# Computer Based Statistics Project 

## Description of data and results

Carita Hommik

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## Goals of the study

The goal of the study is to provide an assessment of the Computer Based Straistics Project. Specifically, the study focuses on students' statistics knowledge, attitudes towards statistics, the project and its lesson materials, as well as teachers' attitudes towards the project and the materials.

The study makes use of a reference group and most of the results are presented as comparisons with the reference group. The main study tools include tests, questionnaires and interviews.

## Identification and development of study tools

## Measuring statistics knowledge

Knowledge measurements were performed by using two similar sets of problems, which were given to students for solving before and after taking the course in statistics and probability.

The compilation of the sets of problems was based on the learning outcomes (subject matters to be taught) of the statistics course according to the current curriculum, as well as general competencies specified in the curriculum (critical thinking, analytical skills, understanding media manipulations, etc.). As the current curriculum specifies that all students have to write a research paper, but there is no mandatory course on research methodology at schools, the selection of problems was also made in consideration of the necessary skills for writing a research paper (e.g., adequate sample creation, formulation of questions, bias problems in sampling/questionnaires, etc.).

The problems were selected from or inspired by the GCSE (General Certificate of Secondary Education, UK) collection Statistics Workbook for Dummies, PISA problems, and information reported in the media.

The process of selecting the problems took a long time and involved various tests with students and discussions with experts. Some problems were modified and improved, and some were rejected, in the course of the process. Score values were assigned to problems on the basis of students' success in solving the problems during the pre-pilot - the problems, which were more difficult to solve, received higher score values. Labour intensity of problems was also taken into account. If a problem was generally difficult to solve but the correct solution could be presented on a single line, it would not have a high score value. The problems and potential score points distributions were reviewed by several mathematics teachers and their suggestions were taken into account.

## Identifying and measuring students' attitudes towards statistics

Attitudes were measured by using the SATS (Survey of Attitudes Towards Statistics) questionnaire, developed by Candace Schau; it includes 36 questions/statements, presented on a

Likert scale (1-7). Students filled out the questionnaire before the start and at the end of the course.

The 36 statements are grouped into six components for measuring attitude:

1. Affect-students' feelings about learning statistics;
2. Cognitive Competence - students' attitudes about their abilities and skills in relation to statistics;
3. Value - students' attitudes regarding usefulness and worth of statistics on one's personal and future professional life;
4. Difficulty - students' attitudes regarding the difficulty of statistics as a subject;
5. Interest - students' individual interest in statistics; and
6. Effort - the amount of effort a student spends on learning statistics.

As the SATS questionnaire is in English, the first step was to translate it to Estonian. Then it was reverse-translated to English and the two English versions were compared to make sure that meaning has not been lost in translation. The Estonian version was corrected as necessary.

Next, the SATS questionnaire was tested on one basic school class and two upper secondary school classes, where students were asked to consider primarily whether all statements had a comprehensible and unambiguous formulation. The students' comments were taken into account and the formulations of some of the statements were modified as a result.

The SATS questionnaire has been used before on several occasions for measuring students' attitudes, but this has been done mostly at the university level. A confirming factor analysis was performed to make sure that the data collected by us conform to the aforementioned structure. However, the data did not conform to the structure as described by Schau. A new best-possible model was found. The new model includes four factors instead of six - Affect, Cognitive Competence and Difficulty were combined in a single factor. The number of items was reduced from 36 to 27 . Some items were distributed differently between factors than in the theoretical model.

## Students' attitude towards the completed project and other questions

In addition to measuring knowledge and attitudes, the students were also asked questions about their computer skills, their opinion about this project, its materials, computer assisted learning, etc.

## Students' and teachers' opinions about Wolfram's materials

Each module ended with a small questionnaire for collecting students' feedback on the completed module. They were presented with five statements and they could indicate their level of agreement by selecting a slider value between zero and one hundred. They could also add comments/justifications to each of the statements.

Teachers were asked to provide feedback on the study materials on a more frequent basis. They
could do this online by providing feedback on each activity after every class and on the module as a whole at the end of the module.

## Teachers' attitude towards the project

Teachers also filled out a questionnaire before the start and at the end of the course. The questions focused on the expected performance of teachers and students in this course (pre-questionnaire) and the actual performance (post-questionnaire). In addition, they were queried about their opinions on computer-assisted learning, the pluses and minuses of the project, and points of comparison with the current curriculum.

Interviews with some of the teachers will be scheduled in the near future. The goal of the interviews is to receive more specific information on teachers' opinions about the materials, as well as recommendations and suggestions on how to improve the materials.

All online questionnaires were created with Google Forms. All questionnaires were prepared in cooperation with Piret Luik, project manager Kristjan Korjus, and Ülle Kikas from the Ministry of Education and Research.

## Data

Data collection took place from February 2014 to June 2014 depending on the start of piloting in individual schools.

A total of 40 teachers from 31 schools and about 1,800 students participated in the project.
For the more extensive survey (which involved filling out the aforementioned questionnaires), each teacher could sign up with one class at most. The selection of classes was made to ensure roughly equal participation of both basic school and upper secondary school students. In addition, it was important that a teacher spent the required amount of time with a class (for instance, some teachers divided the materials of 25 lessons between three different classes and were excluded). Furthermore, it was important that teachers had attended the Wolfram training workshops.

As a result, pre- and post-tests were sent to about 800 students. A similar number of students was expected to fill out the online questionnaires.

Testing of the reference group took place from September to November 2014. The reference group includes 400-500 students and about 20 teachers.

## Data collected from students

## Attitude questionnaire

Table 1. Distribution of students who answered both pre- and post-SATS

|  | Wolfram group |  | Reference group |  |
| :--- | :--- | :--- | :--- | :--- |
|  | Basic school | Upper | Basic school | Upper |
| Boys | $137(44 \%)$ | $137(42 \%)$ | $29(32 \%)$ | $74(36 \%)$ |
| Girls | $172(56 \%)$ | $187(58 \%)$ | $62(68 \%)$ | $129(64 \%)$ |
| Schools in Tallinn, Tartu | $114(37 \%)$ | $168(52 \%)$ | $19(21 \%)$ | $83(41 \%)$ |
| Other schools | $195(63 \%)$ | $156(48 \%)$ | $72(79 \%)$ | $120(59 \%)$ |
| Average age of teachers | 41 years |  | 42 years |  |

## Problems

In the Wolfram group, both the pre-test and post-test were solved by 647 students (334 in upper secondary school and 313 in basic school). In the reference group, the number of students who took both tests was 342 ( 244 in upper secondary school and 98 in basic school).

It should be remembered that students probably did not have particular motivation for solving the problems, because they were not graded and their own teacher did not check these solutions. Consequently, they worked only on the basis of their internal motivation. This could explain the somewhat lower results.

The impact of the school has been taken into account in the analysis of attitudes and knowledge of students, because the characteristic of school turned out to be statistically significant in both cases. The analysis was performed using the SPSS Statistics 22 software and linear mixed models.

## Feedback on individual modules

All students had the opportunity to answer these questions but not everybody did. The number of respondents decreased with each subsequent module (partially also because the number of students who took each subsequent module decreased as well).

## Data collected from teachers

There were 37 teachers in total who participated in Wolfram workshops and answered both the pre- and post-questionnaires.

## Results

## Teachers

Looking at the teachers' assessment of their own and their students' performance in the course in terms of content and technical issues (Table 2), the only statistically significant difference between the responses before and after the course appears with regard to the question, in which teachers expected the students to perform somewhat better in learning the contents than they actually did.

Table 2. Teachers' predictions and assessments of their own and their students' expected/actual performance in the course. Answers on a scale from 1 to 5 where 5 means 'very good'

| Question to teachers in pre- <br> test (in post-test, the same <br> question was formulated in a <br> past tense) | Before <br> the <br> course | After <br> the <br> course | p-value | Adjusted p- <br> value* |
| :--- | :--- | :--- | :--- | :--- |
| How would you rate your <br> computer skills? | 4.0 | 4.0 | 1.000 | 1.000 |
| Please rate your expected <br> performance in conducting this <br> course in terms of technical aspects | 3.4 | 3.7 | 0.146 | 0.730 |
| Please rate your expected <br> performance in conducting this <br> course in terms of content aspects | 3.5 | 3.4 | 0.354 | 1.000 |
| Please rate the expected <br> performance of students in this <br> course in terms of technical aspects | 3.5 | 3.6 | 0.737 | 1.000 |
| Please rate the expected <br> performance of students in this <br> course in terms of content aspects | 3.5 | 3.0 | 0.004 | $0.020^{* *}$ |

* We used p-values adjusted by the Bonferron method. The p values of single tests were multiplied by the number of tests.
** Statistically significant difference occurs at significance level 0.05.
Most of the teachers, who piloted only in basic school, would like to teach according to the Wolfram curriculum in the future (Table 3). However, the upper secondary school teachers would like to see a combination of two curricula. Many of those who preferred to Wolfram curriculum also added that the materials would certainly require improvement and supplementation.
Table 3. Which of the two curricula would you prefer to use in the future for teaching?

| Teacher's school level <br> in the pilot | A combination <br> of both | Current <br> curriculum | Wolfram | Number <br> of <br> responde <br> nts |
| :--- | :--- | :--- | :--- | :--- |
| Upper secondary school | $56 \%$ | $11 \%$ | $33 \%$ | 9 |
| Both | $33 \%$ | $22 \%$ | $44 \%$ | 18 |
| Basic school | $22 \%$ | $0 \%$ | $78 \%$ | 9 |
| Total | $36 \%$ | $14 \%$ | $50 \%$ | 36 |

Both before and after the course, teachers were asked about a desirable extent of computer use in mathematics classes. There were no changes in general attitude before and after. While a few teachers moved between groups, this did not affect the average result.

By the end of the course, $5 \%$ of teachers believed that computers could be used in more than half of the classes.
$38 \%$ responded that roughly in half and $57 \%$ that in less than half of the classes.

## Pluses and minuses of teaching the course

(see the summary table below)

Teach teacher was asked to name three aspects that were the most difficult in teaching this course. The most frequently mentioned issues included technical problems (43\%), students' variable pace of work (35\%), large time consumption in preparing for lessons (27\%), difficulties with time planning and keeping up with the plan while in class (24\%), low motivation of students and maintaining motivation throughout the course (19\%), issues with absent students (19\%), too difficult for students (16\%), difficult for teachers as well (11\%), too many students for a computer class (8\%).

Other mentioned minuses included: it is difficult to understand the objective and materials of lessons, to follow the structure of the module; too many different activities and transitions between activities caused excessive excitement in students; not enough recurring activities to help lock in the material; students were difficult to control; working with computers for so long became tedious for students in the end; difficult to navigate between different views (teacher's and student's view); difficult to gauge and understand how much did students actually learn; it would be good to have more instructions for teachers (concerning simulations); some students had weak technical skills (could not download Mathematica at home).

The teachers were also asked to mention three aspects that they liked the most when teaching this course. They most frequently approved of practical, creative and realistic problems ( $43 \%$ ), visualisations, simulations, charts and diagrams ( $24 \%$ ), possibility and speed of collecting and providing feedback (24\%), students' motivation and interest, eagerness (19\%), an innovative approach that differs from the ordinary (19\%), educational for teachers as well (16\%), lessons led to debates and discussions, improving students' skills of self-expression (14\%).
Other positives mentioned included: variability of learning activities; different activities for students with different abilities; data were provided by students themselves; computer use; independent work; the subject matters helped to expand horizons. One teacher also believed that everything was repetitive.

## Minuses

- Practical and realistic problems - 43\%
- Visualisation - 24\%
- Possibility and speed of feedback 24\%
- Students' motivation - 19\%
- Innovative approach - 19\%
- Educational for teachers - 16\%
- Classroom discussions - 14\%
- Technical problems - 43\%
- Different working pace of students - 35\%
- Time-consuming preparations - 27\%
- Time planning and keeping up with the plan - $24 \%$
- Low motivation of students - 19\%
- Absent students - 19\%
- Difficult for students - 16\%
- Difficult for teachers - 11\%


## Need for additional training

At the end of the course, teachers were asked whether they would need additional training in content or technical aspects if they had to teach this course again in the future. $24 \%$ of teachers did not need additional training. $43 \%$ would like to receive training in content aspects - i.e., they did not fully understand certain subject matters of statistics or they did not understand the rationale (reasons and reasoning) behind some subject matters. 5\% would like to receive training in content aspects only if something is changed in and/or added to the contents.
$22 \%$ would like to receive additional training in both technical and content aspects. $5 \%$ would like to be trained in programming (to be able to write code for Mathematica).

Furthermore, teachers had to state whether, in their opinion, certain important subject matters were not included in the Wolfram curriculum. 32\% said that everything was included. $27 \%$ believed that all subject matters were covered but it was done superficially and students could not develop any specific skills. $16 \%$ mentioned the need for more work with probability and combinatorics. One teacher also identified a need for instructions on data collection, because data are not available in all cases.

## Feedback on learning activities

We do not know the exact number of teachers, who completed any particular module, but we know the modules on which they provided feedback and we could assume that this approximately reflects the completion rate.


Figure 1. Number of teachers who completed a module
After each lesson, teachers had to answer several questions about the module and particular activity. For instance, teachers had to report about each activity whether they omitted it and why and whether it was difficult for students or not (see the picture below).

A similar chart (see Figure 2) was drawn up for each module based on these responses. The x -axis represents activities in the order as they are in the module; the left side of the y -axis shows the number of teachers who submitted feedback (i.e., completed the module). The line graph indicates the percentage of teachers who believed that this activity was difficult for students. The respective charts for modules 1.02-2.09 are provided in Annex 1.


Difficult for students

Figure 2. Use of different activities by teachers

## Students

## What did you like/dislike about this course?

(see the summary table below)
Basic school students mainly (30\%) enjoyed working with charts - both reading information from and modifying the charts. $29 \%$ mentioned various practical activities, particularly production of an advert and a video and the throwing of drawing pins. A quarter of students liked the fact that it was a computer assisted course. They often reasoned that computers enable them to perform this work faster than would be possible with paper and pen. $23 \%$ of students highlighted the work in pairs and in groups and the cooperation of the entire class in general. 18\% also mentioned that this course provided them with new knowledge and expanded their horizons with regard to other subject matters beyond statistics. Some students also liked interesting problems, which made the lessons exciting (11\%). Students further liked the possibility that they could use their own data, thereby learning more about their classmates (9\%). Other positives included the following: a novel method of learning, providing a change from regular mathematics classes; possibility to think independently and express one's opinions; possibility to watch videos; no homework; writing code; independent work; simple, logical and comprehensible structure of the course; suitable pace; and less formal atmosphere in the classroom.

In basic school, the most frequently mentioned negative aspect was reading information from, modifying and creating charts and tables (21\%). It should be recalled that the same activity was also mentioned as the most positive aspect. 15\% of students stated that they often did not understand the assignment or explanations were too complex or there was not enough explanation. Other negative aspects included: requirement to provide reasoning and answer questions, especially in writing (13\%); working pace was either too slow or too fast (10\%); technical problems (9\%); some subject matters/problems were too boring and tended to be repetitive (7\%); complex and difficult problems (7\%); independent work; writing code; making calculations; difficult theory files, too much text; learning was superficial, there should have been more time; long and boring videos; work in pairs and in groups; working with a computer is harmful for the eyes. $1 \%$ of students also said that they only gained limited new knowledge and the lessons were not as much about mathematics as something else (e.g., Estonian language) and they were distracted.

In upper secondary school, the most frequently mentioned positive aspects included the opportunity of group work, incl. work in pairs, communication with classmates and different presentations (25\%), as well as different methods of visualisation (simulations and charts) (20\%). The fact that the course was computer assisted was seen as another positive aspect (20\%), with several students mentioning that this also improved their overall computer skills. They liked that data and problems were realistic and practical (19\%); it was a novel and interesting experience (18\%); interesting problems (17\%); no homework/graded tests made it easier than other classes (9\%). 8\% of students mentioned that the acquired skills are useful in life; they gained an understanding of statistics and acquired new knowledge. $6 \%$ of respondents mentioned a more relaxed pace of the lessons and casual learning environment. Some students also liked the opportunity to analyse and discuss and to improve respective skills; performing independent work; watching videos.

Technical problems (something was not functioning or was only in English) were the main negative aspect for upper secondary school students (47\%). For 30\%, the course was too complex and difficult, with poor explanations, and required frequent clarifications from the teacher. Other negative aspects included: no new mathematical knowledge was gained and the course was not very efficient (13\%); charts and simulations were difficult to understand and modify (13\%); the pace was either too fast or too slow (10\%); did not understand the questions (10\%); subject matters were boring or unrealistic, very repetitive (7\%). Some students also did not like the following aspects: the need to write justifications and answer questions; computer assisted work; independent work; 'pointless' problems that only wasted time (e.g., drawing pins); classroom was noisier than usual and it was difficult to focus; difficult theory files; did not have the requisite knowledge from previous learning; knowledge was not locked in; no theory lessons.

## BASIC SCHOOL

| Pluses | Minuses |
| :---: | :---: |
| Charts - 30\% <br> - Practical activities - 29\% | - Charts $-21 \%$ |
| Computer assisted learning - 25\% <br> Work in pairs/groups 23\% <br> - New knowledge - 18\% <br> - Interesting problems - 11\% | Need to provide reasoning - 13\% <br> Unsuitable pace - 10\% <br> Technical problems - 9\% |

## UPPER SECONDARY SCHOOL

| Pluses | Vinuses |
| :---: | :---: |
| - Group work and presentations $-25 \%$ | Technical problems - 47\% <br> Difficult-30\% |
| Visualisation - 20\% <br> Computer assisted learning 20\% <br> Realistic and practical - 19\% <br> Novel and interesting experience - 18\% <br> Interesting problems - 17\% | No new knowledge - 13\% <br> Charts - 13\% <br> Unsuitable pace - 10\% |

## Knowledge of statistics

Tables 4 and 5 show the results of students' pre- and post-tests. Students' knowledge improved in both school levels. Even though the difference between the post-test scores of the reference group and the Wolfram group is not statistically significant, the knowledge of students in upper secondary school increased more than in the Wolfram group compared to the pre-test.
Table 4. Pre- and post-test results in upper secondary school

|  | Wolfram | Reference <br> group | p-value |
| :--- | :--- | :--- | :--- |
| $N$ | 334 | 244 |  |
| Pre-test | 13.4 | 11.5 | 0.158 |
| Post-test | 17.8 | 18.0 | 0.880 |
| Change | 4.3 | 6.5 | 0.020 |

- The maximum score in upper secondary school was 47.
- 
- Table 5. Pre- and post-test results in basic school

|  | Wolfram | Reference <br> group | p-value |
| :--- | :--- | :--- | :--- |
| N | 313 | 98 |  |
| Pre-test | 15.8 | 13.8 | 0.308 |
| Post-test | 20.5 | 20.7 | 0.970 |
| Change | 4.8 | 6.9 | 0.149 |

* The maximum score in basic school was 46.

It was impossible to detect any difference between the scores of the two groups in relation to the majority of the problems, but some problems did reveal certain differences.

## Upper secondary school

1) Students of the reference group performed better when solving the problem below, with an average score of 1.63 compared to 1.15 of the Wolfram group ( $\mathrm{P}=0.000$ ).

> (3 punkti) Kohalik uuringufirma uurib, et kui rahul on inimesed hetkel võimul oleva erakonnaga. Selleks küsitlevad nad telefoni teel 2000 inimest, kellest 1000 vastab, et on väga rahul, 400 vastab, et ei ole rahul ja 600 keelduvad antud teemat kommenteerimast. Pärast ilmub ajalehes artikkel pealkirjaga „ $71 \%$ inimestest on võimul oleva erakonnaga väga rahul".
a) (2 punkti) Too välja vähemalt 1 kriitiline kommentaar selle lause suhtes.
2) In the urn problem, students of the Wolfram group were slightly better in solving section (a) (average 0.85 compared to 0.70 of the reference group, $\mathrm{p}=0.026$ ), while students of the reference group were better in solving sections (b) and (c). The respective average scores were 0.72 and $0,23(p=0.013)$ for section (b) and 0.50 and $0,04(p=0.001)$ for section (c). The fact that the Wolfram curriculum did not include similar problems could explain the lower scores. However, it is somewhat surprising that the reference group performed so poorly in solving these problems, as it is likely that these are typical problems for the reference group.
( 6 punkti) Urnis on 18 kuuli, neist 6 on kollast värvi, 8 on punast värvi ja 4 on roosat värvi. Kati võtab urnist 3 kuuli. Leia tõenäosus, et
a) (1 punkt) Kolmest kuulist täpselt üks on sinist värvi.
b) (2 punkti) Kolmest kuulist kaks on kollast värvi ja 1 on roosat värvi.
c) (3 punkti) Kolmest kuulist vähemalt 2 on punast värvi.

## Basic school

Differences were noticeable in the solutions of two problems, with the reference group performing better in one and the Wolfram group in the other. The Wolfram group was better in solving the problem, which tested whether students understand the manner of formulating survey questions without introducing any bias to the answers. This is not a classical problem, which could be found in current textbooks, but the subject matter of preparing questions was covered in the Wolfram curriculum. Students of the reference group were better at solving the problem, which required distribution of results in a table according to frequency and determination of relative frequencies. This was a relatively classical problem. In addition, the specification of learning outcomes of the current curriculum includes the skill of creating a table of frequencies and relative frequencies.

1) The Wolfram group was better at solving the problem below (average score 1.16 compared to 0.58 for the reference
group, $\mathrm{p}=0.001$ ).
(5 punkti) Mahlatootja Happy Juice kasutas järgmist küsimust uurimaks inimeste maitse-eelistusi erinevate mahlade hulgas: „Kas nõustute, et Happy Juice'i mahlad on kõige paremad?".
$82 \%$ vastas sellele küsimusele „jah".
a. (2 punkti) Too välja üks põhjendus, miks arvatavasti nii palju inimesi vastas antud küsimusele „jah" (lähtu küsimuse sõnastusest).
2) The reference group performed better in the frequency table problem with, respective average scores of 1.66 and 1.52 compared to 0.58 and 0.97 for the Wolfram group ( $\mathrm{p}=0.000$ and $\mathrm{p}=0.028$ ).
( 6 punkti) Kohalik uuringufirma uurib, et kui rahul on inimesed hetkel võimul oleva erakonnaga. Selleks küsitlevad nad telefoni teel 2000 inimest, kellest 1000 vastab, et on väga rahul, 400 vastab, et ei ole rahul ja 600 keelduvad antud teemat kommenteerimast.
a. (2 punkti) Esita tulemused sagedustabelis.
[^0]
## Attitudes

Tables 6 and 7 show the attitudes towards statistics among basic school and upper secondary school students at the start of the course. It indicates that the attitudes of the reference group and the pilot group were similar before they started learning about statistics and probability.

Table 6. Basic school students' attitudes towards statistics

| Factor | Wolfram |  |  | Reference group |  |  | df | F | Sig. | Sig. corrected (Bonferroni) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | N | Mean | Std. <br> Error | N | Mean | Std. Error |  |  |  |  |
| Belief in | 309 | 4.467 | . 092 | 91 | 4.400 | . 164 | 21.563 | . 127 | . 725 | 1.000 |
| one's abilities <br> Value of | 309 | 4.550 | . 076 | 91 | 4.783 | . 135 | 20.061 | 2.270 | . 147 | . 588 |
| statistics <br> Interest <br> in | 309 | 4.334 | . 089 | 91 | 4.396 | . 159 | 21.525 | . 114 | . 739 | 1.000 |
| statistics |  |  |  |  |  |  |  |  |  |  |
| Effort | 309 | 5.265 | . 109 | 91 | 5.521 | . 193 | 22.356 | 1.329 | . 261 | 1.000 |

Table 7. Upper secondary school students' attitudes towards statistics

| Factor | Wolfram |  |  | Reference group |  |  | df | F | Sig. | Sig. corrected (Bonferroni) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | N | Mean | Std. <br> Error | N | Mean | Std. <br> Error |  |  |  |  |
| Belief in one's <br> abilities | 324 | 4.468 | . 083 | 203 | 4.386 | . 104 | 28.286 | . 374 | . 545 | 1.000 |
| Value of statistics | 324 | 4.912 | . 098 | 203 | 4.889 | . 121 | 26.683 | . 022 | . 883 | 1.000 |
| Interest in statistics | 324 | 4.523 | . 105 | 203 | 4.474 | . 129 | 27.415 | . 087 | . 770 | 1.000 |
| Effort | 324 | 5.147 | . 112 | 203 | 5.555 | . 138 | 23.117 | 5.253 | . 031 | . 124 |

In order to assess changes in students' attitudes, a 'change' characteristic was found by subtracting the scores of the pre-test from the scores of the post-test (Tables 8 and 9). A comparison of the reference group and Wolfram group indicates that there was no statistically significant change in the attitudes of basic school students with regard to any of the components. In both groups, the mean change was negative in the factors of 'effort' and 'interest' and positive in the factors of 'value' and 'belief in one's abilities'.

In upper secondary school, there was a statistically significant difference with regard to the factor 'belief in one's abilities', which increased more in the reference group than in the Wolfram group. This could perhaps be explained by the assumption that the materials were too difficult for many Wolfram students. The mean change was negative in both groups with regard to the remaining components.

Table 8. Change in attitudes in basic school

| Factor | Wolfram group |  | Reference group |  |  | df | F | Sig. | Sig. <br> corrected <br> (Bonferroni) |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | N | Mean | Std. <br> Error | N | Mean | Std. <br> Error |  |  |  |  |
| Belief in | 309 | .412 | .083 | 91 | .595 | .148 | 18.634 | 1.163 | .295 | 1.000 |
| One's abilities <br> Value of | 309 | .025 | .059 | 91 | .183 | .106 | 18.876 | 1.693 | .209 | .836 |
| statistics <br> Interest <br> in | 309 | -.214 | .068 | 91 | -.187 | .124 | 19.961 | .035 | .853 | 1.000 |
| statistics |  |  |  |  |  |  |  |  |  |  |

Table 9. Change in attitudes in upper secondary school

| Factor | Wolfram group |  |  | Reference group |  |  | df | F | Sig. | Sig. corrected (Bonferroni) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | N | Mean | Std. <br> Error | N | Mean | Std. <br> Error |  |  |  |  |
| Belief in one's abilities | 324 | . 114 | . 115 | 203 | . 665 | . 142 | 25.516 | 9.113 | . 006 | . 024 |
| Value of statistics | 324 | -. 058 | . 084 | 203 | -. 104 | . 104 | 21.217 | . 117 | . 736 | 1.000 |
| Interest in statistics | 324 | -. 348 | . 091 | 203 | -. 207 | . 112 | 25.887 | . 956 | . 337 | 1.000 |
| Effort | 324 | -. 989 | . 133 | 203 | -. 916 | . 164 | 29.960 | . 119 | . 732 | 1.000 |

## Opinions about the course and the materials

Figure 3 shows students' responses to various questions concerning the course; higher values correspond to a more positive assessment. This figure indicates that basic school students enjoyed this course more than upper secondary school students. The course was least rated by girls in upper secondary school, for whom the course was also most difficult (questions 2 and 3).
2.500

Figure 3. Students' opinions about the course by school level and sex. Answers on a scale of 1-

5 where 5 represents the highest level of interest/easiness/enjoyability, etc. [1] - How interesting was the course? [2] - How difficult was the course in terms of contents? [3] - How difficult was the course in terms of technical aspects? [4] - How did you like the use of computers in the course? [5] - How did you like the appearance of study materials? [6] How confident are you in having learned the material of the course? [7] - Would you take another course in statistics in the future if possible?
As the attitudes of basic school students are better with regard to each question, we try to take a closer look at the results in upper secondary school. Figure 4 shows the mean ratings of all 15 upper secondary schools when responding to various questions about the course. It is clear to see that opinions about the complexity of the course (questions 2 and 3) are more similar than opinions about the remaining questions, where there is a larger dispersion of mean values.


Figure 4. Mean ratings of the course among upper secondary schools. Answers on a scale of 15 where 5 represents the highest level of interest/easiness/enjoyability, etc. [1] - How interesting was the course? [2] - How difficult was the course in terms of contents? [3] - How difficult was the course in terms of technical aspects? [4] - How did you like the use of computers in the course? [5] - How did you like the appearance of study materials? [6] - How confident are you in having learned the material of the course? [7] - Would you take another course in statistics in the future if possible?

This leads to a question about the type of schools that had either positive or negative attitudes. The difficulty here is with the selection of a descriptive characteristic of schools. One possibility is to look at the overall performance of the school. It is customary in Estonia, at least to some extent, to compare the performance of schools (students) on the basis of the results of state examinations. We can add to each school its mean result of school in state examination in mathematics in year 2014 (for both narrow and wide mathematics examination), and find different correlations.

All found correlations are negative (except for question 2), which means that students of schools with better results in state examination gave more negative responses. All correlations varied between -0.54 and 0.14 . The only statistically significant correlation
(at significance level 0.05) was found in relation to the question 4 (How did you like the use of computers in the course?) where p-value was 0.038 and correlation coefficient was -0.54 . However, even this negative correlation becomes insignificant if p-values are adjusted by the number of tests. Consequently, it is not possible to claim at 5\% confidence level that answers to these questions are dependent on the overall performance of the school (if school performance is measured on the basis of state examinations).

## Opinions about the modules

Students' feedback on the modules (Figures 5 and 6) indicates that the feedback of basic school students remained relatively stable in relation to different modules. However, there is a falling trend in upper secondary school, i.e., each subsequent module was more difficult and less interesting for students, requiring increasing explanations from the teacher.


Figure 5. Students' feedback on upper secondary school modules


Figure 6. Students' feedback on basic school modules

## Conclusion

It could be said in conclusion that there were no major identifiable differences between students of the reference group and the Wolfram group in terms of knowledge and attitudes. Generally, students were more satisfied with first modules, after which they started to lose interest. This was probably associated with increasing technical problems, particularly in upper secondary school modules. The students' attitude could be improved by a review of the materials and correction of errors, after which teacher can be more confident in using the materials in teaching.

It seems that if teachers decided to teach a particular module, they tried to complete the majority of learning activities in that module. However, there are some activities that were omitted on more occasions than others for various reasons. It could also be worthwhile to review the activities, which were considered to be more difficult by teachers.

## Annex 1. Teachers' feedback on learning modules 1.02-2.09




Difficult for students




Difficult for students


Module 2.02



Difficult for students




Difficult for students




Difficult for students


[^0]:    b. (2 punkti) Täienda punktis a) tehtud sagedustabelit ka suhteliste sagedustega (st osakaalud protsentides).

