Game-Based Learning while Research Activities of Engineering Students

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Abstract—This work describes the experience of Tomsk Polytechnic University in involving students in scientific research. The involvement is to be achieved by including scientific research elements into laboratory class programs, game-based learning, conducting laboratory classes in real-life scientific research facilities, including "Scientific research work for students" into Bachelor's curriculum (starting the second grade) and other actions. The experience described should be considered a success, as over the last decade the number of Bachelor's graduates at TPU willing to pursue the Master's degree (and then do postgraduate studies) has multiplied. The competition for enrolling into postgraduate studies has increased as well.

Keywords—game-based learning, laboratory practicum, active learning, scientific research activities, team training, engineering education

1 Introduction

Tomsk Polytechnic University (TPU) is ranking fourth domestically and is the oldest institute of technology in the Asian part of Russia. In the last decade, the university has set a goal to get high rankings in the top part of major international ratings. The development of a research university is implausible without involving students into scientific research, starting from their junior years.

The research work this annotation is a part of describes the university's experience in involving junior grade students in scientific research. The above goal is to be achieved by including scientific research elements into laboratory class programs, game-based learning, conducting laboratory classes in real-life scientific research facilities, including "Scientific research work for students" into Bachelor's curriculum (starting the second grade) and other actions.

The experience described should be considered a success, as in the last decade the number of Bachelor's graduates at TPU willing to pursue the Master's degree (and then do postgraduate studies) has multiplied.

2 Background

Tomsk Polytechnic University was founded in 1896 as an institute for training practicing engineers. From the very onset, TPU has become the heart of engineering and technical creativity in the Russia's Asian part. From the very beginning of its history, the institute has conducted scientific research within the frame of professional training, and, of course, the students were involved as well. In engineering sciences, the demarcation line between scientific research and engineering development is very thin, if sometimes noticeable at all.

That is why serious scientific research projects have been developed in engineering student project groups (created under the auspices of the respective institute departments as early as in the beginning of the 20th century). Thus, in 1913 the aeronautics department student group directed by professor B.P. Veinberg has built the world's first experimental maglev. In 1927 students from the same team, but this time directed by professor G.V. Trapeznikov, built Siberia's first airplane whose engine was created by students from another department's group (thermal engineering) directed by professor A.V. Kvasnikov.

In 1953 in the radio engineering department's group directed by associate professor V.S. Melikhov, an amateur TV broadcast station was created that has laid foundation for Tomsk TV broadcast station, the fifth of a kind in the USSR. In all of the above cases, engineering design development was preceded by deep scientific research [1, 2, 3].

Still, despite all these (and other) success stories, the cultivation of student-driven scientific research through science groups is obviously not enough to position the university as a major research center.

3 “Training through collaboration”, a pedagogical technology for game-based learning

The theoretical foundation for this technology was laid by American teacher John Dewey, 1916. In Russian pedagogy science, "training through collaboration" has acquired widespread acceptance, thanks to the works by Ye.S. Polat [4, 5].

According to Ye.S. Polat, "training through collaboration", as different from the traditional forms of group work, is peculiar for the following aspects:

1. Mutual dependence of all group members
2. Personal responsibility of each group member both for their own success and for the success of other fellow members

3. Joint educational, cognitive, creative and other activities of students in a group
4. Student activity socialization in groups
5. Overall group activities are evaluated by adding up the results of assessing students' form of group communication as well as their academic achievements.

The implementation of education through collaboration is underpinned by a common system. The teacher selects students to form a group. Each group should be formed to include students with a varying level of command of the foreign language, different experience of collaborative educational efforts, the group should be a mix of genders, etc. Such principles of selection give each team member a real opportunity to develop the necessary skills in the course of collaborative project delivery. Also, it is obvious that there a different skill set will be developed by each member. For students lacking in linguistic proficiency, that would be language communication skills. For students with high linguistic proficiency, the skills acquired previously will develop, as well as leadership skills, the ability to organize team education, etc.

1. Each group is given a problem that requires each member to participate in the solution. Roles are allocated between group members, and each is provided with a separate work cluster.
2. Each group is given a set of required materials (one text copy, one set of exercises, one web page to keep track of the project, etc.).
3. One mark is given to the whole group for the project delivery [6, 7, 8].

The peculiarity of the "education through collaboration" pedagogical technology is that each participant is responsible both for their part of the job and for the entire project. Eventually, it is not the work of every single team member that gets evaluated. It is the result of the collaborative effort. The final product will tell how the students managed to collaborate. This teaching technology encourages communication and teamwork to achieve the best result.

The general experience of project work shows that education through collaboration as a pedagogical technology for game-based learning may become efficient for groups of 4-5 persons with varying level of competence. It can be presented as a part of blended learning [9, 10]. While working together on the project, the participants are inherently placed into a situation when the project can be delivered, and positive results can be achieved through collaboration only. In the meantime, in the course of project delivery, the team decides which member is capable of leadership and who is apt for research activities and who is more comfortable as a doer.

4 Possible solutions to the problem

The first step to solve this problem was the introduction of scientific research elements into the laboratory practicum, utilizing the "training through collaboration" technology as game-based learning. Laboratory practicum is an integral part of engineering and natural science courses and is a required activity for all students without exception. Traditionally, a student group is broken into teams, three to five persons each. Each team's program is compiled in such a way, so that it's impossible to complete it without role allocation and personal responsibility of each student for their respective part of the common effort. Such workflow is applied for all laboratory practicum as training through collaboration, irrespective of the university department. Role allocation is done by team members, and the teacher is not getting involved in any way. However, the teacher takes notes which roles which students take. Later on, this information is useful for outlining the student's education path and deciding whether to offer the student to participate in real scientific research, send the student to work at an industrial plant or in a scientific laboratory or recommend them to pursue Master's or Specialist's degree, or to graduate with Bachelor's. Of course, role allocation alone is not enough to draw conclusions about aptitudes and capabilities. Still, when putting together a student's profile, this information may come handy.

Starting with the second grade already, students are taught to correctly set up experiments and are required to substantiate their choice of the physical model of the researched process/ phenomenon as well as the experimental toolset. It is also important to teach students how to process experimental results. At the department of experimental physics and general physics, this is taught as early as the 1st semester of the Bachelor's course [11, 12, 13]. Since teaching physical and technical subjects is the current work authors' specialty, the examples are taken from the departments of the respective profiles. The result of this training is the convincement of a student that any natural science experiment is an event with certain probability, so the result thereof must be treated accordingly. Further on, when experiments are set up and conducted in the course of other laboratory courses and educational and scientific research efforts are carried out, the students do not feel repulsion or have difficulties doing multiple repeat measurements (i.e. collecting statistical material) and further statistical treatment of the experimental results [14, 15, 16].

Starting from the first grade of Bachelor program, scientific research elements are included into the laboratory works curricula. For example, for the work "Determining the free fall acceleration", the department of experimental physics suggests that students not only determine the acceleration but also calculate the dependency between the free fall acceleration and the latitude, taking into account the Coriolis force and the altitude above sea level. The department of electric networks and electric engineering suggests that when performing the laboratory work "Emission of a two terminal circuit", the dependency of the output parameters of the circuit on the load intensity and type as well as internal impedance of the circuit should be researched. Also, the conditions for matching an active two terminal circuit with the load are to be determined.

Correctly documenting the research results is another important aspect. That is why specific attention is paid to adequately composing laboratory work results. Students might think those are just teachers' critiques but we need students to achieve understanding that a research result only matters when it is has been made publicly available to scientists. Therefore, the publication must be easily readable and comply with the academic standards.

Senior grade Bachelor students get access to experimental facilities and installations that were used (or are used) for real scientific research. This way, the department of high voltage electricity physics and high current electronics uses the installation described in [7] (see Figure 1). A research of the characteristics of contaminated insulation of overhead power transmission lines (a real-life scientific research) was performed on that installation.

Fig. 1. Insulator testing unit

At the Physical and technical institute, a series of laboratory courses have been developed for the operational scientific nuclear reactor IRT-T (see Figure 2, 3), that is actively used for scientific research and isotope production. Now it is also used in the students' laboratory courses.

Fig. 2. A group of students at the IRT-T reactor

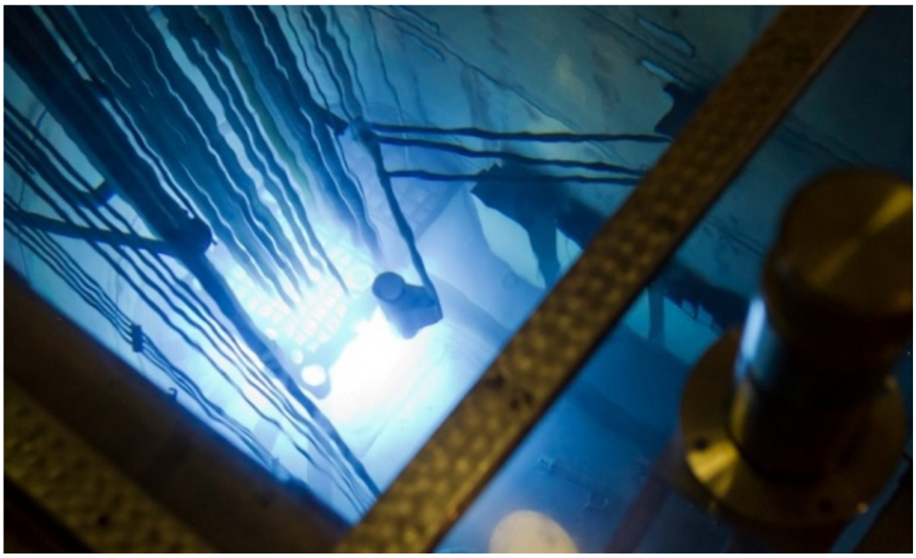

Fig. 3. Reactor`s active zone

The next step is introducing discipline named "Educational and research work for students" into the curriculum of virtually all engineering specializations. This discipline is taught starting the second grade of Bachelor's degree course. Within the scope of this discipline, sets of lectures are delivered to students: bibliographic search, theory of inventive problem solving, rules and techniques for preparing research publications, etc. This is very useful for a future researcher: student will already be able to properly handle experimental equipment, thanks to laboratory practical trainings on chemistry, physics, theoretical and applied mechanics and electrical engineering. Then, with the assistance from their mentors, the students will gain the expertise and skills that they lack in when they start real research work. However, it is equally important to correctly set the research goal, define the approaches to its solution, choose the adequate physical model for setting up the experiment and choose the mathematical model for processing the experimental results. Besides, as we have already mentioned, any research result is only worthy if it becomes publicly available.

Starting from the second grade, students work with literary sources pertinent to their specialization and write papers on topics set by their academic advisors. For solving real research objectives, third grade students are assigned to labs. There they participate in experimental research in conditions that are as close to real life as possible, the whole process based on game-based learning used together with "training through collaboration" [18]. By that time, the students will have had enough time to study the research topics and to master experimental research methods. It allows them to become co-authors of articles written by their academic advisors and deliver reports at international science conferences.

Thus, by the moment when a student earns their Bachelor’s degree, they will have become a full-featured member of a scientific research team. The student will have a set of science research skills, from setting the goal to adequately interpreting experimental results. Such students’ graduation papers are normally based on the results of real scientific research conducted in the laboratory where they have been studying. In most cases, such papers are the starting point of more serious works performed to pursue Master’s degree.

For Master's Degree students, scientific research involvement is the cornerstone of their curriculum. Master's Degree students can only pass graduation certification if they have published an article or delivered a report at a science conference. The paper itself is called a dissertation (i.e. “a document submitted in support of candidature for an academic degree or professional qualification presenting the author's research and findings” [19, 20]) for a reason.

5 Conclusion

The above efforts have allowed for substantially increasing students' interest and motivation towards scientific research activities. There is a steady annual inflow of graduates (between 900 and 1100 Bachelor degree holders) who choose to continue their education and seek Master's degree. Also, about 200 Master degree holders go for post-graduate. It is also worth noting that in the recent four years, the number of graduates who have chosen science research as their profession is increasing, year to year. As of current, over 80% of Master degree students have received their Bachelor’s degree at TPU. You can decide for yourself whether this is good or bad, depending on how you look at it. On one side, when students from outside TPU come to TPU to pursue Master's degree, it is a win because it means TPU's popularity in the education community increases, domestically and internationally. On the other hand, candidates compete to enroll into Master's course (in 2016 the competition was 2.5 contestants per vacancy). So, if more students of Tomsk Polytechnic University succeed, that means they are better prepared. Being experience in d scientific research activities, gained in the frames of education through collaboration as a pedagogical technology for game-based learning let Master's degree students take an active part in international scientific and educational areas in the frames of international collaborative projects and funds. It is possible to implement not only while studying but in the future professional work.

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7 References

[1] Mapelli, C., Klochkov, N. S., Egorov, U. P., and Zabrodina, I. K., Tin and nickel influence on the structure and properties of the leaded bronze obtained by means of the centrifugal casting. Solid State Phenomena, International Conference on Industrial Engineering, May 2016, 870: 248-252

[2] Bychkov, P. N., and Solodovnikova, O. V., Influence of the Radiation Destruction of Polymeric Insulation on its Ageing in the Impulse Electric Field. Advanced Materials Research, 2014, 880: 88-92

[3] Uskov, V. L., Bakken, J. P., et al., Smart pedagogy for smart universities. Smart Innovation, Systems and Technologies. 4th International KES conference on Smart Education and Smart e-Learning, SEEL 2017, 75: 3-16

[4] Caballero- Hernández, J. A., Palomo-Duarte, M., et al., Skill assessment in learning experiences based on serious games: A Systematic Mapping Study. Computers and Education, 2017, 113: 42-60 https://doi.org/10.1016/j.compedu.2017.05.008

[5] Kao, G. Y.-M., Chiang, C.-H., and Sun, C.-T., Customizing scaffolds for game-based learning in physics: Impacts on knowledge acquisition and game design creativity. Computers and Education, 2017, 113: 294-312 https://doi.org/10.1016/j.compedu.2017.05.022

[6] Rulevskiy, V. M., et al., Mathematical model for the power supply system of an autonomous object with an AC power transmission over a cable rope. IOP Conference Series: Materials Science and Engineering. 2017, 177, 1: 012073

[7] Kim, B., Park, H., and Baek, Y., Using meta-cognitive strategies in game-based learning. Computers and Education, 2009, 52: 800-810 https://doi.org/10.1016/j.compedu.2008.12.004

[8] Pringle, J. K. Educational egaming: the future for geoscience virtual learners?. Geology Today, 2012, 30, 4: 147-150 https://doi.org/10.1111/gto.12058

[9] Dostal, J., Educational software and computer games – tools of modern education. Journal of Technology and Information Education, 2009, 1, 1: 24-28 https://doi.org/10.5507/jtie.2009.003
[10] Gee, J. P. Video Games: What They Can Teach Us About Audience Engagement. Nieman Reports, 2010: 52-54
[11] Bainbridge, W., The scientific research potential of virtual world. Science, 2007, 317, 27: 471-476 https://doi.org/10.1126/science.1146930
[12] Squire, K., and Gaydos, M., Role playing games for scientific citizenship. Cultural Study of Science Education, 2012, 7: 821-844 https://doi.org/10.1007/s11422-012-9414-2
[13] Barab, S., Scott, B., et all., Transformational play as a curricular scaffold: Using video-games to support science education. Journal of Science Education Technology, 2009, 18: 305-320 https://doi.org/10.1007/s10956-009-9171-5
[14] Lin, G. H. C., Kung, T. W. T., and Chien, S. C., Computer Games Functioning as Motivation Stimulants. International Conference on Computer Assisted Language Learning, 2011: 148-155
[15] Bevington R., and Robinson, D. K., Data Reduction and Error Analysis for the Physical Sciences. 3nd. edition, McGraw-Hill, NY, 2003
[16] Bychkov, P. N., Zabrodina, I. K., and Shlapak, V. S., Insulation contamination of overhead transmission lines by extreme service conditions. IEEE Transactions on Dielectrics and Electrical Insulation. 2016, 23, 1: 288-293 https://doi.org/10.1109/TDEI.2015.005323
[17] Falloon, G., Using avatars and virtual environments in learning: what do they offer?, Journal of Educational Technology, 2011, 41, 2: 108-122
[18] International Standard ISO 7144: Documentation – Presentation of theses and similar documents, International Organization for Standardization, Geneva, 1986
[19] Reynolds, C., Patton, J., Rhodes, T., Leveraging the e Portfolio for Integrative Learning: a Faculty Guide to Classroom Practices for Transforming Student Learning. Sterling: Stylus Publishing, 2015
[20] Barr, M., Video games can develop graduate skills in higher education students. Computers and Education, 2017, 113: 86-97 https://doi.org/10.1016/j.compedu.2017.05.016

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