Practical Aspects of Teaching via the Group-Based Learning Environment

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Abstract

As a result of the modern phenomenon of globalization, accrediting agencies and employers alike are emphasizing the importance of non-technical (also called key, transferable, or generic) skills (critical thinking as in design, group skills, and communication skills) in engineering education in addition to the traditional technical skills. While the use of group activities within the context of active, student-centered learning in the basic lecture-based learning environment provide students the opportunity to learn key skills to an extent[1,2], those skills are better learned in the group-based learning environment[3,4,5], the two main examples of which are problem-based learning (PBL) and project-based learning. There are, however, many uncertainties regarding how best to teach or facilitate learning in the group-based learning environment. This paper discusses some of those issues and summarizes the results of a year-long practical study to determine some best practices in this approach to teaching and learning.

Introduction

Many studies[1,2] have shown that lecture-based active student-centered learning (SCL) methods can be very effective at improving the depth of students' understanding of the technical concepts being addressed. However, in recent years, accrediting agencies in Ireland, the United Kingdom, Australia and the United States have identified several other critical issues that need to be addressed in modern engineering schools[6]. These include problem-solving skills (critical thinking and design), communication skills, and teamwork skills. Known alternately as key, transferable, or generic employability skills[7], they can be taught and learned much better in the group-based learning environment than in the lecture-based environment[3,4,5]. In fact, when viewed from the perspective of constructive alignment[1], group-based learning is more directly aligned with the attainment of a greater number of key skill learning outcomes than is lecture-based learning.

Types of group-based learning activities include problem-based-learning (PBL) and project-based learning, which are very similar, distinguished perhaps by an emphasis on acquiring technical and key skills in PBL versus an emphasis on application of those skills in project-based learning. In either case, teams of students are given open-ended, unstructured, real-world problems to solve without the benefit of relevant prior in-depth lecture-based instruction[2]. They follow a certain but imprecise scheme that defines good group work[3]; they are often assisted and facilitated by tutors who perform in a certain but imprecisely defined way; and both the team's performance as a working group (the process) and their technical results (the product) are assessed in various unperfected ways.

Group-based learning, particularly PBL, has been used successfully for many years in medicine[8] and other health-related disciplines such as veterinary medicine and nursing[2], as well as in physics education[3]. It has been introduced in engineering education[9] also, but it has not become as widely used there as in the other fields, probably because of fundamental differences among the various disciplines, especially between medicine and engineering[6,10], which make it more difficult to apply to engineering education. Thus, there is still much to learn about the practical aspects of using group-based learning to teach engineering. To this end, a year-long practical study was conducted to determine some "best practices" regarding the group-based learning environment in general and the tutoring and assessment processes in particular. The following sections include a description of the study and some resulting recommendations concerning group work, tutoring, and assessment.

The Program

The study was conducted by the authors as part of a Fulbright Fellowship to study and conduct research on active student-centered learning, including group-based learning, at the Dublin Institute of Technology (DIT) in Dublin, Ireland. To study group-based learning, the authors served as learning-group tutors in the laboratory sessions of three different lower level undergraduate courses in the School of Electrical Engineering Systems. Those courses were one in basic instrumentation, one in signals and systems, and a robotics sumo-wrestling (Robo Sumo) project course. While the three courses were managed differently from each other in certain ways, they had in common that their laboratory components followed similar formats. In the Instrumentation and Signals and Systems courses, the students conducted five and three multi-week projects throughout the semester, respectively, whereas the Robo Sumo course consisted of a single project lasting the entire semester. In all three cases, however, the students were given virtually no relevant technical instruction prior to being presented with the project statements, and they conducted the projects in teams of mostly three students, which were formed either randomly by the course instructor or by the students themselves. Also, as these were lower level courses, the students involved had little or no prior experience working in groups, dealing with tutors, or with the associated assessment instruments, which influenced the evolution of the process as the year progressed.

The process of group work that the teams of students were required to follow was a slight variant of the basic seven-step process used for years in medical education[11]. In each of the three courses the process was applied slightly differently, but in all cases the essential elements of brainstorming, forming hypotheses, determining learning needs and assigning associated tasks to individual team members in team meetings, performing self-study and assigned tasks between meetings, and reporting back (a form of peer instruction) on the results of assigned tasks at subsequent meetings were always present.

The general role of the tutors consisted of three basic tasks: facilitating and encouraging the group process described above; observing and assessing individual contributions to the group process; and facilitating technical learning[12]. It is relatively easy to see what is required by each of these tasks, but implementing them successfully in practice was very challenging. One way of doing so, and which was used in this program, is to use Socratic inquiry[12]. In Socratic dialog, the tutor asks a series of questions which encourage the student to critically analyze (and hopefully ultimately solve) the problem. The degree of guidance provided can be varied (through the tutor's choice of questions) to reflect the individual needs of the student. Questions that "spoon-feed" or essentially give the solution away should be avoided. However, doing this well requires experience related to: knowing when to ask questions related to the group process or to the technical product; knowing whether to pose the questions to individuals in the group or to the group as a whole; and knowing when to intervene at all, rather than allowing the group to continue on their current course of action. Novices to group work require greater amounts of contact time (intervention) from the tutor, who should initially focus on the development of group work (process) skills among the members of the group and not just on the technical results produced by the group[13]. Group work skills include group discussion, managing self-directed tasks, and critical thinking, which overlap with the above-mentioned key skills associated with employability. Another challenge for the tutor is dealing with the group dynamics that arise from personality and work ethic differences among group members.

Assessment

Assessment varied somewhat among the three courses. In the Instrumentation course, student teams conducted five projects. Assessment was divided between technical results (product) and group work (process). For assessment of technical results, each project culminated in either a written report (one case), a poster paper (two cases), or a team presentation (two cases). Group work was assessed by instructor and tutor observation and a one-page reflection submitted by each student at the end of each project. Instructors assessed these items (assessment instruments) and provided written and verbal feedback to each student that was both formative, because it could be used by the students to improve subsequent work, and summative, because the assessment score contributed to the student's final "grade" in the course. The instructor of the course noted that the assessment scheme worked reasonably well, but it required significant work by the instructor.

In the Signals and Systems course, student teams conducted three projects. At the end of each project, one student (a different one for each project) submitted a written report, which was assessed by the instructor for structure and layout, writing style, quality of the technical content, and the quality of the Matlab code that was needed to solve the problem. By the end of the term each student had written and submitted one report. In addition, based on instructor and tutor observations during project laboratory sessions, each member of the group was given a written assessment of his technical contribution to the project, his communication skills within the group, and his learning of Matlab. Thus, both assessment instruments, i.e., the student reports and the instructor-written reports, assessed both group work and technical results. They were also used both formatively and summatively, as in the Instrumentation course. The course instructor was reasonably satisfied with the assessment scheme used, but in the future he plans to add an assessment activity in which students provide regular evidence of tasks completed throughout the semester, i.e., via a notebook or on-line Wiki page, as in the Robo Sumo project course, discussed below.

Finally, the semester-long Robo Sumo project consisted of four assessment instruments. Two of them, individual contribution to the group process and individual contribution toward achieving technical goals, were assessed with regular written formative feedback. A third one, establishment of and regular updates to a Wiki page with information on accomplishment of individual tasks, was also assessed with regular written feedback; this assessment instrument was both formative and summative because the associated learning outcome was for students to demonstrate accomplishment of semester-long record-keeping regarding individual task accomplishment. The final assessment instrument, the actual performance of each team's robot in the "wrestling" competition at semester's end, was assessed summatively, of course. The instructors were satisfied with the assessment scheme, although a fifth component, evaluation of a video presentation by each group, could not be conducted because of insufficient time.

Lessons Learned: Good, Rather Than Best, Practices

The lecturers and tutors (the authors) met regularly throughout the above-described program to discuss their experiences. As a result, good practices evolved, and at the end of the program, several features were identified as being very useful in the group-based learning environment. Since these "findings" are based on observations from only three semester-long courses over a school year, it would be premature to call them "best" practices, so instead they are called "good" practices here.

First, concerning administration of a group-based course, an orientation or induction meeting of instructors, tutors, and students should be held at the beginning of the course to introduce students to the group-based learning environment, including the model of group work to be used, the role as well as authority of the tutors, and whatever assessment instruments are to be used. It should be made clear that group work itself (the process) will be assessed as well as the technical results (the product). In group work, students should contribute and actively participate in team meetings, be respectful of others' input, and do assigned tasks on time. To emphasize the importance of the group process and motivate students to engage with it, group work should be explicitly included as an intended learning outcome (ILO) for the course.

Second, much has been written about the ideal size of and methods of forming learning groups. During the study, it was found that a group size of three or four students was optimum for working on laboratory-based projects, but such small groups generally require more tutors and laboratory resources than are available, so that a compromise may be required. Concerning group formation, some instructors allow students to form the groups themselves, and other instructors prefer to do it themselves, by selecting members for groups randomly. However the groups are formed, instructors agreed that, to encourage success, each group should include at least one reasonably strong or responsible student.

Third, concerning the tutoring process, since no two tutors are identical, either in technical ability or in group work facilitation skills, a lack of consistency, for example, in their interpretations of self-directed learning, could cause students to revert to rote learning[14], which would defeat the purpose of group-based learning. Thus, the “roving tutor” concept, in which each tutor is responsible for working with every student group, is preferred to the option of assigning specific tutors to specific groups. Also, in order to solve the problem or complete the project, student learning needs are ultimately related to fundamental technical issues, so tutors should be reasonably expert in the technical subject of the problem or project, particularly in lower level courses, where students are predominantly acquiring, rather than applying, technical knowledge[6,10]. Finally, as mentioned above, good tutoring requires expertise, which can only be acquired with experience in knowing, for example, when to intervene, whether to ask questions related to process or product, and whether to address questions to the group or individual group members.

Finally, concerning assessment, it was found that between the two principal items, i.e., the group process and the technical product, learning and assessment of group work should be heavily emphasized early in the course, and as students become comfortable with it, greater assessment emphasis can be placed on the technical product. This is probably most true in lower level courses (the early years of the degree program and the subject of this work), when students are unfamiliar with the whole group-based learning phenomenon. As they mature and become familiar with it, group work and group skills can, hopefully, be treated as prerequisite prior knowledge and not emphasized as heavily.

One good way to assess learning of the group process is for the tutor to observe a team meeting, at which the various above-mentioned components of brainstorming, hypothesizing, determining learning needs, assigning tasks, and reporting on the results of self-study should take place. It was found that such meetings were most productive if held at a location away from the laboratory bench where the technical work was being done, e.g., a table at the front of the lab or, ideally, in an appropriate room off to the side. Also, group members should alternate chairing the meetings in order to steer the group process and allow each member to develop the skills of the chairperson.

Although there are many possible assessment instruments available for the group-based learning environment, one that was found to be especially effective is the use of either a physical notebook or an online “notebook” such as a Wiki page, for students to record evidence of completion of tasks assigned during team meetings. This notebook can also be used by the student to record ideas generated during reflection on his or her work. A good reflective practice is an important skill in itself[4], but it is also the first step in developing good self- and peer-assessment skills[4], additional possible assessment instruments for the group-based learning environment[15], that were not used to any significant extent throughout the program.

Regardless of which assessment methods are used, care should be taken to ensure that both the group work process and the technical product are both assessed adequately, as promised in the orientation, and that helpful formative feedback is provided in both cases. Finally, care should also be taken to ensure that the tutors don't over-prescribe assessment tasks that burden themselves with unreasonable amounts of work.

Conclusion

The group-based learning environment, in which students solve open-ended problems and conduct lengthy projects by working in teams in a manner at least similar to the one described here, is probably the most ideal setting for learning the non-technical transferable skills that engineering employers and accrediting agencies are emphasizing as being so important for today's engineering graduates. However, teaching via this method is unfamiliar to most engineering instructors, and best ways of doing so have not been identified and widely agreed upon. The "good" practices identified in this study should hopefully help with this, but many questions remain to be answered, particularly concerning the role of the tutor. In fact, it may be that there is not likely to be a "one-fits-all" prescriptive approach to tutoring. A tutor's approach will vary considerably depending on his or her personality and style, in much the same way that there are different ways to managing people in general. There is not necessarily a right or best way. Instead, what might be needed is a set of guidelines that support a variety of good approaches.

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Robert O'Connell received the B.E. degree in electrical engineering from Manhattan College and the M.S. and Ph.D. degrees in electrical engineering from the University of Illinois. He is a Professor of Electrical and Computer Engineering at the University of Missouri-Columbia and a registered Professional Engineer. He recently completed a Fulbright Fellowship in the School of Electrical Engineering Systems at the Dublin Institute of Technology in Dublin, Ireland, during which he studied modern teaching and learning methods for engineering education, including student-centered and group-based learning.

Gavin Duffy earned undergraduate and Master's degrees in chemical engineering from University College, Dublin. After gaining several years' experience in instrumentation and control in industry, he joined the School of Electrical Engineering Systems at the Dublin Institute of Technology, where he is now a full time lecturer. He has interests in engineering education, and he recently completed a MSc degree in Applied eLearning at DIT.

Ted Burke received BE, MEngSc and Ph.D. degrees in electronic engineering from University College Dublin, Ireland. He is a lecturer in the School of Electrical Engineering Systems at the Dublin Institute of Technology, where he teaches computer programming, embedded systems, robotics and biomedical engineering using student-centered learning approaches. He is a founding member of the TeaPOT research group, which conducts research into novel modes of interaction between humans and technology.

David Dorran earned honours undergraduate and Ph.D. postgraduate degrees in electrical/electronic Engineering from the Dublin Institute of Technology. He has worked in industry in both a hardware and software engineering capacity, and he is currently a lecturer in the School of Electrical Engineering Systems at the Dublin Institute of Technology. He was instrumental in forming the Institute's Audio Research Group. His current research interests are in the area of speech transformations and audio processing, and he is also involved in promoting a group-based project-driven learning environment for undergraduate students.