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ACQUISITION OF STATISTICAL CONCEPTS BY SOLVING REALISTIC PROBLEMS

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Abstract

In contemporary society the abundance of information includes plenty of statistical data, so it is vital for everyone to understand basic statistical concepts and in consequence to be able to know what actually is the content of the information, i.e. to be statistically literate. As statistics is usually taught in mathematics classes, mathematical thinking often prevails and the use of techniques is often more important than dealing with the basic statistical problem, which does not contribute to understanding statistics. With a study among 269 students of the first year of secondary schools we wished to examine whether the acquisition or mastering of basic statistical concepts could be improved with problem teaching, i.e. with resolving the statistical problem situations and thus by getting to know new concepts directly in solving the problem. Students with equal socio-economic status and with no significant differences regarding their previous performance in mathematics were divided into experimental and control group. The findings of the study show that in the case of such approach to learning and teaching statistics students adopt the true meaning of new terms and concepts, they can reasonably justify their procedures in solving everyday statistical problems and verify the meaningfulness of the solution.

Keywords: Statistical information, statistical literacy, statistical notions, teaching of statistics, mathematics, problem situation..

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1. Introduction

Several international organisations, and especially the UNECE, The United Nations Economic Commission for Europe, in conjunction with national institutions emphasise the importance of using statistics in everyday life, and particularly mention the significance of building genuine understanding of statistics in the sense of developing statistical literacy, as only by acquiring a high enough level of statistical literacy an individual becomes an active and critical member of modern information society. To prevent arriving into a situation in which many are not capable of relating the language with statistical concepts and accurate reading with interpretations of graphical displays that describe socio-economic developments, the relevant syllabi should of course be improved to allow attaining the objectives of statistical literacy (Barbieri & Giacché, 2006).

2. Problem Statement

Statistics requires fundamental understanding of statistical concepts, while statistical literacy entails the ability of expressing this understanding with words, not just with mathematical formulae (Watson & Kelly, 2003). Schield (1999) concludes statistical literacy is the competency to read and to interpret data and to use them as support in argumentation or as the ability to think critically about statistical data. In making decisions statistically literate persons focus on the use of statistical data just as in justifying persons possessing reading literacy focus on the use of words. On the other hand statistical literacy is understood as the use of the basic language of statistics (Garfiled & delMas, 2010), although many also consider higher levels of knowledge, such as the ability of interpreting and critically evaluating results, as belonging to statistical literacy (Sanchez, 2010; Gal, 2002, 2011).

Mathematical capabilities are necessary to be able to understand statistics, while for statistical literacy a feeling for numbers and especially the skill of managing them are necessary, a feeling for estimation, awareness of the diversity of interpretations, as well as the knowledge of statistical concepts. Statistical literacy also means the ability of reading and communicating not only of data but also of the meaning thereof. If someone is statistically literate they must always be asking themselves what they can do with new information, which means they must be able to set it into some context (UNECE, 2012). Biehler (2008) emphasises precisely the importance of statistical literacy that includes understanding graphical displays and the interpretation of the outcomes of research, with which the individual can estimate by himself whether it is about credible assertions or perhaps lies.

Statistics is usually taught within mathematics, although experts in the field are not unanimous in thinking that covering statistics in mathematics instruction is the best option. Some of them underline the great differences between statistics and mathematics, in particular between statistical and mathematical thinking. However, others do not – provided we stressed logical thinking when solving problems instead of solving problems with the use of learnt algorithms (Begg, Pfannkuch, Camden, Huges, Noble & Wild, 2004; Watson, 2006; Biehler, 2008; Porkess, 2011). Solving statistical problems too often tends to be dominated by mathematical thinking, emphasizing mathematical models, methods and procedures, with the techniques being more important than the central statistical problem itself (Graham, 2006; Stuart, 2005), and not enough emphasis is placed on understanding the problems or on a critical interpretation of

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the results. Thus, mathematics becomes an obstacle to understanding statistical problems, and such teaching certainly does not help improve statistical literacy.

Several authors point out that examination of the level of statistical literacy occurs very rarely, as in the framework of the examination of mathematical knowledge tasks appear at the most that check the knowledge of procedures (Ridgway, Nicholson, & McCusker, 2007; McCusker, Ridgway, & Nicholson, 2010; Nicholson, Ridgway, & McCusker, 2009).

3. Research Questions

There is insufficient encouragement of students to think critically and interpret data and results critically and, most importantly, there is not enough emphasis on the circumstances that students are acquainted with. So we were developing a new approach that would enable students to make sense and be aware of statistical concepts during the procedure of solving statistical problems or resolving statistical problem situations. We were wondering about whether students will better acquire statistical concepts by solving realistic problems taken from their real life.

4. Purpose of the Study

Our research was oriented into an overview of the current state of teaching statistics in the framework of teaching maths in secondary schools in Slovenia and into the use of the approach in the framework of which students would provide meaning to statistical concepts and raise the awareness of them in the process itself of resolving statistical problem situations or of solving statistical problems. With the support of realistic problems taken from real life students are expected to develop critical attitude toward acquired information, create new strategies for solving statistical problems, develop the abilities of interpreting outcomes and the abilities of critical attitude toward the interpretation of result, in this way building and upgrading statistical literacy.

Positioning the teaching of statistics into mathematics classes is extremely “technical” as the teaching of statistics is mostly oriented into learning formulae by heart, while there is at the same time too little emphasis on the understanding of statistical concepts themselves for students to be able to become aware of them. In solving statistical problems mathematical thinking often prevails, which emphasises mathematical models, methods and procedures, where the use of these techniques is often more important than dealing with the basic statistical problem. The realistic problem is often torn out of the realistic situation with students seeing the problem as a set of data that need to be processed by computation according to a learnt procedure, while the real understanding of the problem or of the problem situation represented by the problem is neglected. Students are not aware of the content of the statistical problem or what kind of problem situation the task is about.

It is precisely because of this gap, which emerged with the inclusion of teaching statistics into maths classes that we wished to examine whether the acquisition or mastering of basic statistical concepts could be improved with problem teaching, i.e. with solving realistic statistical problems and with resolving the corresponding problem situations.

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5. Research Methods

The research was carried out on the population of students of the first year of secondary schools, who in the framework of the school subject of mathematics become acquainted with some basic statistical concepts.

In the research 269 students of the first year of secondary school participated, 134 of them included in the experimental group and 135 in the control group. The students of the experimental group received problem-solving teaching in the framework of which they solved realistic statistical problems and resolved relevant problem situation actively participating in the classes, while the students of the control group were taught in the traditional way, i.e. receiving transmission instruction.

In our study the descriptive and causal-experimental method of educational research was used. In the framework of the research the educational non-random experiment was used with intentional introduction of the experimental factor into the research situation. We were interested in how the integration of problem situations or realistic statistical problems, which had been foreseen in the teaching and learning approach, influence the understanding of statistical terms and concepts.

Data were gathered with two written tests of knowledge in statistics, one at the beginning and the other at the end of the experiment. In the preparation of both tests, we were inspired by the tasks of the international research PISA (PISA, 2012) and TIMSS (IEA, 2013), which included tasks from data processing.

Prior to the tests we applied the χ^2-test to check whether the experimental and the control group were equal with regard to the socio-economic status of each student's family ($p = 0.323$) where the status was checked according to the highest education level of each student's parents (the parents being classified into six groups: basic or unfinished basic school, lower or secondary vocational school, secondary technical or professional or general education, post-secondary professional education, higher professional or university education, master degree or doctorate).

Likewise we confirmed with the χ^2-test between the experimental and the control group there were no statistically significant differences regarding students' previous performance in mathematics ($p = 0.400$), where the students' final grades at the end of basic school were taken into account.

6. Findings

With the initial knowledge test the knowledge or understanding of the basic statistical terms and concepts was tested that the students ought to have acquired in the framework of basic school education: the ways of illustrating data with pie charts and with presentation in columns and the knowledge of statistical terms average, mode, and median.

The minimum difference in the average achievements of the students of both groups in favour of the students of the control group was evident, as the students of the experimental group collected an average of 75.4% of points and the control group students 76.1% of points. Also the results of the t-test ($t = –0,250$; $g = 267$; $2P = 0.803$) have confirmed in mastering the basic statistical concepts there were no statistically significant differences between the students in the experimental group and those in the control group.

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At the final test the knowledge and understanding of basic statistical terms and concepts were examined that, according to the syllabus for secondary schools, the students should have acquired or upgraded in the time of the duration of the experiment, i.e. at the beginning of the first year of secondary school: the average, the mode and the median, and the average of standard deviations and the standard deviation.

In the experimental group the introduced approach to the teaching of statistics was designed in such a way that the students acquired the basic statistical concepts on the basis of data taken from their real life. The acquisition of the basic statistical concepts included critical thinking in reading and interpreting statistical data, critical attitude toward information, the ability of interpreting the results, and of adequate representation thereof. It had been expected at the final test the students of the experimental group, who received a new approach to learning and teaching statistics, would master the basic statistical concepts more successfully than the students in the control group.

In Table 01 the basic statistical parameters of the final test of knowledge in mastering the basic statistical concepts are presented, namely the number of students of the experimental and of the control group, the arithmetic mean, standard deviation, as well as the lowest and the highest score.

Table 01. Basic statistical parameters of the final test in mastering the basic statistical concepts

Group	Number of students	Arithmetic mean	Arithmetic mean (in %)	Standard deviation	Min	Max
EG	134	7.00	77.8	2.23	0	9
CG	135	6.41	71.2	1.96	0	9

At the initial knowledge test of mastering the basic statistical concepts the students of the control group performed slightly better than the students of the experimental group, the differences were, however, not statistically significant. In contrast, at the final test a difference showed in the average performance of the two compared groups, as on average the students of the experimental group attained 7.00 points (77.8% of points), and the students of the control group 6.41 points (71.2% of points).

Leven's test (Table 02) showed between the variances of the performance of the experimental and the control group there was no statistically significant difference ($F = 0.850$; $P = 0.357$). At the final test the dispersal of performance in mastering the basic statistical concepts expressed by standard deviation was lower with the students of the control group than with the students of the experimental group, as in the control group standard deviation was equal to 1.96 points, while in the experimental group it was equal to 2.23 points (Table 01). This indicates more similar results among the students of the control group than among those of the experimental group.

Table 02. Differences between the EG and the CG in mastering the basic statistical concepts

Test of the homogeneity of variances		Test of the differences of arithmetic means		
F	P	t	g	2P
0.850	0.357	2.317	267	0.021

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The result of the t-test (t = 2.317; g = 267; 2P = 0.021) reveals in mastering the basic statistical concepts there were statistically significant differences between the performance of the experimental and of the control group, namely in favour of the students of the experimental group (Table 02).

7. Conclusion

The statistically significant difference in favour of the students of the experimental group can certainly be attributed to the difference between the two groups regarding the concepts of teaching statistics. The students of the experimental group learnt the basic concepts of statistics through activities of resolving problem situations that originated from students' experience, strengthening simultaneously the understanding of the basic statistical concepts, while the students in the control group were engaged in learning statistics in the traditional way with the teacher first explaining the new concept, which is followed by consolidation of the learning matter by repeatedly solving similar tasks that contain the concept.

The students of the experimental group thoroughly understood statistical concepts, which is a precondition for higher levels of statistical literacy that also requires the ability of expressing the understanding of concepts (Watson & Kelly, 2003).

Learning statistical skills and abilities that is not related to student's everyday life does not contribute to understanding statistics, as in this case the student mainly learns the skills and abilities by heart. In such cases there is also no elaborated approach to teaching statistics that would be oriented into solving statistical problems and problem situations of everyday life and thus into developing statistical literacy. In consequence students solve statistical problems in an entirely routine way, where it is merely about the use of definitions and procedural solving of "typical" statistical tasks, while real understanding of problems or problem situations represented by these statistical tasks, the awareness of the purpose and of the efficiency of the solving procedures, as well as the assessment of the correctness of the solution remain neglected.

In discussions with the teachers who participated in the research we noticed difficulties in planning classes and in adopting the right approach to teaching statistics. Some teachers lack the awareness that for the student to understand statistics it is not enough to just introduce a statistical concept the student applies in solving a number of examples of tasks. The emphasis should be on providing meaning to statistical contents, understanding and relating new terms and concepts, on developing critical attitude toward interpretation of data and results as well as towards information in media, and on solving realistic statistical problems taken from real life. Such approach to teaching and learning additionally motivates both teachers in teaching as well as students in learning statistics, while simultaneously resulting in more permanent knowledge of better quality.

To sum up we can say statistical literacy is extremely important to be successfully informed in the society and that it should therefore not be neglected. In everyday life we are namely often exposed to a lot of data and information supporting assertions that result from different studies; we must be sufficiently statistically literate to be able to judge and to assess the correctness of the assertions, as they can significantly affect adequate personal decisions that allow responsible participation and functioning in

the society. Looking at the long term, we must be aware that we are educating young people to become future users of information, future decision makers and data providers.

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