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Gender differences in chemical engineering students identified in understanding of rolling motion

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Abstract: In this research paper we presented the results of exploration of gender differences in conceptual understanding of rolling motion (velocities and work-energy principle). For this purpose, we have selected nine conceptual items and conducted experiment with 184 first year students at the Faculty of Chemical Engineering and Technology, University of Zagreb. Results show that male students significantly outperformed female students. We detected particularly large differences on items that tests knowledge of the rolling phenomena. Results of our research can help teachers to create lessons that are adapted to general student population.

INTRODUCTION

The goal of every teacher at the university level should be to transfer the knowledge about a particular phenomenon to his/her students as effectively as possible. Many factors affect the effectiveness of the teaching and learning process and the teacher's task is to adopt his/his lectures to the target group of students. Motivated by the fact that majority of students at the Faculty of Chemical Engineering and Technology in Zagreb are females, we decided to conduct a study in which we are comparing gender scores from test that includes phenomena from mechanics i.e. rolling motion (velocity and work-energy principle). We focused our research to the phenomena that includes rolling of rigid bodies.

We have chosen these phenomena from mechanics because this knowledge is the basis for understanding other fields of physics as well as other scientific disciplines in curricula for chemical engineering students.

Furthermore, in this field of physics, it is necessary for students to develop visuospatial skills i.e. have ability to visuals the rotation in order to successfully solve conceptual problems.

Lohman defines spatial ability as "the ability to generate, retain, retrieve and transform well-structured visual images" (Lohman 1996, p. 112). There are many studies that emphasize importance of visuospatial ability and its relation to mathematical conceptualization, problem-solving skills, creative and higher order thinking skills in science and mathematics, design and graphical representation skills in engineering and technology (Maeda and Yoon, 2013).

Furthermore, studies have shown that male students outperform female students in solving visuospatial tasks (Voyer and Saunders, 2004; Peters, 2005).

Visuospatial skills are especially important in tasks that require to visualization of 3D-objectsrotation. It has been shown that male students are outperforming female students in the tasks related to visualization of three-dimensional rotation ability (Linn and Petersen, 1985; Voyer, Voyer and Bryden, 1995; Maeda and Yoon, 2013).

Therefore, study from Fisher, Schult and Hell presented evidence that female students have higher achievement motivation which results in a better secondary school grades. (Fischer, Schult and Hell, 2013)

From a biological point of view, the causes of such differences can relate to functional, morphological, hormonal or genetic differences in the brains of males and females (Jordan et al., 2002; Koscik et al., 2009; Hausmann et al., 2000; Thomas and Kail, 1991).

From a sociological point of view, gender differences may exist because boys are often engaged in activities that help them to resolve visuospatial tasks. It is well known fact that they are more likely to play video games, certain sports, and more often play with building toys such as Lego cubes (Cherney, 2008; Ginn and Pickens, 2005; Deno, 1995).

In order to accurately solve our conceptual tasks related to rotation and energy, students should use visualization skills. In our example of body rotation, we should emphasize that students need to visualize what is happening with the points on the edge of the wheel that are in contact with other ground material in the process of rigid body rotation.

Furthermore, earlier studies have shown that students have many misconceptions related to this phenomena. It is often the case that students haven't developed an understanding of wheel velocity in contact with the ground, as well as some seemingly unintuitive aspects of applying mechanical energy conservation law in the context of rolling. Other students also believed that, for a very large static friction coefficient, the body on the slope would not even move at inclination angles near 90 degrees (Rimoldini and Singh, 2005). Results from other study that was using simulations and physical experiments showed that many students do not understand how to identify the exact direction of the velocity of a point on the edge of a rolling body (De Ambrosis, Malgieri, Mascheretti, and Onorato, 2015).

Generally, it is well known that many student misconceptions are rooted in the daily student experiences (Reiner et al., 2000).

Aim of the present study

Our goal in this study is to investigate gender differences in understanding the velocity and work-energy principle in the rolling motion example. This type of research is very importnat because it provides us with feedback that is useful in creation of lectures that are more effective for teaching introductory courses at the Faculty of Chemical Engineering and Technology.

METHODOLOGY

Research design

To answer our research question we conducted a survey research study were students had lectures and recitation sessions in their natural learning environment. Covered topics were about velocities and work-energy principle in rolling motion example. Students had 20 minutes to solve the nine questions test.

Participants

Our study was conducted in academic year 2017./2018. The number of 184 first year students at the Faculty of Chemical Engineering and Technology, University of Zagreb (Croatia) was included in the research project Student population mostly consist of 19 year old first year students that were enrolled in introductory physics course. Gender analysis showed that our sample consisted of 74 % female and 26 % male students.

Curriculum and teaching treatment

We conducted research in standard teaching processes. Before the conceptual test students participated in standard traditional lectures and seminars about velocities and work-energy principle in the example of rolling motion. In the curriculum of the introductory physics course, the phenomena of rolling is taught in the first semester of the first year at the Faculty of Chemical Engineering and Technology in Zagreb. Traditional seminars are based on summarizing and applying the most important principles and facts that students encountered earlier in their lectures. We can characterize this introductory physics course as standard introductory physics course for scientists and engineers in Croatia.

Assessment instruments

To enable effective assessment of student differences we decided to create a conceptual diagnostic test that consisted of nine multiple-choice and open ended items. In the test we have used most common student misconceptions as distractors. We provided short description of the conceptual test items in the Table 1.

Table 1: Short description of the conceptual test items

Item 1	Item 2	Item 3	Item 4	Item 5
Determine linear velocity vectors at points on the wheel that is rotating around the center.	Determine linear velocity vectors at points on the wheel that is rolling down an incline.	How slipping of the car wheel's influences magnitudes of linear velocities of points on the wheel.	How the motion trajectory of the point on the cylinder edge looks like?	Comparetravelled distances of points on the bottom, center and top of the the cylinder.
Multiple-choice	Multiple-choice	Multiple-choice	Open-ended	Multiple-choice

Item 6	Item 7	Item 8	Item 9
What is the direction of linear velocity at point on the wheel's edge.	Writing an equation for the linear velocity at point on the wheel's edge.	Influence of inclination on the motion of the cylinder.	What is the maximum height that ball will reach during its motion in a hard material surface groove?
Multiple-choice	Open-ended	Multiple-choice	Multiple-choice

RESULTS

In order to detect between-gender differences we used analysis of variance (ANOVA) on the given nine items test. Results of ANOVA revealed that there was a statistically significant difference between male and female students on the selected test items, $F(1, 182)=7.098$, $p<0.01$, partial $\eta^2=0.038$.

In the following lines, we will focus our research on in-depth exploration of the four multiple-choice test items on which we discovered the biggest gender differences.

Table 2 provides a concise overview of students' achievement on four multiple choice test items.

Table 2: Summarized overview of correct answers average proportion for male and female students. Standard deviations are provided in parentheses.

	Item 3	Item 6	Item 8	Item 9
Male students	0.64 (0.48)	0.52 (0.50)	0.60 (0.49)	0.41 (0.49)
Female students	0.52 (0.50)	0.43 (0.49)	0.51 (0.50)	0.36 (0.48)

From the answers provided in the Table 2 it is evident that male students have better results than their female colleagues on all four test items. On the Item 3 we discovered most prominent difference (12%).

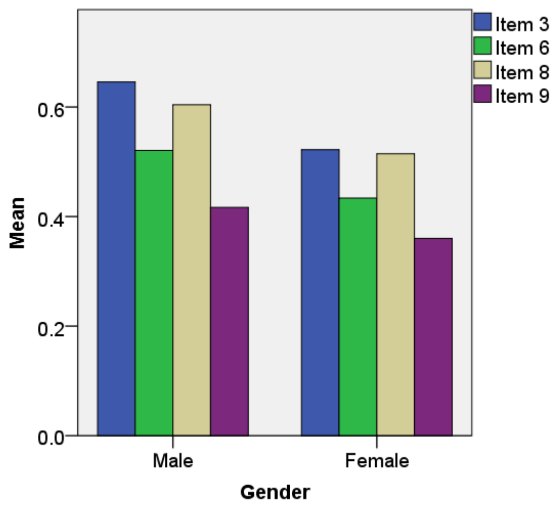

Figure 1: Mean value of the correct answers for the conceptual test items 3, 6, 8 and 9.

From Figure 1 we can see that the between-gender differences in correct answers mean value are pronounced for all four items.

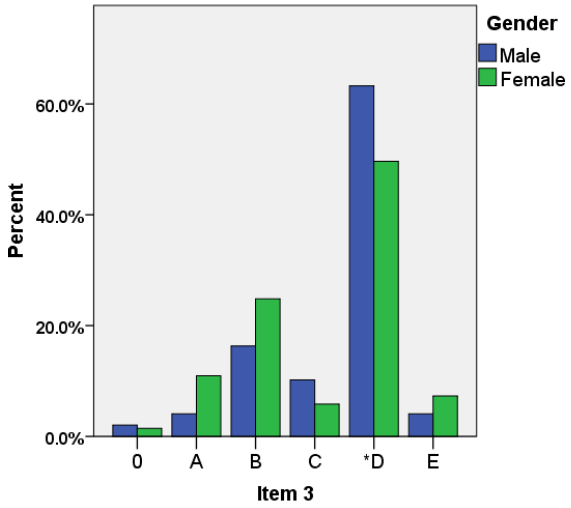

Figure 2: Percentage of chosen answers for the male and female students on the Item 3. Correct answer is labeled with asterisk. Zero indicates percentage of students that didn't choose any answer.

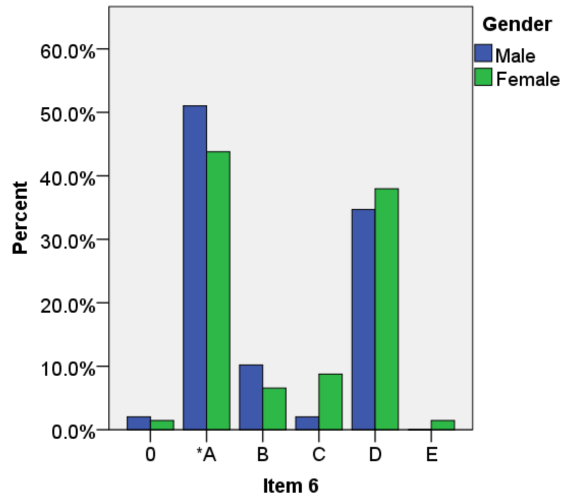

Figure 3: Percentage of chosen answers for the male and female students on the Item 6. Correct answer is labeled with asterisk. Zero indicates percentage of students that didn't choose any answer.

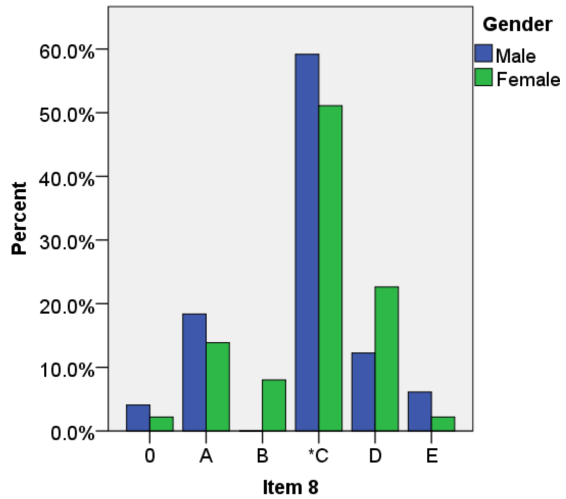

Figure 4: Percentage of chosen answers for the male and female students on the Item 8. Correct answer is labeled with asterisk. Zero indicates percentage of students that didn't choose any answer.

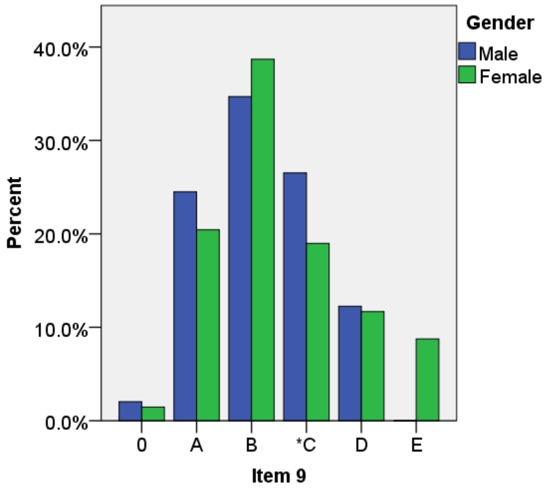

Figure 5: Percentage of chosen answers for the male and female students on the Item 9. Correct answer is labeled with asterisk. Zero indicates percentage of students that didn't choose any answer.

From the given figures, we received information about mean values and chosen answers on the items 3, 6 and 9 for the male and female students.

DISCUSSION

We should firstly mention that overall achievement in our sample was low on all four items but we can see from data provided in Table 2 that male students outperformed female students. However, we cannot say that these results are very surprising because previous research has shown that the concepts covered in our experiment have not been effectively addressed within traditional teaching. In the study from Rimoldini and Singh, none of the 16 students in the study did not explain the velocity at the top and bottom of the wheel relative to the ground, and they discover many difficulties with the application of the vwork-energy concepts (Rimoldini and Singh, 2005). Furthermore, low efficiency of traditional seminars is in line with Kim and Pak's research where they found that many students fail to solve conceptual problems even after they have completed more than 1000 traditional problems (Kim and Pak, 2002).

Most prominent between-gender differences on individual items

In this section, we will discuss the score differences between genders for the selected items.

In Item 3 students were required to reason how slipping of the car wheel's influence magnitudes of linear velocities of points on the bottom, center, and top. Visualizing the rolling process of the wheel could have facilitated creation of student mental models that were more compatible with scientifically acceptable knowledge. Scores of male students are 12% higher than female students.

In Item 6 students were shown a wheel of radius R that is rolling without slipping along the horizontal plane and they needed to find direction of linear velocity at point on the wheel's edge. Correct visualization and summing of the vectors resulted in accurate answer. Male students outperformed female students by 9%.

In Item 8 students were shown cylinder on an incline and they needed to visualize what will happen if the coefficient of static friction between the cylinder and the inclined plane amounts to zero. In order to answer this question correctly, students needed to visualize what happens with cylinder motion when it is in contact with the surface and static friction coefficient is changing. When the coefficient of friction decreases the cylinder is starting to slip and in the case of a completely smooth surface, it only slide. On this item male students scored 11 % higher than their female colleagues.

In Item 9 students needed to visualize how steel ball rolls down a groove to conclude the maximum height that will ball reach during its motion in a hard material groove. Ball is in contact with surface and students need to visualize collisions of the ball surface with the groove surface. Mechanical energy of the ball is transforming into elastic potential energy. Male students have 5% higher scores then their female colleagues.

According to the above results we can conclude that our research supports earlier studies where male students outperformed female students on visuospatial tasks (Voyer and Saunders, 2004; Peters, 2005; Maeda and Yoon, 2013).

Students' misconceptions and conceptual change

Next, we will discuss misconceptions that we identified for four test items.

In Item 3 students were required to reason about the influence of slipping on the velocity of the selected points on the wheel.

From Figure 2 we can see that the most common wrong answer for Item 3 was answer B (male students - 16%, female students – 46%). Incorrect answer B reflects the idea that the magnitude of linear velocity for all points on the wheel decreases when slipping occurs. A given example shows that male students have less often chose this misconception. It is possible that male students visualized better to make their mental models more compatible with scientifically acceptable knowledge.

In Item 6 students were required to reason about the direction of linear velocity of a point on the wheel.

From Figure 3 we can see that many students in this context apply rotation model, which is evident from the fact that they chose answer D (male students – 34%, female students - 38%). According to this answer, the velocity of the point at the wheel edge has the direction of the tangent at that point while the correct answer is the direction of the tangent to the trajectory point. This misconception in rolling motion is obtained by combining parts related to rotation and translational motion which has been identified in previous research (De Ambrosis, Malgieri, Mascheretti, and Onorato, 2015; Rimoldini and Singh, 2005). Male students have recognized accuracy of this motion in greater proportion.

Items 8 and 9 are addressing the role of static friction and mechanical energy in the rolling motion.

From Figure 4 it is obvious that the most common wrong answer for Item 8 was answer D (male students - 12%, female students - 22%). This answer reflects the misconception that the cylinder will roll on an incline (no slipping) for all angles of inclination. Our data is in accordance with the results of De Ambrosis, Malgieri, Mascheretti, and Onorato (2015). In fact, their study found that 40% of students did not recognize how the kinetic force of friction creates a transition from sliding to rotational motion of the ball, and 42% of students answered that the ball simply cannot slide on an incline without friction. It is no surprise that male students outperformed female students because in this item visualization is a key that unlocks correct answer.

From Figure 5 we can see that the most frequent wrong answer for Item 9 was answer B (male students – 34%, female students - 38%). It is evident from the results of answer B that more than 30% of students in both groups had a misconception that the effect of static friction results in the loss of mechanical energy of the rolling object. This result showed that students have generally realized that there is a static friction force, but they often believe that a static friction force does a negative work on the ball which leads to energy losses. Furthermore, most students realized that the work performed by the static friction force was equal to zero, but some students failed to recognize that the losses of mechanical energy due to micro-collisions were not negligible in this case.

Presented results are showing that male students outperformed female students on tasks that involve rolling which could be probably explained that male students can more successfully develop certain visual mental models of rolling which facilitate solving of chosen tasks (Nersessian, 2008; Greca and Moreira, 2000; Maeda and Yoon, 2013).

Both genders achieved lower scores on tasks that involve work-energy concept. The reason of lower scores could be more complex visualization of this phenomena which stimulated higher intrinsic load and negatively affected scores of both genders (Sorden, 2005).

Finally, it should be noted that the findings of our study are limited to the contexts of introductory courses in physics for scientists and engineers at the university level. Main limitation of our study is related to the relatively small number of test items which can be justified by using narrow field of measurement i.e. rolling and work-energy principle.

CONCLUSION

In this study, we have investigated the difference in achieved scores between male and female students on answers related to the rolling and work-energy principle. We have found that male students outperformed female students when solving these problems. The most prominent differences were on the tasks that required visuospatial reasoning. It is useful to emphasize that among visuospatial skills is also the ability of intuitively choosing an appropriate system of reference i.e. to choose between the laboratory system and the system where the center of wheel is at rest. Presented results support earlier findings that students in traditional introductory physics courses fail to develop a deep understanding of velocity at the top and the bottom of the rolling body, as well as the application of the laws of conservation of mechanical energy in the context of body rolling. Furthermore, these results supports past findings in which male students outperformed female students in the tasks related to three-dimensional mental rotation ability and visuospatial tasks (Voyer, Voyer and Bryden, 1995; Maeda and Yoon, 2013). Based on the findings from our and other studies we strongly believe that it would be beneficial for female student population if teachers put an emphasis on visualization and enrich their lectures with visually abundant models that could improve visuospatial skills. In future research related to understanding of rolling and work-energy principle it would be useful to conduct a mixed research design that will allow us further explore the content and structure of students' mental models (Creswell and Clark, 2011).

REFERENCES

Cherney, I. D. (2008). Mom, let me play more computer games: they improve my mental rotation ability. Sex Roles, 59, 776–786.

Creswell, J. W. & Clark, V.L.P. (2011). Designing and Conducting Mixed Methods Research (2nd ed.). California: Sage Publications.

De Ambrosis, A., Malgieri, M., Mascheretti, P., & Onorato, P. (2015). Investigating the role of sliding friction in rolling motion: a teaching sequence based on experiments and simulations. European Journal of Physics, 36(3), 035020.

Deno, J. (1995). The relationship of previous experiences to spatial visualization ability. Engineering Design Graphics Journal, 59, 5–17.

Fischer, F., Schult, J., & Hell, B. (2013). Sex differences in secondary school success: Why female students perform better. European journal of psychology of education, 28(2), 529-543.

Ginn, S. R., & Pickens, S. J. (2005). Relationships between spatial activities and scores on the mental rotation test as a function of sex. Perceptual and Motor Skills, 100, 877–881.

Greca, I. M., & Moreira, M. A. (2000). Mental models, conceptual models, and modelling. International journal of science education, 22(1), 1-11.

Jordan, K., Wüstenberg, T., Heinze, H.-J., Peters, M., & Jäncke, L. (2002). Women and men exhibit different cortical activation patterns during mental rotation tasks. Neuropsychologia, 40, 2397–2408.29-543.

Kim, E., & Pak, S. J. (2002). Students do not overcome conceptual difficulties after solving 1000 traditional problems. American Journal of Physics, 70(7), 759-765.

Koscik, T., O'Leary, D., Moser, D. J., Andreasen, N. C., & Nopoulos, P. (2009). Sex differences in parietal lobe morphology: relationship to mental rotation performance. Brain and Cognition, 69, 451–459.

Lohman, D. F. (1996). Spatial ability and G. In I. Dennis & P. Tapsfield (Eds.), Human abilities: their nature and measurement (pp. 97–116). Hillsdale, NJ: Erlbaum.

Maeda, Y., & Yoon, S. Y. (2013). A meta-analysis on gender differences in mental rotation ability measured by the Purdue spatial visualization tests: Visualization of rotations (PSVT: R). Educational Psychology Review, 25(1), 69-94.

Nersessian, N. J. (2008). Creating Scientific Concepts. London: The MIT Press.

Peters, M. (2005). Sex differences and the factor of time in solving Vandenberg and Kuse mental rotation problems. Brain and Cognition, 57, 176–184.

Reiner, M., Slotta, J. D., Chi, M. T., & Resnick, L. B. (2000). Naive physics reasoning: A commitment to substance-based conceptions. Cognition and instruction, 18(1), 1-34.

Rimoldini, L. G., & Singh, C. (2005). Student understanding of rotational and rolling motion concepts. Physical Review Special Topics-Physics Education Research, 1(1), 010102.

Sorden, S. D. (2005). A cognitive approach to instructional design for multimedia learning. Informing Science, 8.

Thomas, H., & Kail, R. (1991). Sex differences in speed of mental rotation and the X-linked genetic hypothesis. Intelligence, 15, 17–32.

Voyer, D., Voyer, S., & Bryden, M. P. (1995). Magnitude of sex differences in spatial abilities: a meta-analysis and consideration of critical variables. Psychological bulletin, 117(2), 250.

Voyer, D., & Saunders, K. A. (2004). Gender differences on the mental rotations test: a factor analysis. Acta Psychologica, 117, 74–94.

Linn, M. C., & Petersen, A. C. (1985). Emergence and characterization of sex differences in spatial ability: A meta-analysis. Child development, 1479-1498.

Summary/Sažetak

U ovom istraživanju fokusirali smo se na provjeru spolnih razlika u konceptualnom razumijevanju kotrljanja (brzine i principi povezani s radom i energijom. U tu svrhu odabrali smo devet konceptualnih zadataka i proveli istraživanje na 184 studenata prve godine na Fakultetu kemijskog Inženjerstva i tehnologije, Sveučilišta u Zagrebu. Rezultati pokazuju da su studenti značajno nadmašili studentice. Osobito značajne razlike otkrili smo u zadacima koji testiraju znanje o brzinama kod kotrljanja. Rezultati našeg istraživanja mogu pomoći nastavnicima u stvaranju lekcija prilagođenih općoj studentskoj populaciji.