POGIL and reflection: a perfect duo to increase students´ performance in a General Chemistry course for Engineering careers

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ABSTRACT

Active learning has proven to be an effective way to approach teaching and learning in the 21st century compared to traditional teaching. In the traditional teaching formats, there was almost no interaction or room for the student-teacher and student-student interactions, and not to mention for reflecting on the process of learning. Teaching and learning in Engineering is not an exception when it comes to move from traditional to active learning to place students in the center of the teaching and learning process. The General Chemistry course for first year students, from five different Engineering specialties, at the University of Engineering and Technology (UTEC) was only passed by 49 to 59% of the students, and with failing percentages around 40 to 42% under traditional teaching methods. Then, the challenge was to increase students´ performances and to find active methodologies to teach chemistry as a general course for engineering students whom not necessarily continue with other chemistry courses in their curricula. These groups of students include: Energy, Electronic, Industrial, Mechanics and Chemistry Engineering fields. Chemical Engineering students are the only group having upper level chemistry courses in their curricula. The implementation of POGIL as a way to improve students' chemistry content knowledge, key process skills such as problem solving, deductive reasoning, communication, self-assessment, team-work, and time management have shown to increase students´ performances from 54 to 85% approximately in the first semester of its implementation, compared to 2 previous semesters of traditional teaching. Additionally, by reflecting on their learning progress, engineering students have the opportunity to recognize the need of lifelong learning and the importance of chemistry in their daily life despite their career field, and as an important tool to communicate and relate to other engineering tracks. Student-centered methodologies, specifically process-oriented guided inquiry learning and reflection, have resulted in increasing rates of approval of the General Chemistry course and less students having to retake the course, delaying their progress towards their professional degree.

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1 INTRODUCTION

> "*Knowledge results only through active participation in its construction. Students teach each other and they teach the instructor by revealing their understanding of the subject.*" (Elmore, 1991).

With new approaches in teaching and learning processes and the knowledge provided by the neurosciences; academic institutions understands the need for more effective learning environments in which students can actively engage, an environment that offers students something to do (Johnson *et al*, 1991). Although the lecture mode of teaching is often considered the "traditional" approach, several studies have shown that active learning leads to enhanced student outcomes compared to lecture classes, as it was reviewed by Douglas and Chiu (2013). Active learning is a student-centered approach based on engaging students in activities and creating classroom environment that allows student ownership of the learning process (Mohamed, 2008). In addition to the cognitive benefits of active learning, there are also opportunities for students to enhance what is known as process skills. Among these are the ability to work in teams, to communicate effectively, and to be able to assess their own work (Douglas & Chiu, 2013).

The University of Engineering and Technology (UTEC) offers a mandatory General Chemistry course to all first-year students in its different engineering majors. UTEC is seeking to promote active learning, innovation and professional development along with soft skills to all its students. In the process of moving towards more active ways to engage students and to improve students' performances, active learning methodologies were proposed. In particular, the General Chemistry course decided the implementation of process-oriented guided inquiry learning (POGIL) and reflection to increase students´ performances (measured by their final course grade).

POGIL is a student-centered instructional strategy that provides opportunities, simultaneously, to teach both content and key process skills such as problem solving, deductive reasoning, communication, self-assessment, teamwork, and time management (Vishnumolakala, Southam, Treagust, Mocerino, & Qureshi, 2017). POGIL was designed to replace lectures in the classroom and thereby involve students in discussing the course material, rather than just hearing about it (Eberlein *et al*, 2008), then, instructional focus should be on the activity of the students rather than the presentation of the instructor (Moog and Spencer, 2008).

UTEC follows the criteria stated by The Accreditation Board for Engineering and Technology (ABET) for engineering students. The students are required to develop teamwork, communication, and lifelong learning, among other skills. POGIL was proven to be a tool to achieve the first two skills. In order to recognize the need for lifelong learning, students were asked to reflect on their learning progress. Reflection on experience is used as an intentional form of thinking where a person revisits an experience with a specific meaning making lens. Reflection is frequently discussed alongside the concept of metacognition. Metacognition and reflection seem quite related when the metacognitive concepts of self-awareness and self-assessment are the metacognitive issues being foregrounded.

Reflection in engineering education explores emotional indicators as a way to initiate student reflection in engineering programs. They acknowledge a need to “stimulate purposeful student reflection”. Using reflection to promote the community´s understand of teamwork and how to support students in teamwork (Turns *et al*, 2014).

2 METHODOLOGY

In order to determine the impact on students´ performance, General Chemistry final course grades data from three academic terms were considered: 2016-1, 2016-2 and 2017-1. Additionally, students were randomly assigned in different sections in all the terms. Five Engineering majors were under consideration for this study: Energy, Electronic, Industrial, Mechanics and Chemistry. Noteworthy in 2016 terms, students were subjected to “traditional” teaching methods where instructors provided an oral presentation of the topics, explained a few model exercises, and then students were asked to solve those problems individually. A midterm and a final exam were conducted to evaluate their performances. On the other hand, in the 2017-1 term, when active methodology was implemented, students had the opportunity to follow the POGIL structure. Students worked in teams, typically of four students, to complete worksheets. The worksheets contained three components: 1) Data or information as background material; 2) Critical thinking questions, which are designed to lead the students to understanding the fundamental concepts represented by the data, and 3) Application exercises. The instructor´s role was to guide the students, walking around the room and probing them with questions to check their understanding (Douglas and Chiu, 2009). Only a final exam, at the end of the term, was given to students.

To complete the incorporation of active learning methodologies, students were asked to answer four reflections assignments throughout the term. For the purpose of this study, only the final reflection with four questions was considered. These reflections were classified and categorized according to a Likert-liked scale based on their content. The rank went from excellent to unacceptable in terms of how much depth the answer had, and how its content shows the way the student perceived its learning progress. The four categories considered for each reflection submission (quality of the reflection) were: 1 – unacceptable, 2 – improvement needed, 3 – good, and 4 – Excellent. Finally, the depth of the reflection was correlated with the final grade. Reflection was only collected during the 2017-1 term. In the other two terms, reflection was not incorporated since active learning techniques were not used. Based on the reflection answers, teamwork variable was also included in the analysis. While teamwork is obtained through a student survey on class perceptions, reflection, as it was described before, is the result of the qualitative analysis of student responses of a particular reflection survey at the end of the course.

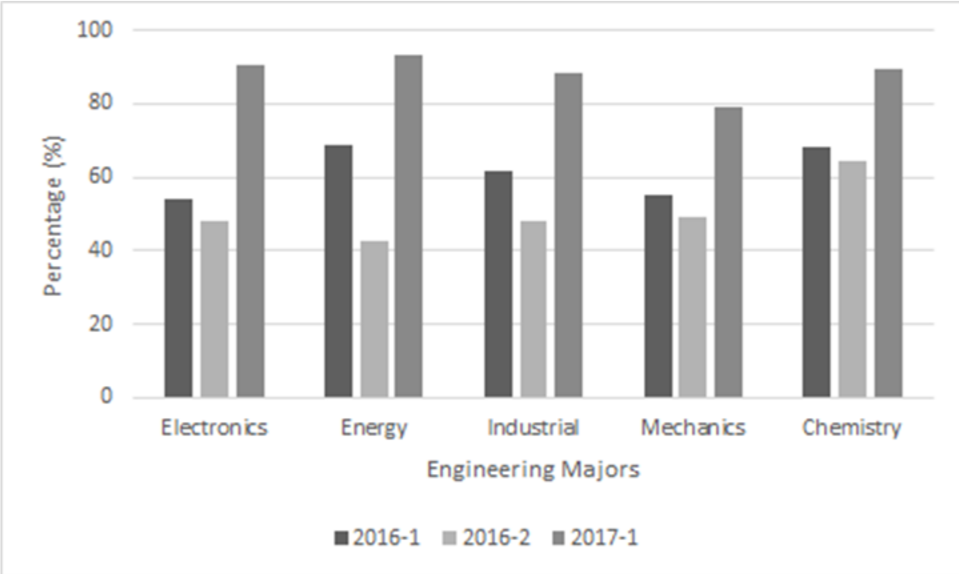
3 FINDINGS

Table 1 shows percentage of students passing the course, indicated by term and major. The data shown reflects total number of students and number of approved students. The five majors considered were: Electronics, Energy, Industrial, Mechanics and Chemistry. The total numbers of students considered for each term were: 219, 395 and 431 for the 2016-1, 2016-2 and 2017-1, respectively.

Table 1 – Percentages of approved students passing the course at the different terms

Term		**Engineering majors**				
		Electronics	**Energy**	**Industrial**	**Mechanics**	**Chemistry**
2016-1						
	N	70	35	118	131	41
	Passed	38	24	73	72	28
	%	**54.29**	**68.57**	**61.86**	**54.96**	**68.29**
2016-2	N	50	14	58	83	14
	Passed	24	6	28	41	9
	%	**48.00**	**42.86**	**48.28**	**49.40**	**64.29**
2017-1	N	62	31	176	124	38
	Passed	56	29	156	98	34
	%	**90.32**	**93.55**	**88.64**	**79.03**	**89.47**

Figure 1 – Percentage of approved students according to their Engineering majors



Data shown in Figure 1 indicates an increasing percentage of approved students compared to the previous term, specially the comparison between the 2016-2 and 2017-1 terms.

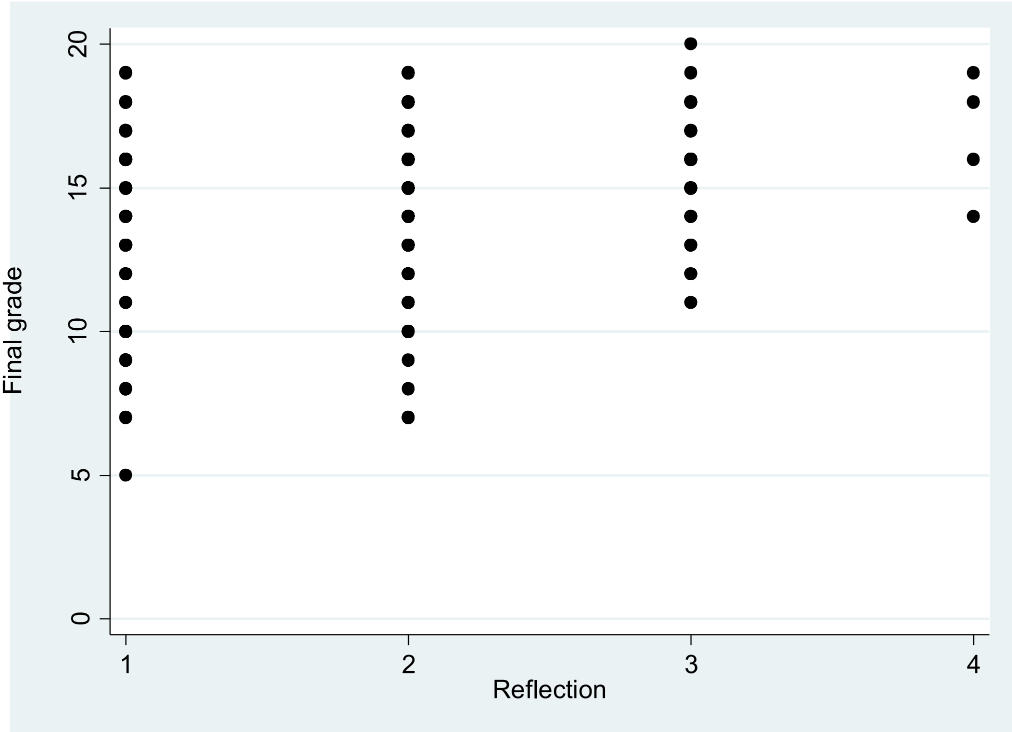
As shown in Table 2, students from the General Chemistry course got higher final grades than their peers from the other majors, which were expected due to the course being fundamental in their career.

Table 2 – Summary statistics for final grade (by major)

Major	**N**	**Mean (final grade)**	**Std. Dev.**	**Min.**	**Max.**
Electronics	62	13.90	3.87	0	18
Energy	30	15.50	2.45	8	19
Industrial	175	13.75	3.30	0	19
Mechanics	122	12.96	3.96	0	19
Chemistry	38	15.60	3.77	3	20

During the implementation of the reflection survey in our course, we thought that students able to reflect and internalize more about their learning, were going to improve their final grades. Figure 2 shows the scatterplot between final grades (‘y’ axis) and the evaluation of reflections based on a Liker-liked scale (‘x’ axis), being one unacceptable and four excellent. As it can be seen, there is a positive correlation between the two variables, which actually could lead us think that better reflection could lead to a better student performance.

Figure 2 – Scatterplot between final grades and reflections evaluated on a Likert-liked scale



However, more analysis is needed in order to determine the impact that reflections could have on the final grade. Therefore, we analyzed the impact on students' performance (measured through final grades) of two relevant variables for the nature of our course: teamwork and reflection. While teamwork is obtained through a student survey on class perceptions, reflection, as described before, is the result of the qualitative analysis of student responses of a particular reflection survey at the end of the course. With those two independent variables and the career dummies, we had a censored dependent variable (final grades are between 0 and 20), so we had to perform a Tobit regression which fits best with our data distribution (Greene, 1999). The results are shown in Table 3:

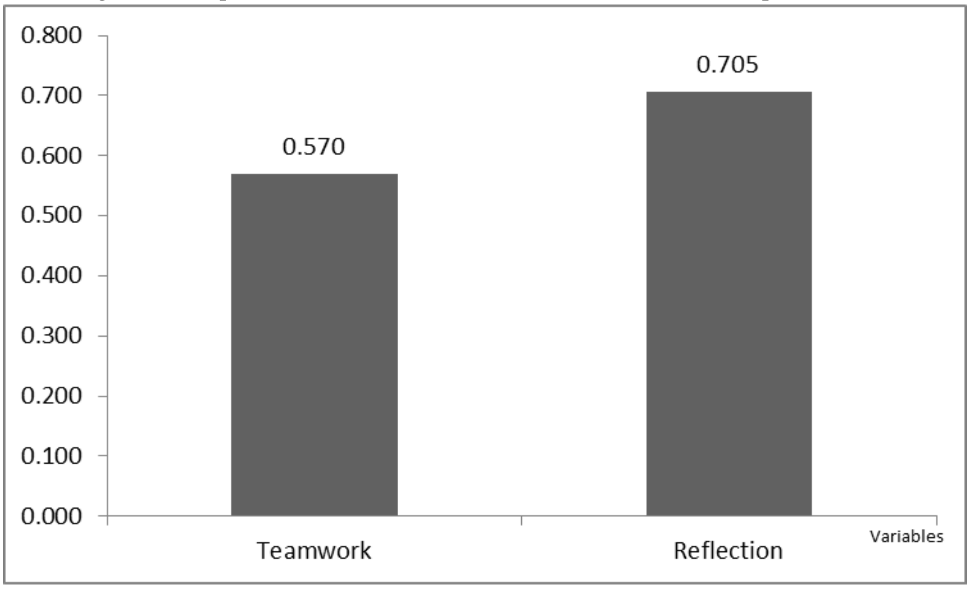
Table 3 – Tobit regression model for measuring impact on student performance

Final grade	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
Relevant variables						
Teamwork	**0.5696131**	0.2815526	2.02	**0.045**	0.0137276	1.125499
Reflection	**0.7053076**	0.2336394	3.02	**0.003**	0.2440199	1.166595
Career dummies						
Energy	1.88598	0.907552	2.08	0.039	0.094146	3.677814

		7			3	
Industrial	-0.5268575	0.5124735	-1.03	0.305	-1.538664	0.4849485
Mechanics	-1.178419	0.5617464	-2.1	0.037	-2.287508	-0.0693311
Chemistry	1.769066	0.6740539	2.62	0.009	0.4382426	3.09989
_cons	11.92292	1.085727	10.98	0	9.779308	14.06654
/sigma	2.243188	0.121416			2.003469	2.482906
N	172					
LR chi2(6)	41.6					
Prob > chi2	0					
Pseudo R2	0.0517					

Our two relevant variables are highlighted in bold. As it can be seen, both teamwork and reflection have a strong and statistically significant effect on the final grade. In the case of teamwork, for a one point improvement in the Likert-liked scale, there is a statistically significant improvement (at 5%) of 0.569 points on the final grade. Likewise, reflection has a stronger effect, which tells us that for a one point improvement in the Likert-liked scale, there is a statistically significant improvement (at 1%) of 0.705 points on the final grade. So, as seen in Figure 3, both teamwork and reflection are vital components for improving student performance and for having a more student-centered class.

Figure 3 – Impact effects of teamwork and reflection on student performance



4 CONCLUSIONS

This paper described the implementation of process-oriented guided inquiry learning (POGIL) and reflection in a General Chemistry course for all engineering majors at UTEC. The goal of this course was to reverse the pedagogical effect of traditional teaching methods as seen on students' performance (primarily measured through final grades). Reflection was added as a mean to promote not only contextualization of the learning process, but also to foster professional skills such as teamwork, communication and recognize the need for lifelong learning.

Active learning methodologies positively helped the learning of General Chemistry for Engineering majors. As it was shown by other authors, the use of POGIL to teach Chemistry was effective at improving students' outcomes.

Student-centered environments and students working in groups highly correlated ($p<0.005$) with improvement in students' academic performances. The combined results of how students work in groups and how they reflect on their learning progress is generally encouraging, but can be improved. The practice of reflection in our students must be fostered to help them better understand the power of reflecting.

The purpose of reflections in General Chemistry was generally viewed by students as having positive associations with learning, and, in most cases, also correlate with a passing grade.

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