BLENDED AND RESEARCH BASED LEARNING TO BOOST STEM ABILITIES IN QUANTUM INFORMATION EDUCATION: A VIEW FROM ANALYTICS

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ABSTRACT

Frontier science sets changes in the paradigms, so when those changes establish a valuable application, it produces social changes in relatively short periods of time. The above is also true in education, where disciplines at the edge of knowledge must fight against traditional education to land contents holding the most visible and dominant part of its technological development. In our days, Science, Technology, Engineering and Mathematics (STEM) initiatives are looking for the approach towards scientific and technological applications from the general student population. Research-oriented learning (ROL) is a teaching technique supporting STEM movement through motivation into scientific and technological research. This article examines the relationship between blended learning in a yearly workshop of quantum information and its impact on research proposals submitted by the participants, measured through evidences and an evaluation by experts during the workshop, as well as the learning analytics embedded in the respective training site.

KEYWORDS

Blended Learning, STEM, Learning Analytics, Quantum Information Education

1. INTRODUCTION

Quantum information and quantum technologies were shaped in the 20th century; despite in the 21st century are generating the majority of non-conventional technological proposals. Thus, it has been an evolution in the value of the domain of quantum information and quantum technologies. However, these areas are relatively new and they have not been settled in the curricula of potentially interested professionals. It is not well-known among students that there is a strategic plan of development for quantum technologies in the world society (Weisskopf, 2015). STEM strategies seek to promote the attention of these disciplines in students of the overall levels. In this trend, ROL seeks to establish an early relationship between such educational disciplines and related professional research (Griffiths, 2004; Healey, 2005) thus motivating to students from different perspectives, to develop them in scientific and technological areas.

For Boyer (1990), one of the activities of the University is to achieve that ideas become developed in the most possible productive way. Therefore, he proposes to change the culture that students are recipients of knowledge instead generators of it, thus approaching the undergraduate level into graduate one, making them able to generate individual work regardless of the discipline to develop (Barnett, 1992). Thus, learning activities should be integrated to show the richness, diversity, scale and scope of interdisciplinary learning. Research seminars at universities seek to attract new students in the involvement of the research activities of academic groups. Thus, such integrative activities should allow students to set significant questions about some related topics of interest requiring be communicated to a broader community (Wade, 2014). ROL, in the sense of Willison and O'Regan (2007) encourages undergraduate students to propose and to develop their own research projects, moving them from the commonly known into the commonly unknown, an approach few exploited in the universities as a generality.

Today, universities are gathering data from different aspects of academic life. Its use is becoming a more powerful input to establish predictive analytics (Desouza and Smith, 2016). Analytics regard the process to collect, assess, analyse and report data for decision-making (Campbell, DeBloise and Oblinger, 2007). Similarly, learning analytics process and reports behaviours in teaching and learning. Originally, in a way not automated, analytics of learning were initiated in face-to-face education, but with the emergence of the distance, online and hybrid learning, today it presents the ideal context where a greater number of students participates, works and reports results through computers and mobile technologies generating a large amount of data for analysis (Wong, 2017). Although extended works in Higher Education have not been published regarding analytics, there is at least certain identification of the type of records that can be tested: qualitative assessment, quantitative measures, classification and differentiation among groups of students (between groups or within each group under some established criteria), effectiveness, work, study, trends in the delivery of activities, etc. (Wade, 2014; Wong, 2017).

Under those guidelines, the National Workshop of Quantum Information (NWQI) for students of science and engineering of Tecnológico de Monterrey, has been offered by the Quantum Information Processing group (QIPG) since two years ago. It is an initiative seeking to train and to attract engineering students to the Quantum Information discipline to participate in research (Delgado, 2018a). At the end of workshop each participant proposes a tentative research activity in that area as final product. For two weeks, each student makes an intensive incursion in the discipline, then proposing a project based on their own levels of experience and knowledge through collaboration and individual contribution, in agreement with Healey (2005). This initiative aims to promote also postgraduate studies among undergraduate students (Bauer & Bennet, 1999).

The aim of this article is to present an analysis about the impact of hybrid learning on the quality of the research proposals through two editions of a national workshop on quantum information. The orientation of research is based on the use of several checkpoints during the workshop but mainly on learning analytics in the online segment. Section two provides a description of the workshop and some outcomes in previous studies to contextualize the present report. The third section outlines the objectives of research in relation to the analytics. The fourth section structures the analytics around the research objectives. The fifth section presents the structured outcomes and their discussion. The last section presents the conclusions extended on the overall experience.

2. A NATIONAL WORKSHOP IN QUANTUM INFORMATION FOR UNDERGRADUATE STUDENTS

Quantum Information Education (QIE), has different characteristics compared to quantum mechanics as a basic discipline. While quantum technologies are developed, primarily settled around the quantum information, i.e. the ability of the quantum systems to contain, manipulate and process information with features not seen in its classical counterpart, it has been clear that inclusion of diverse professionals in its technical implementation and algorithms is necessary (NSF, 1999; EU, 2016). Thus, the transformation and electronics engineering, as well as computational, chemistry and biological sciences together with disciplines such as economics and sociology inclusive, even could be contributing with human resources providing applications and potential problems to be solved by quantum computation (nIU, 2016). Despite the reality of contemporary education is different, for students in engineering or computer science most of the introductory courses must go first through formal quantum mechanics courses out of scope of those disciplines, then making inaccessible their immersion in the discipline of quantum information.

2.1 STEM Initiatives for QIE

Frontier sciences offer a broad appeal to propose STEM initiatives (Wade, 2014). Around them, an aura of innovation tends to attract young people motivating them to continue their learning and to develop them professionally under those trends. In Quantum Information and Processing, there is an accelerated development plan for the following 20 years in the number of opportunities for human resources immersion and development (nIU, 2016), so there are the conditions of training to add it into traditional curriculum.

Teaching based on trends in frontier engineering is an approach in Education to introduce students into high level technology development while they learn some basics (Weisskopf, 2015). As a group of research, GPCI developed two years ago the NWQI for students of the Tecnológico de Monterrey. By including several engineering programs and campus in Mexico and under a strategy of blended learning, with the first week taking place online and the following week moving to students to a face-to-face session in Mexico city.

In agreement with those initiatives, Tangle (Delgado, 2018b; 2018c) is a suite of four courses developed in Weebly (two in MOOC format and two more in MOOR format) (Gleeson, 2014; Hosler, 2014; Goral, 2014) being used in several contexts, particularly within NWQI. In the suite, it is outstanding the transverse focus, the multilevel educative coverage (from high school until graduate studies) and the STEM approach, which establishes an innovation by itself. There, monitoring of effective learning becomes an important element, particularly if the materials are intended to be covered in a blended form (Siemens, 2005). Efficiency should be measured not only in terms of performance, instead of student retaining. In the suite, Google and Weebly analytics are tools gathering information about the way in which a user navigates within the site and interacts with different content. Analytics data can be statistically identified by user either from a given IP address or through a previous access registration.

2.2 Blended Learning and Learning Analytics for TANGLE Suite

Google analytics is a tool to collect information and interaction from the user, even after visiting the Tangle site. It only requires the inclusion of a code on the site to account for its use. A Weebly site can receive this type of code and then interact with Google analytics to build more robust analytics and tracking that those native in Weebly. Experimentation with the use of analytics in blended learning resources becomes transcendental as they pursue tangible learning objectives (as the research product in the NWQI) by analysing behavioural data related with them. Those data includes some of the following properties: a) to reach large groups, b) to considers the diversity (level and ethnicity), c) to consider flexibility (depth and time), d) to involve distance or blended education, and e) to relate cross-cultural or multidisciplinary issues.

The series of learning modules in Tangle are MOOC's (Massive Online Open Course) and MOOR's (Massive Online Open Research). They are reconfigurable for the key areas within Quantum Information and Computation being designed with alternating levels of depth to meet different formations: scientific, engineering and computational (Delgado, 2018b; 2018c). There, ROL is included as methodology in the MOOR's in the final two modules.

3. RESEARCH OBJECTIVES

The objectives of this report are settled as: a) to set up an assessment of the products of research of the workshop from the perspective of learning analytics outcomes (which have been improved since the previous edition) in order to find sensitive demographics or behaviours, and b) to establish a criteria-based assessment for the final product of workshop through expert evaluations and learning analytics. The group of students considered for the research includes those attending any of the two editions of the NWQI.

3.1 Learning Analytics Being Used

In order to attract, train and build up human resources from the earliest stages of education into graduate programs (master and doctorate programs in nanotechnology), NWQI searches to promote research and inclusion in this area. Therefore, the monitoring of participants' interests is important to the QIPG. The coverage of workshop has a diversity of activities: experimentation, theoretical training, computer based practices with simulators (QUANTUM from Mathematica, QISKit from IBM), etc. Figure 1 shows some aspects within the workshop: a) optics experiments assembled by students during the workshop, b) scenes of participation in reception of transmissions of foreign experts (France and United States) and exhibition of student projects, and c) research posters to prepare them for this type of experiences in real conferences.

Figure 1. a) Quantum optical experiments during the workshop, b) some student learning activities during the workshop, and c) scientific posters prepared and presented by the students as final product

Learning analytics term was coined to define the process of measurement, collection, analysis and reporting of data obtained during a process of learning and its relationship with its users and behaviours (Greller, 2012). For online learning, it involves a series of indicators on the behaviour of users during learning, the way they interact with the content, and in some cases direct evaluations of performance. Such information is used to understand the process of interaction searching its optimization through data obtained from an internet connection (Picciano, 2012; Siemens et al., 2011). Analytics should be inserted along the different sections of online course. Weebly analytics allows collaboration with Google analytics to make the collection of information (access, time, links, use of resources, etc.) to establish correlational statistics of usage and performance. Those analytics must be established as a roadmap of inferences within the different sections and/or activities of the MOOC's and MOOR's (Black, 2014; Desouza and Smith, 2016).

Analytics should have a design registering links from one stage of learning to another. Today, the use of mobile technologies and the extensive development of educative applications there make it possible. Figure 2 shows a summary of some available analytics in Tangle by combining Weebly and Google analytics. Many of them are employed in the present study to infer trends in the users of the workshop. They are grouped into the demographics of access and in the registration of visits and visitors, together with the time of permanence and the terminal page for a given search. Another source of information is an exit survey of the workshop, which gathers information on three aspects: 1) Motivation: the attitude and commitment of the participant by adhering to the workshop, 2) Learning success: the evaluation of success accorded in the offer of workshop (methodology, support, and reflection), and 3) Lifelong learning: the value given as lifelong learning (other aspects were assessed such as the correct management of the workshop, but they are not included here). Then, the hypothesis of research is that some of those analytics conditioning the effective use of blended learning segment in the workshop on the final product quality required in it. Thus, the research was developed to find such possible dependence on the final performance given by the entire experience on each student through the blended learning component.

3.2 Evaluation Metrics based on Analytics and Rubrics Evaluation by Experts

This section describes the method of grouping the analytics within this study as well as the methodology of observation and evaluation by the experts who conducted the workshop. First, analytics seek to compare the two editions of the workshop (2017 and 2018) departing from demographics, whose main average data are

reported in Table 1 together with their dispersions (standard deviations, S.D.). With 25 and 28 participants respectively, both editions have very similar demographics: a) related profile (1, physics, chemistry, nanotechnology; 2, computer science; 3, mechanics, electronics and mechatronics; 4, other engineering), b) semester (1 to 9), c) average online usage (percentage), d) average face-to-face performance (0-best to 1-worst), e) average quality product performance (0-best to 1-worst), f) average non-online performance (average of face-to-face and final quality product performances). Thus, in the bulk outcomes is reasonable to consider the whole group as a uniform population.

Figure 2. Learning analytics included in the course site from Weebly and Google analytics

To analyse the relationship between analytics obtained online during the first week of workshop with the quality of the final product there (the research proposal on a topic selected by the students), several analytics were used: a) local or foreign student, b) workshop edition, c) gender and d) profile. The analytics of usage of Tangle were standardized so the maximum of online participation was established in 100% (presented on a scale 0-1). While, evaluation of final product was performed by three experts during the workshop based on the dimensions: a) originality, b) support to the proposal, c) deepness, d) individual domain, and e) contextual knowledge (measured by the capacity to respond the questions of experts and other participants during the presentation). The following section presents specific outcomes and their related analysis.

Table 1. Demographics and performance averages and dispersions

<i>Year</i>	<i>Avg. profile</i>	<i>S. D.</i>	<i>Avg. semester</i>	<i>S. D.</i>	<i>Avg. online</i>	<i>S. D.</i>	<i>Avg. face-to-face</i>	<i>S. D.</i>	<i>Avg. quality product</i>	<i>S. D.</i>	<i>Avg. no-online</i>	<i>S. D.</i>
2017	1.7	0.8	4.2	2.2	0.8	0.1	0.8	0.2	0.9	0.1	0.9	0.1
2018	1.5	0.7	4.0	1.7	0.8	0.1	0.8	0.4	0.9	0.1	0.8	0.2

4. OUTCOMES AND DISCUSSION

In order to visualize the main two correlated variables (online and quality of the final product performance) as function of the other variables of interest selected by the author and depicted in the previous paragraph, Figure 3 shows synthetically all those results using a scatter diagram and using the symbols shown on the right side. Profile is indicated by the signs on the quadrant of each student mark (1, 2, 3 and 4) as it was defined before. A simple visual analysis denotes some aspects: a) differences in the profile suggests the

increased use of online resources in the initial week of the workshop (mainly for the profile 1), and b) an advanced semester and gender (female) suggests a better result in the final product performance. A careful analysis suggests the remaining variables do not establish a sensible deviation in the parameters analysed (online and quality product performances), thus they are not considered as source in the remaining analysis.

Figure 3. Entire population depicted in terms of their overall online and quality product performances as function of their provenance (border), gender (filling), workshop edition (centre dot), semester (disk size) and profile (coloured quadrant)

To have conclusive outcomes between the differences established on both possible stated correlations: the online performance versus profile and the quality of final product performance versus semester and gender we have run two ANOVA tests with one and two factors respectively. In the first case, we mix both populations (due to the similar behaviour between them in the Table 1) and then we split the group in four subgroups by profile. In the second case we split the data in six groups combining the gender and the third (due to the reduced number of data by semester, instead to take the semester of student directly, we group the semesters of each student in thirds of their program). Outcomes of both tests are reported in the Table 2.

Table 2. ANOVA tests discriminating demographic factors on online and quality product performances

One factor ANOVA test for online performance differentiated by profile						
Source	S.S.	F.D.	M.S.	F_{calc}	p -value	$F_{critical}$
Between	0.008	2	0.004	0.325	0.723	3.199
Within	0.569	46	0.012			
Total	0.001	2				
Two factor ANOVA test for quality product performance differentiated by gender and third						
Source	S.S.	F.D.	M.S.	F_{calc}	p -value	$F_{critical}$
Gender	0.003	1	0.003	1.184	0.390	18.513
Third	0.004	2	0.002	0.832	0.546	19.000
Error	0.005	2	0.002			
Total	0.012	5				

Both ANOVA tests use $\alpha=0.05$. Thus, the first analysis discriminates correlations between profiles with the online usage given by the usage analytics, while the second one discriminates among groups of gender and third Information provided by the demographics analytics on the quality of final product. Despite, neither the first nor the second tests exhibit statistical evidence of such correlations ($p=0.723>0.05$ for the first and $p=0.390>0.05$, $p=0.546>0.05$ for each variable in the second). Those aspects could appear disappointing but otherwise, it shows that the workshop becomes useful for the overall student interested (the only requirement for the inclusion in the NWQI is the dominion of vector spaces and complex algebra topics), demonstrating that gender or semester are few important for a successful participation. In addition, the profile does not seem meaningful in the involvement of the online activities. It is interesting in terms of the workshop format: open for all semester students, which has been criticized in terms of maturity, despite it does not appear as relevant issue. While, the use of the online component has become useful to boost the workshop activities at distance, notably improving the outcomes achieved in only one week during the face-to-face section (Delgado, 2018a).

5. CONCLUSIONS

NWQI has been offered for two years under a nationwide call for students of science and engineering. It has had a good response in terms of attendance and representation of the profiles of students. As it was shown previously, it exists a good response in the first week for the most of the participants attending to the online activities planned as previous preparation for the second week in the face-to-face segment. As it was stated in the outcomes, any biased condition (gender, semester or profile) appears meaningful on the impact in the use of materials in Tangle, neither in the quality of final product. It provides certain evidence about the wide orientation of workshop in terms of audience. As an additional element, we extend the analysis of the survey exit evaluation outcomes (Delgado, 2018a). Figure 4 presents those outcomes in terms of the generic dimensions on the survey. There is a similar average behaviour and high in that evaluation (the scale is 0-worst to 10-best) for both cohorts (solid lines). While, the behaviour in those averages (μ) has become more consistent reducing the dispersion (σ) in the opinions (lines for $\mu-\sigma$ and $\mu+\sigma$ in each cohort), denoting a best opinion in the second cohort for the overall participants (regarding it was an exit survey). At the current stage, this activity has provided additional outcomes in the enrolment of six participants (from first cohort) into the research modality for undergraduate students who are preparing original research with QIPG researchers as advisors. Surely, most of them will follow graduate studies in a related area. Thus, the NWQI has become a valuable activity providing advanced outcomes in Education in the way of STEM initiatives.

Figure 4. Dimensions of survey exit evaluation for the two cohorts 2017 and 2018

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