

The Translation and Validation of the Calculus Concept Inventory and its use in Czech Republic on Physics-Gifted High School Students

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The Calculus Concept Inventory (CCI)

- The CCI was developed by Jerome Epstein (recently deceased).
- The test is validated [1], [2] and it has been used in several institutions worldwide f. e. [3], [4] etc.
- It is tool that should test the **conceptual understanding** of the most basic principles of **calculus**.
- It is inspired by *Force Concept Inventory* (FCI) by Hestenes et al. [5].
- Motivation for creation of this test was also to determine whether the more active methods of teaching (in comparison with the talk-and-chalk) are more effective in learning.
- The CCI is under non-disclosure agreement, therefore there cannot be any examples of problems.

Reasons for Choosing of the CCI

- We searched for some standardized tool that measures the knowledge how to use calculus or even better the conceptual understanding of calculus. The primary incentive was to try to measure the gain of physics gifted participants of FYKOS' camps (FYKOS = The Internet Physics Competition or The Physics Correspondence Seminar in Czech Republic) for high school (ISCED²⁰¹¹ 3). At these camps we are trying to teach at least the basics of calculus in very short time in order they can use it in physics lectures at these camps.
- The main reason for using a standardized test and not our own is that we are able to do qualitative validation of the test, but it is hard for us to do the quantitative one.
- The only corresponding tests found by a literature search (at late 2014) on Web of Science™ and Google Scholar were one test which was at that time only in Turkish [6] and the Calculus Concept Inventory. Because of Turkish language barrier we decided for translation of CCI.

The Importance of Calculus in Physics

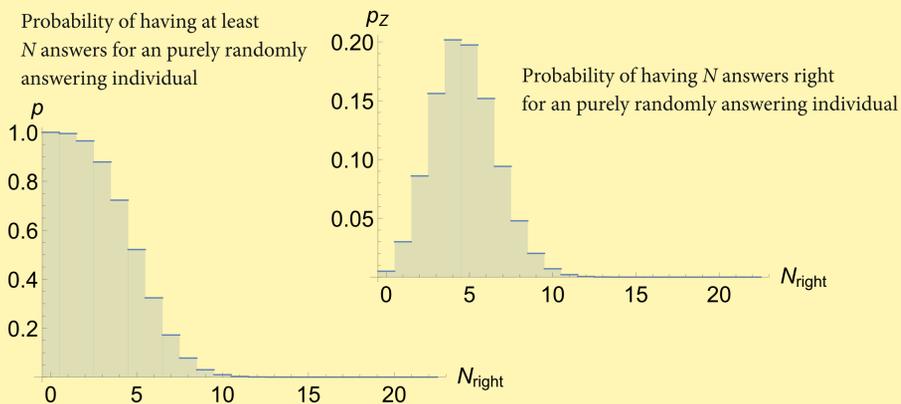
- Calculus is the very essence for understanding of Physics at university/college level (ISCED²⁰¹¹ 6, 7, 8).
- Situation in the Czech Republic
 - Basics of calculus are taught at some high schools (ISCED²⁰¹¹ 3), especially at gymnasia, mostly as optional course in Mathematics (but in some gymnasia is Calculus mandatory) in the 12th or 13th grade (out of usual 13 grades).
 - University students of Physics take deep course of Calculus throughout their bachelor study, in their first semester they are usually taught of limits, derivatives, integrals and some basics of differential equations.
 - These both type of courses should cover all the basic understanding of differential and integral calculus.

CCI in numbers

- 22 closed questions
- 4 - 5 possible choices every question
- 30 minutes for solving = max 82 sec/problem
- 1 introductory page + 8 pages of test (6 after translation)
- 17 pictures/graphs
- Czech translation is based on version 5 (Aug 2006)

Distribution of Random Answers

- We put the question, how would look like results if a group would be answering randomly. Graphs in this section shows such distribution. Mean score should be 4,7 correct answers per respondent.



- So we can see that scores 8 and more are almost certainly thanks knowledge and not random choice.

Translation Issues and discovered imperfections of CCI

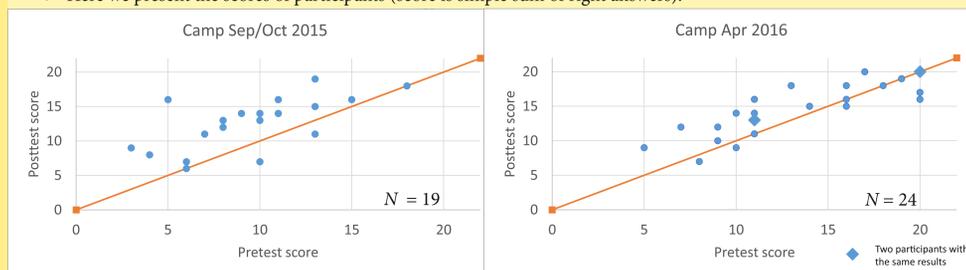
- Units - Most of units were converted in the translation to the SI. For solving of the CCI problems is not necessary to know the real values of units and for a reader used to the SI is one more unnecessary complication to realize that he/she does not have to know the conversion rate.
- Pictures - We had only PDF version of test and printscreens were not good and also the original pictures are not „nice and clean” but are hand-drawn. So we made these pictures in Ipe (<http://ipe.otfried.org/>).
- Misconceptions - We realised that the mathematical-right answer of some questions could lead, in some cases, to creation of misconception in a different field of science. The greatest of them is that some kind of bacteria is dividing too much rapidly and that they can fill entire beaker with themselves by dividing - this is quite unrealistic. But the formulation can be improved without changing the goal of the problem, but it leads to the need for changing of distractors. Second possible misconception could arise from a bit unrealistic changing of temperature throughout one day - but this issue is not so evident.
- Mathematical imprecision - Especially the teachers of Calculus argued that formulation of some questions could be a bit misleading because of imprecision of used language and not explicit definition of domains we are using.
- Choosing of right answer - Even if we clearly say before the test, they should use the special place, where they should put the letter of the right answer, about half of them are still only making circles around their chosen option. So we changed the design a bit, so they now have to use circles.

Validation of Czech Translation

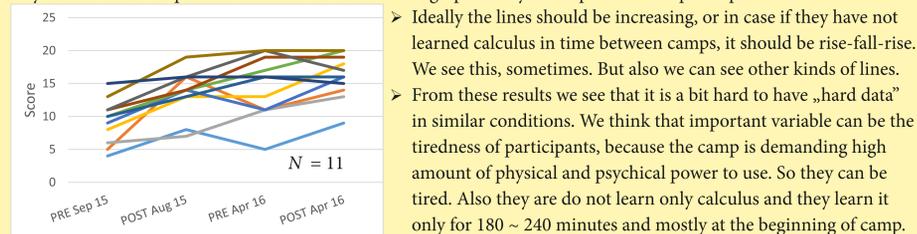
- Following people solved some version of translations of CCI. Their solutions were discussed by the author of this poster with them. Thanks to them, the acquired feedback was used for improving the wording of some questions for better understanding.
 - Senior Assistent Professor of Didactics of Physics teaching calculus
 - 4 Ph.D. students of Didactics of Physics
 - Ph.D. student of Theoretical Physics
 - Associate Professor of Theoretical Physics, working on Didactics of Physics
 - Associate Professor of Mathematical Analysis
 - High school teacher
 - 2 High school students (12th grade of 13) - just learning calculus
- Moreover it has been piloted on two FYKOS' camps - more below - this also gave us some feedback.

Application at FYKOS' Physics Camp

- At first - it has to be emphasized that this following use was actually piloting of the text and that the version used on the first camp was different from the second use. Although the questions were from certain point of view very similar, there was a lot of minor changes.
- FYKOS has camps twice a year - the first use was in Sep/Oct 2015 and the second Apr 2016.
- At both cases the CCI was administered at the beginning of the camp (first day - Saturday afternoon) and at the end (afternoon of the day before they leave - second Saturday afternoon).
- Important role of pretest is - the participant is informed about his result and that he/she should choose corresponding level of Calculus lecture which is usually content of the first two lectures.
- Here we present the scores of participants (score is simple sum of right answers):



- There are only respondents of both pre- and posttest. Orange line is no gain, region upper from it is area positive gain, under is negative. We see, that most common is small gain. Some of participants were tested all the 4 times - you can see development of their results in the next graph. Every line represents one participant.



- Ideally the lines should be increasing, or in case if they have not learned calculus in time between camps, it should be rise-fall-rise. We see this, sometimes. But also we can see other kinds of lines.
- From these results we see that it is a bit hard to have „hard data” in similar conditions. We think that important variable can be the tiredness of participants, because the camp is demanding high amount of physical and psychological power to use. So they can be tired. Also they are do not learn only calculus and they learn it only for 180 ~ 240 minutes and mostly at the beginning of camp.

Future plans

- We would like to use the CCI in the Calculus courses in first semesters of our bachelor study, but it seems to be complicated to convince the professors that it is important to measure such things and that their talk-and-chalk style is not the best. We would like to try to convince at least some of them to at least give some space for the test.
- We would like to continue using some test on FYKOS' camps, but there is increasing risk of remembering the concrete questions.
- If you are interested in working with CCI and its use, you can try to contact jerepst@att.net, but the email is of the deceased Jerome Epstein and it is opened only occasionally. If you are interested in our finding and Czech version, write the author of the poster.

References

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Acknowledgments

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