National assessment of knowledge of engineering and technology topics at the end of middle school - the Slovenian experience

S. Kocijancic

University of Ljubljana
Ljubljana, Slovenia

Opening Address

ABSTRACT: Most educational systems include national assessment of students' knowledge at the pre-higher level of education. Although design and technology is a middle school subject in many countries, national examination of knowledge is rarely practised. In Slovenia, engineering, technology and design topics are taught within different subjects up to the 5th grade. However, from the 6th to 8th grade there is a sole compulsory subject named *Engineering and Technology*. In 2006, the Ministry of Education introduced national assessment for so called *third subject* after the 9th grade. The Engineering and Technology subject was tested in 2008 and 2010 as compulsory for about 25% of all the population aged 15 years. This paper presents the outcomes of the last examination, which was also used in parallel for trainee teachers of technology. Among the findings is that both students and trainee teachers achieved unsatisfactory scores for practical, problem-based questions requiring a high cognitive level. Among a range of content areas, mechanical engineering was the weakest.

INTRODUCTION

National assessment of students' knowledge at the pre-higher level of education is conducted in the majority of countries. Information about national objectives and organisation of assessments of knowledge gathered by INCA - International Review of Curriculum and Assessment Frameworks Internet Archive [1] shows, that there are considerable differences between 19 educational systems in 16 countries on all continents reviewed by INCA. EURYDICE reports many differences in national testing of students within EU countries [2].

More information about the assessment of knowledge in particular countries is available from national organisations such as the NAEP in the USA [3], the National Curriculum Assessment in the UK [4], and the National Assessment Programme (NAP) in Australia [5], etc. Advantages and benefits of national examination of particular subjects are discussed, for example for, mathematics [6] and physics [7].

Despite the unquestionable importance of technological literacy, national assessments of the knowledge of technology and engineering topics are not often included in national (external) testing [8][9]. Analysis of the technology education curriculum of six countries showed that technology topics are generally not tested at the national level, so national examinations in technology would be appreciated [10].

In the USA, the NAEP is the largest nationally representative body and it provides continuous assessment of what students know and can do in various subject areas. However, the first-ever NAEP Technology and Engineering Literacy Assessment (TELA) is currently under development.

The assessment is intended to measure what students know about technology and engineering. The initial assessment, planned for 2014, will be a probe - a smaller scale, focused assessment on a timely topic that explores a particular question or issue. The initial assessment is likely to be limited to particular grades [11][12].

NATIONAL ASSESSMENT OF KNOWLEDGE (NAK) IN SLOVENIA

Slovenian middle school (also known as *junior high school* or *lower secondary*) is coupled with primary school in a unique compulsory elementary school with nine (9) grades for children aged 6 to 15 years. Engineering, technology and design topics are taught by classroom teachers within science and art subjects up to the 5th grade.

However, from the 6th to 8th grade there is a sole compulsory subject named *Engineering and Technology*, similar to a subject named *Design and Technology* in some countries.

In 1991, the Slovenian Ministry of Education introduced national assessment of knowledge co-ordinated by the National Examinations Centre (NEC) [13]. Currently, at the end of the 6th grade, students apply to sit for tests of their own accord in their mother tongue, mathematics and a foreign language (English or German). Results of the assessment give additional information to schools, students and their parents on the students' achieved knowledge and have no influence on the final grade in individual subjects or the students' general achievement. At the end of the 9th grade, the national assessment of knowledge is compulsory for all students.

The knowledge of mathematics and the Slovenian language is tested each year. In addition, each year the Ministry selects four so called *third subjects* out of about 12 possible subjects. Each pupil is, therefore, tested in mathematics and the Slovenian language plus one subject out of four selected by the Minister for a particular school year. The results of the tests have no influence on the overall achievement in primary education; however, it can be considered as a criterion for the selection of candidates in cases of limited enrolment into secondary schools but only with previous agreement of students and their parents.

The basic goal of the NAK is to acquire additional information or feedback on students' knowledge and to strive for better quality in the learning and teaching processes.

NATIONAL ASSESSMENT OF KNOWLEDGE OF ENGINEERING AND TECHNOLOGY

The Engineering and Technology subject was chosen as a so called *third subject* in 2008 and 2010. The outcomes of the national examination in 2010 are presented in this paper. There were 20 written problems from the syllabus of Engineering and Technology taught in the 7th and 8th grades. Each problem was worth one (1) to three (3) points, totalling 33 points for a compete test.

The structure and contents of the problems followed various pre-defined criteria. Ten multiple-choice problems were worth 10 points and 23 points were devoted to various structured problems. About 30% of the points were for straightforward cognitive level questions (knowing facts, definition, etc), 55% for middle level questions (understanding and usage) and 15% for advanced cognitive level questions (problem solving in new situations).

The examination covered several topics divided into four major content areas as follows: man and creation, technological resources, materials and processes and technical documentation.

The test was prepared by a team of four members - two teachers of technology, a representative of the National Institute of Education (who also used to be a teacher) and a representative from higher education (the author of this paper). The test in the Slovenian language is available from the NEC Web site [14].

General Statistical Data

The national assessment of knowledge of Engineering and Technology involved 4,762 students from 121 schools, approximately a quarter of the total population of the 9th grade. The average score was 17.56 (53.2%). The standard deviation was rather large at 17.73%, meaning that there were significant differences in students’ achievements. The distribution of results is shown in Figure 1.

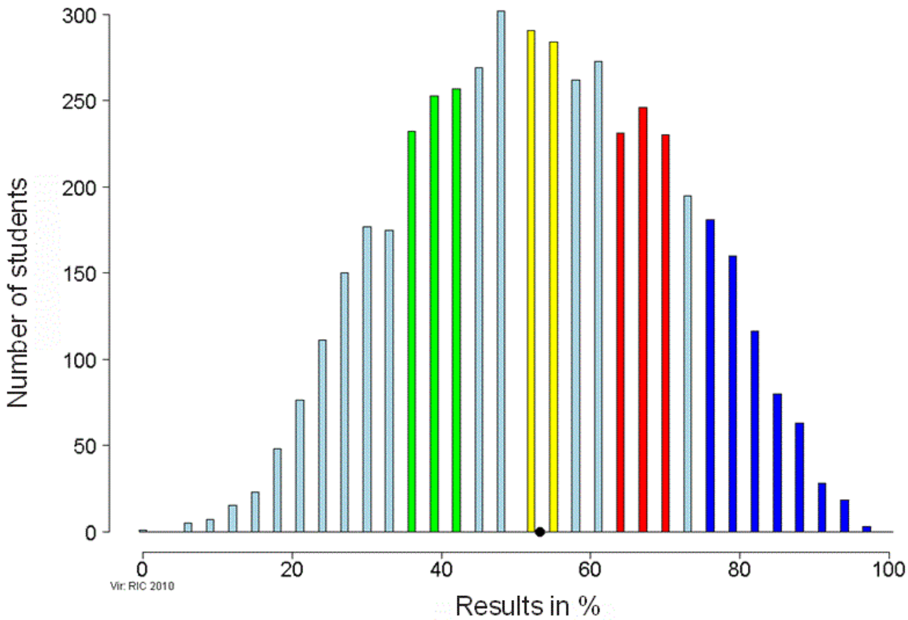


Figure 1: Histogram presenting the distribution of students regarding their score on test in percentage (source: NEC).

When comparing the results regarding gender, it was observed that more boys achieved more than 70% of the points allotted, while the average result does not significantly differ between boys and girls (Figure 2).

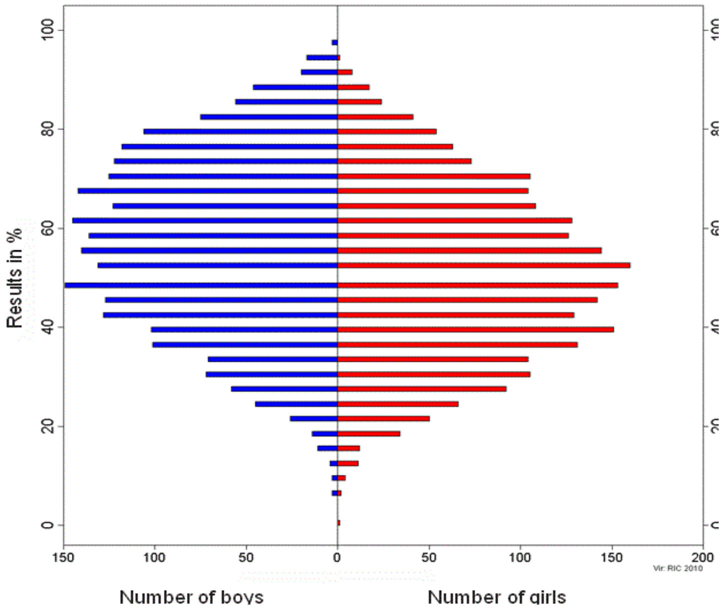


Figure 2: Histogram presenting the distribution of boys and girls regarding their score in percentage (source: NEC).

Achievements for Different Content Areas

In order to explore outcomes of the national examination more specifically, the test has been divided into six content areas, so that the 33 points were assigned to areas as shown in Table 1.

Table 1: Distribution of points between the content areas.

Content areas	Abbreviations	Points
Man and creation: technology and environment, economics, energetic.	M-CRE	4
Information and communication technology: informatics, computers and technology, CAD/CAM.	ICT	2
Design and technical documentation: sketching, orthogonal and isometric projection, graphic expression and graphic design.	DES-DOC	6
Materials and processing: properties and processing of synthetic solids (plastics) and metals, tools and machines for material processing.	MAT-PRO	11
Technological resources - mechanical engineering: mechanisms, mechanical drives, internal combustion engines.	TR-ME	5
Technological resources - electrical engineering: electrical circuits, electric devices, electric control.	TR-EE	5

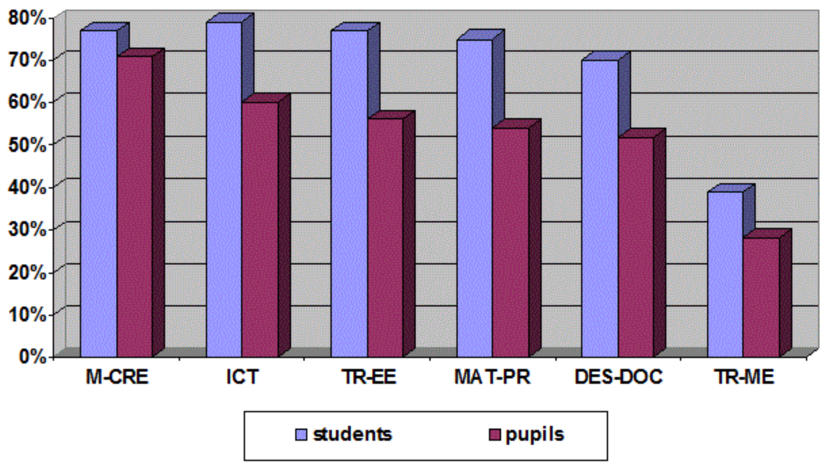


Figure 3: Results of students (trainee teachers of technology) compared to results of school students for different areas of problems (see abbreviations in Table 1).

Before the national examination was available to the public, it was also used to test technology education students - the trainee teachers of technology at the Faculty of Education, University of Ljubljana. In other words, 40 prospective teachers of technology in the 3rd and 4th year solved the same tests as the 9th grade students. Results of both groups are presented in Figure 3.

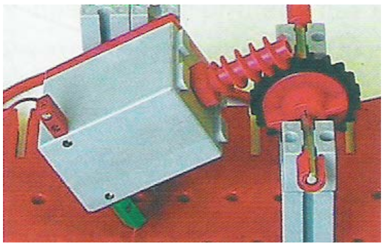
The university students performed better than the school students, but not as much as one might have expected. The next outcome was that results of both group of students were proportional - the lower the knowledge of technology education, the lower the result of the students. Unfortunately, one could not test the teachers - but one could imagine that the results would also reflect the obvious influence of teachers' knowledge on students' outcomes. Concern should be raised about the significantly lower scores for both groups in mechanical engineering.

Examples of Problems with Low Scores

To illustrate problems with unexpectedly low scores, three such examples are presented here. The problems have been translated from the national examination in 2010.

Example 1

The figure below shows a model of a worm gear.



When the screw is rotated for one turn, the cylindrical wheel is rotated by one tooth. Determine the gear ratio for the case where the cylindrical gear has 20 teeth.

Write the answer to the line: ___________________

Answer: 20:1 or 20.
Average score: 18%

Example 2

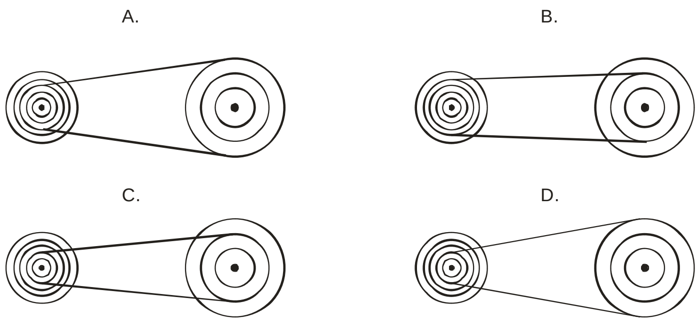
Using a DC electric motor make a model of a lift. To enable the task to be completed, the shaft of the motor must be mounted to:

A. Gear system so that we increase the number of revolutions - the multiplier.
B. Gear system so that we reduce the number of revolutions - reducer.
C. Crank mechanism.
D. Lever.

Answer: B
Average score: 24%

Example 3

Jakob is riding a bike with five gears on the rear wheel shaft and three gears at the pedals. Which combination of gears is the best for riding up hills?



Answer B.
Average score: 31%

CONCLUSIONS

School students generally achieved relatively good results for problems ranked as being low cognitive level, where questions mostly require memorising of facts and definitions. On the other hand, low scores were obtained in problem-based questions even if they required solutions to practical, sometimes even everyday situations. Evaluating the results of trainee teachers (university students) being examined with the same test as school students clearly showed a high correlation in outcomes for different content areas. Among the areas, the mechanical engineering content was the weakest for both groups.

The national assessment of knowledge of engineering and technology provided valuable information for both teachers and for teacher trainers in order to improve the efficiency of teaching and learning process for engineering and technology topics in the middle school. Presumably, there might also be some benefits for engineering at the higher education level, as well as for general technology and engineering literacy.

ACKNOWLEDGMENT

Most of the data used in the paper were collected and analysed by the National Examination Centre (RIC - Državni izpitni center). The examination test was prepared by Gorazd Fišer, Drago Slukan, Tatjana Vičič and Slavko Kocijancic.

REFERENCES

1. International Review of Curriculum and Assessment Frameworks Internet Archive, October 2011, http://www.inca.org.uk/index.html
2. EURYDICE, National Testing of Pupils in Europe: Objectives, Organisation and Use of Results, The Education, Audiovisual and Culture Executive Agency (2009), October 2011, http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/109EN.pdf
3. National Assessment of Educational Progress (NAEP), October 2011, http://nces.ed.gov/nationsreportcard/
4. National Curriculum Assessment, October 2011, http://en.wikipedia.org/wiki/National_Curriculum_assessment and http://curriculum.qcda.gov.uk/key-stages-3-and-4/index.aspx
5. National Assessment Program (NAP), October 2011, http://www.det.act.gov.au/teaching_and_learning/assessment_and_reporting/national_assessment_program_nap
6. Hill, H.C., Rowan, B. and Loewenberg, D., Effects of teachers' mathematical knowledge for teaching on student achievement. *American Educ. Research J.,* 42, **2**, 371-406 (2005).
7. Bajc, J., National assessment of knowledge of physics after finishing primary school: important information for physics teachers. *Proc. Frontiers of Physics Education: Selected Contributions*. Rijeka (2008), October 2011, 474-480, http://www.ffri.uniri.hr/GE2/Library/159_Bajc.doc,
8. Bybee, R.W., Engineering student outcomes for infusion into technological literacy programs: Grades 9-12. *J. of Technol. Educ.*, 21, **2** (2010).
9. Wicklein, R.C., Five good reasons for engineering as the focus for technology education. *The Technol. Teacher*, 65, **7**, 25-29 (2006).
10. Rasinen, A., An analysis of the technology education curriculum of six countries, *J. of Technol. Educ.*, 15, **1**, 31-46 (2003).
11. NAEP Technology and Engineering Literacy Assessment, October 2011, http://nces.ed.gov/nationsreportcard/techliteracy/
12. Technology and Engineering Literacy Framework for the 2014 National Assessment of Educational Progress, WestEnd Pre-Publication Edition (2011), October 2011, http://www.edgateway.net/cs/naepsci/download/lib/249/prepub_naep_tel_framework.pdf?x-r=pcfile_d
13. National Examinations Centre of Slovenia, National Assessment in 9-year Primary Education, October 2011, http://www.ric.si/national_assessment_of_knowledge/general_information
14. National Examinations Centre of Slovenia, Examination of Knowledge - Engineering and Technology (2010), October 2011, http://www.ric.si/mma_bin.php/$fileI/2010061508043267/$fileN/N101-641-3-1.pdf (in Slovenian).