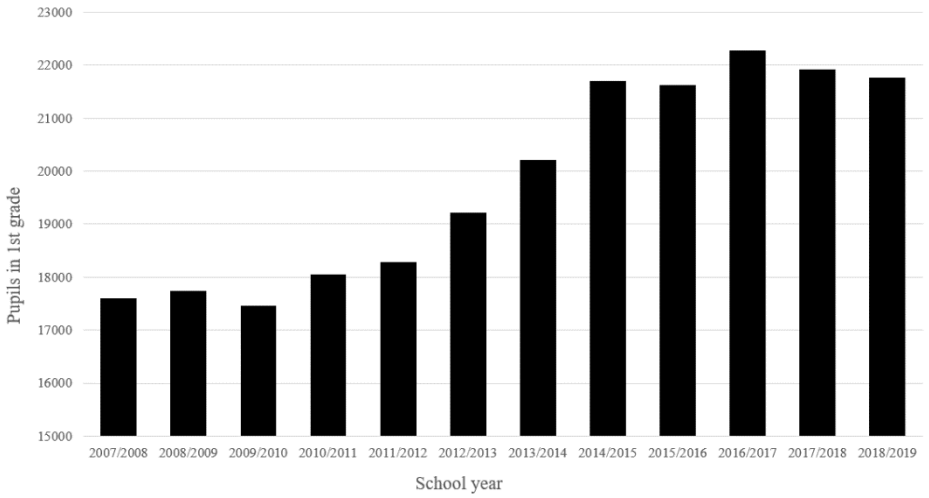

Figure 1: The fluctuation in the number of 1st-grade pupils over time (SURS, 2019)

From Figure 1, based on data from the Statistical Office of the Republic of Slovenia (SURS, 2019), it is possible to establish trends in the number of pupils enrolled in elementary school. The number of children in elementary education has been increasing since 2009/10, when the population of pupils was the lowest in independent Slovenia. The growth trend in the number of pupils enrolled in the first grade (see Figure 1) affects secondary schools and tertiary education after a time lag. Numerically, the smallest generation of first-graders in elementary school from 2009/10, appears as the smallest generation of first-graders in secondary schools in 2018/19, and the same generation of children will enter tertiary education in 2022/23. The numerically strong generations of children starting elementary school in 2014/15 (see Figure 1) will enter tertiary education in 2027/28.

The information on future teacher retirement in STEM fields (particularly TaT) can be used to explain concerns about the shortage. The data on teacher retirement received from the Ministry of Education, Science and Sport is shown in Figure 2. The data follow the retirement rules in Slovenia, which define the allowed retirement age as 60, with at least 40 years of service, and 65 for those with less than 40 years of service. The data shown in Figure 2 exclude teachers who teach STEM subjects in schools but lack formal education. To replace the retiring teacher population, at least the same number of students should be in master's studies before their retirement, an act of coordination that should be planned by the authorities.

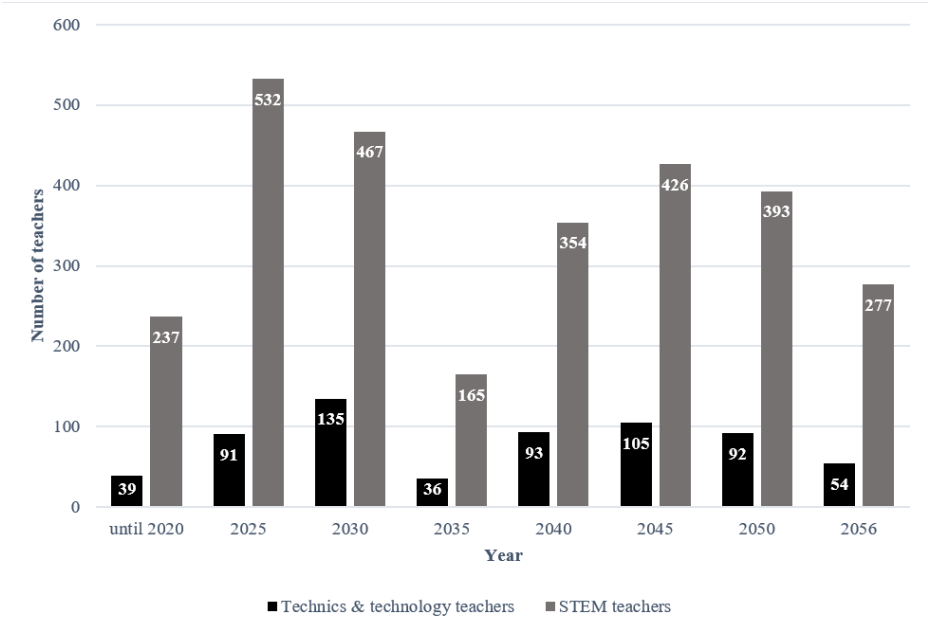

Figure 2: Projected teacher retirement over time

The number of all STEM teachers in lower secondary schools in Slovenia is 2206, and 645 of those have formal education in TaT and teach this subject. We can recognize two waves of retirement among STEM teachers from Figure 2. The first one has just begun and will peak in 2025; the second one will peak in 2045. The data is similar for TaT teachers, apart from the first peak, which will happen in 2030. Taking the retirements of 2020, 2025 and 2030 together, it is evident that there will be a total of 1236 STEM teachers retiring by 2030, of which 265 are teachers of TaT. These retirement numbers may not look high, but for a small country like Slovenia, this number represents 56% of all STEM teachers and 41% of TaT teachers in lower secondary schools in Slovenia.

As educators of pre-service STEM teachers, we have been observing a trend in the enrolment in programmes for prospective STEM teachers, which has fallen by 80% over the past 5 to 10 years. Data charting fluctuation in new student numbers in STEM pedagogical study programs over time shows a major drop in new students (Figure 3).

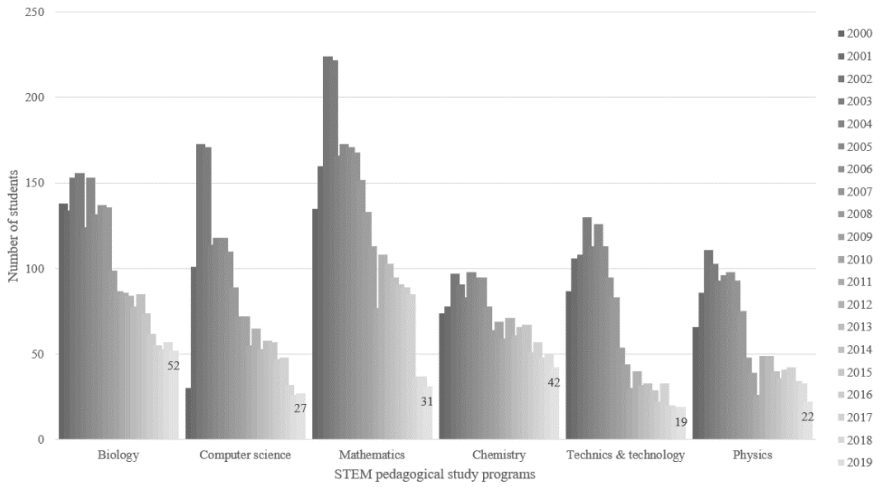

Figure 3: The fluctuation in the number of new students in STEM pedagogical study programs at both Universities over time

Figure 3 shows the fluctuation in the number of new students in STEM pedagogical study programs at both Universities that educate future elementary (mostly two-stream) school STEM teachers in Slovenia: the University of Ljubljana, and the University of Maribor. Data was extracted from their annual reports (unpublished data).

Data gathered from the University of Maribor, Faculty of Natural Sciences and Mathematics, show a drop of approximately 85% in the number of students in STEM pedagogical study programs. From an average of 220 new students around the year 2000, it has decreased to less than 30 students per year in 2019. Enrolment in the TaT pedagogical study program decreased from an average of 45 students around the year 2000 to only 3-5 students per year in 2019.

Data gathered from the University of Ljubljana's Faculty of Education show a less serious decrease. These data show a drop of approximately 40% in students in STEM pedagogical study programs. From an average of 250 new students in around 2000, the figure decreased to fewer than 150 students per year. Enrolment in the TaT pedagogical study program decreased from an average of 70 students around the year 2000, to 30 students per year in 2019.

Consequently, the fluctuation in newly graduated STEM teachers from both universities also shows a decreasing number of newly graduated STEM teachers, as shown in Figure 4.

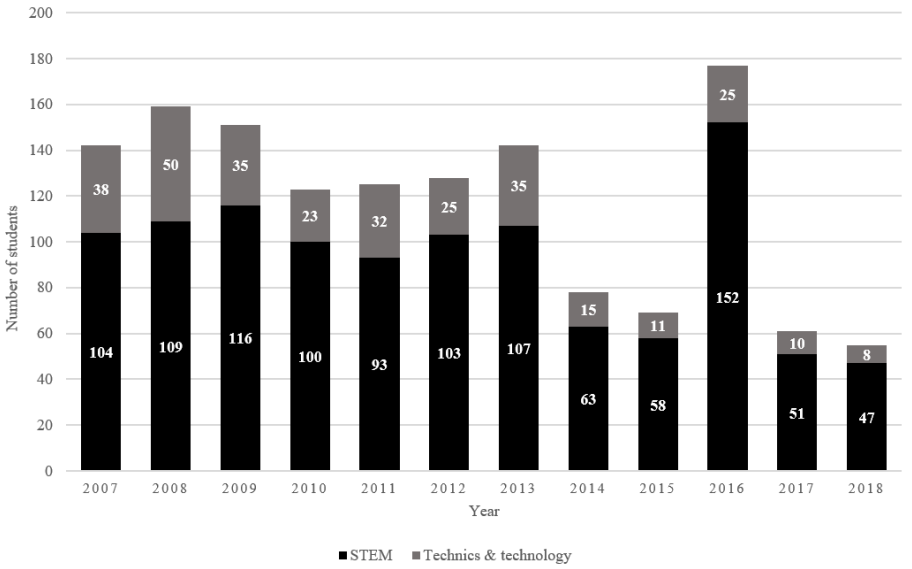

Figure 4: Newly graduated STEM (Technics & Technology, separately) teachers over the years

Because there are no restrictions or entrance exams for students enrolling in the first-year classes, and many of them recognize a teaching career as a secondary or even tertiary study choice (Tomažič, & Vidic, 2009), there is considerable drop-out during successive study semesters, which results in an even lower number of STEM teachers graduating from the program.

There was an increase in new STEM teacher graduates in 2016 because of the closure of the old pre-Bologna STEM study programs; many took this last chance to finish the programme. However, the additional number of 4-year Bachelor's degrees qualifying them to teach did not significantly improve teacher structure in the schools, because many of these graduates were already working in schools, while others had jobs outside the educational sector, and just wanted to finish their education and get a degree.

The greatest shortage is identified among teachers of TaT and Physics. Overall, 1236 STEM teachers (more than 50%) will retire between 2020 and 2030. The difference between the yearly supply of qualified teachers from universities and the retirement projection is presented in Figure 5.

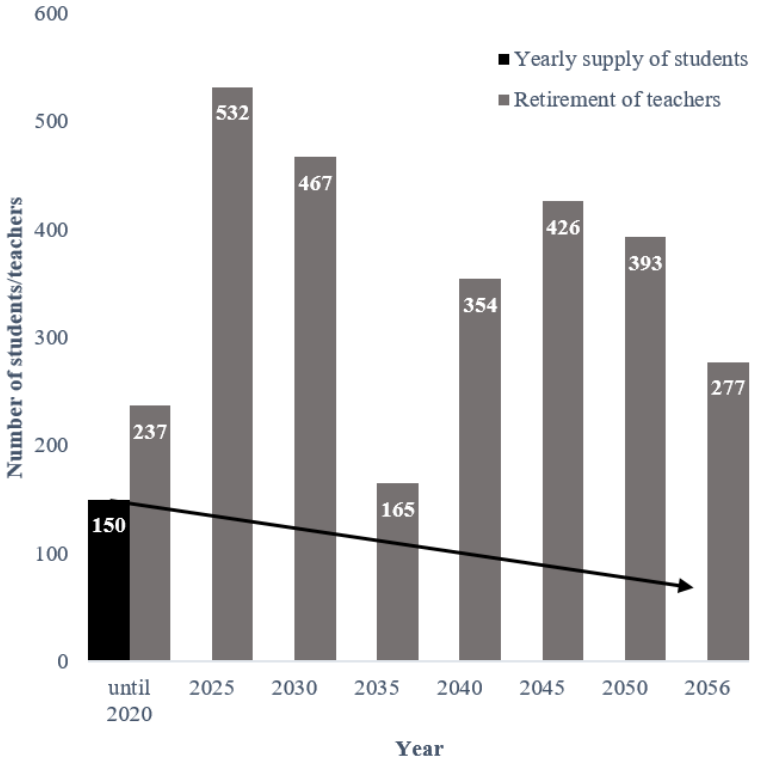

Figure 5: The difference between the annual supply of qualified STEM teachers from universities and the retirement projection

The trend line in Figure 5 shows the expected trend in annual supply, according to the current state of student enrolment if nothing is done to stop the trend. At first glance, the numbers are not high, but they are critical to the Slovenian situation. Moreover, because the official and obligatory language of teaching is Slovene, opportunities to import teachers are limited, and this means that the problem can only be solved by increasing the supply of STEM teachers from Slovenian universities to the employment market. It is only speculation that some teachers from the years of surplus and those recently employed in other economic sectors could be reactivated. Honestly said, we doubt that anyone would find the motivation to enter the educational sector after a career elsewhere.

Since the teacher is one of the key factors influencing the choice of further study (Šorgo et al., 2018) and the shortage of STEM teachers is evident, we can raise the following question: Will the shortage of STEM teachers in the long-term exert an impact on the technological development of Slovenia?

New rules of the game

At the beginning of 2020, there was an outbreak of COVID-19. At this moment we cannot predict the future; however, there exists a possibility that the number of students in each class will be limited if a new outbreak should occur. If this happens, the shortage of teachers in all subjects can only worsen and the problem become more extensive. We cannot make calculations based on the numbers we possess, but knowing the situation in the schools, the shortage could be severe

Discussion and Conclusions

From the data presented by the Ministry of Education, Science and Sport, it is evident that there will be a total of 1236 STEM teachers retiring by 2030, of which 265 are teachers of Technics and Technology (TaT). This number represents 56% of all STEM teachers and 41% of TaT teachers in lower secondary schools in Slovenia. There has been no unemployed STEM teacher registered at the Employment Service for several years. At the same time, the enrolment in programmes for prospective STEM teachers has fallen by 80% over the past 15 to 20 years. The data clearly predict a shortage of teachers, a situation worsened by the increasing number of school-age pupils, which is evident from the growth trend in the number of pupils enrolled in the first grade.

Based on the numbers presented in the Figures, we can predict that, without a change in educational policy towards encouraging students to choose the teaching of STEM subjects as a career, the number of STEM teachers will fall below all acceptable levels.

Recently, the greatest shortfall has been in the STEM field, especially in technical subjects and Physics, where schools already cannot employ teachers from these fields. With the decrease in students at both faculties that educate future STEM teachers, planning data for STEM subjects indicates that the need for STEM teachers is already greater than this year's supply.

The only solution that would maintain the quality of STEM education is an increase in the number of STEM students enrolled in pedagogical studies. The proposed solution needs serious government support and the incorporation of teacher education planning at the level of Slovenian national policy. Based on research (Feng & Sass, 2015) confirming that financial effects provide positive motivation for the decision to choose an area of study, it would also make sense to discuss scholarships for those studying towards occupations with a supply deficit, as was the case in good practice during the 1980s and 1990s.

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Declaration of Interest statement

The authors declare that they have no conflict of interest. The article is an original work of all the authors, and has not been submitted elsewhere, nor is it under consideration for publication in any other journal.

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