Active Learning in Higher Education by SOLO Taxonomy

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ABSTRACT

The objective of the study is to use the Structure of Observed Learning Outcomes (SOLO) taxonomy, a significant tool used in differentiating curriculum and providing cognitive challenges to the learners, to motivate students for active classroom learning in engineering subjects. Normal and SOLO taxonomy structure modes are alternately and exclusively used for preparing question papers of four class tests in an undergraduate materials science and engineering course. The performance of one hundred students on those tests is compared. Additionally, a separate feedback survey is conducted to understand students' satisfaction and learning. Performance-wise, students are observed to learn better using SOLO taxonomy. The feedback indicates that this taxonomy promotes, engages, and enhances the cognizance quality of the students and orients them to accept learning challenges.

Keywords: active learning, cooperative learning, SOLO taxonomy, Generation Z, post-millennials

Introduction

Students at all levels of education have different approaches to learning which largely influence their learning experience. In today's world, effective class room teaching has become a major challenge for educators (Seemiller & Grace, 2017). However, in the higher education sector, traditional lecture mode teaching is still the most popular pedagogic style (Shatto & Erwin, 2016). Teaching strategies need to be developed in such a manner that they create interest among students in the class room; and at the same time can promote, engage and enhance their learning.

The Structure of Observed Learning Outcomes (SOLO) taxonomy is one of the most powerful meta-cognitive tools to motivate learners for active class room learning (Biggs & Collis, 1982; Biggs, 2011). It assesses the ability of learners to synthesise a deeper level of understanding in their subjects of choice. Extant literature is very scant on how the post-millennial generation perceives the SOLO taxonomy as a learning approach. In this paper, the focus is on the application of this taxonomy in an engineering (Materials Science and Engineering) course attended by Generation Z students.

Literature Review

Based on the Cognitive Development Theory, Biggs and Collis (1982) derived five levels of SOLO Taxonomy. The five levels are well-organised in terms of various characteristics- from the conceptual to the abstract level. It is a true hierarchic taxonomy, which is nothing but aggregate of quantity and quality of thought, where the quantitative stages of learning occur first and then there is a shift towards qualitative learning (Biggs 1987, Biggs 2011).

The structure within each stage becomes increasingly complex as the cycle within that stage develops. Each stage holds the previous level but adds something more. The five stages are: 1. Pre-structural 2. Uni-structural 3. Multi-structural 4. Relational and 5. Extended Abstract. The Uni-structural and Multi-structural level questions test students' surface level of thinking and Relational and Extended Abstract level questions test higher order or deep level of thinking. When the students are able to immerse themselves completely within the context behind the learning, they can slowly escalate from a shallow 'surface' level to a more ingrained 'deeper' level of comprehension.

An important model that explains the difference between surface and deep learning has been developed by Biggs (2011) through the comparative analysis of two hypothetical learners – Robert and Susan. Susan is an academically

committed deep learner and Robert's aim is to obtain a qualification for a decent job. Teachers face challenges to teach such different learners. Figure 1 shows a big difference between Robert and Susan (Point A) where Susan is operating deep level of approaches and Robert is operating surface level of approaches. The objective is to reduce the gap between deep and surface learners and move to point B. To reduce the gap between deep and surface learning, the teaching pedagogy must focus on active and co-operative learning.

The objective of the study is to use active and collaborative learning in such a way that the surface learner is encouraged to use the higher cognitive level activities like deep learner and the active teaching can have narrowed the gap between their ways of going about learning which can reflect in their performances.

Methodology

This research utilises a pre-test, post-test repeated measures type experimental design to test the proposed hypotheses. The study followed a sampling without replacement strategy (Hair et al., 2006). Paired sample T-test is conducted to test the various hypotheses.

Participants

To determine the Quality of learning (QOL) of the learners, this experiment was envisaged and arranged for one hundred Chemical Engineering undergraduate second year students in Materials Science and Engineering. The course provides the students with a systematic review of the basic structures of inorganic solids (metallic, ceramics, and polymers) and techniques to determine basic microstructures and phases. Emphasis is given on structures-properties, correlations, and applications in chemical industries. Advance materials and their applications are also covered. Therefore, SOLO taxonomy was expected to have a different impact on the student's learning behaviour, since there was ample scope to change the students' approaches of learning.

Research Design

The evaluation components were introduced as class participation problem (CPP) and mentioned in handouts and discussed in the first class. As an institutional norm, total seven CPPs are conducted in a complete semester within 16 weeks of period. But the experiment took to Mid-semester, up to which four CPP components are covered. CPP1 and CPP 3 tests were organised in the normal mode, while CPP2 and CPP4 were organised using SOLO taxonomy (Figure 2).

The normal mode CPP1 was preannounced and it covered two chapters covered over two weeks (T1) of lectures and the CPP3 covered six chapters completed across six weeks (T3) of lectures. The CPP2 conducted using SOLO mode covered four chapters covered in a duration of four weeks (T2) and CPP4 comprised all the chapters covered across eight weeks leading up to the mid-semester (T4).

The assignment was designed in such a way that the students must prepare one question (with answer) based on SOLO taxonomy, which must have four parts; Uni-structural, Multi-structural, Relational, and Extended Abstract, marked as U, M, R, and E (the authors did not introduce Pre-structural level in this study). The domain of the question preparation was defined within four chapters of the class text book, which were already discussed in class and CPP2 was done using SOLO taxonomy. Students were provided 10 days' time period for both CPP-2 and CPP-4. The general instruction was that the marking will be based on standard/complexity of question/answer which followed SOLO taxonomy. The submitted questions must be original, and students were strictly warned against adopting plagiarised content. In CPP-2 and CPP-4, 6 marks were on question preparation and 4 marks on class test (pre-announced). In CPP-2, the best question paper prepared by the students was chosen (with proper modification) for the class test. In CPP-4 class test, the question papers were swapped among the groups.

Based on the literature reviews and the underlying theoretical underpinning of SOLO, the following hypotheses have been formulated for further empirical validation:

H1: The performance of students will increase if they are taught through SOLO taxonomy (T_2) compare to traditional teaching (T_1)

H2: Student performance will not show any major deviance if they use traditional methods (T_3) of learning after being exposed to SOLO taxonomy (T_2)

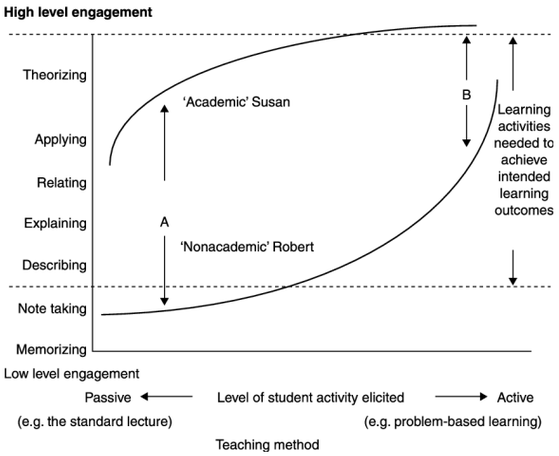

Figure 1. Student orientation, teaching method and level of engagement (source: Biggs, J.B., 2011. Teaching for quality learning at university: What the student does. McGraw-hill education (UK))

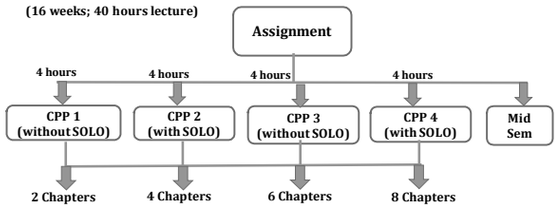

Figure 2. Experimental Design *(Source: developed by authors)*

H3: The performance of students should improve when they are again exposed to SOLO taxonomy (T_4) than the traditional technique (T_3)

Result and Analysis

We conducted paired-sample t-tests to compare the performance of students across different time periods. It is observed that the performance of students at time T_1 is significantly lesser that at time T_2 (MD =-1.37, p <.001). This gives support for our Hypothesis 1, that the students are able to learn better using SOLO taxonomy. It is observed that the performance of students at time T_3 only marginally increases from the performance during time T_2 (MD = -0.635, p <.05). It is also observed that the performance of students in T4 is not statistically different from T_3 as expected (MD = -.05, p >.05) and it also observed the overall variance of the group significantly reduces.

From figure 3, it is evident that on an average the students were able to outperform themselves in CPP 2 compared to CPP 1. Also, it is observed that by the time the experiment is repeated in CPP 3and CPP4, the mindset of the students has acclimatised to the learning philosophy of SOLO taxonomy, and hence there is no radical change in the two performances.

From figure 4, it may be deduced that majority of the students were able to perform better after their orientation towards SOLO taxonomy when their performance during mid-semester is compared to that during their evaluation based on SOLO taxonomy.

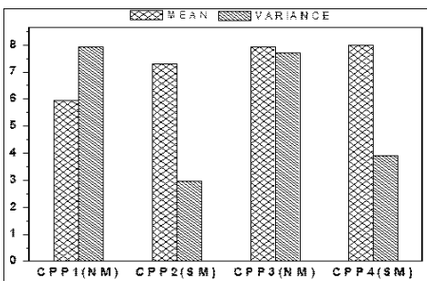

Figure 3. Comparison of the various test performances
(Source: computed by authors)

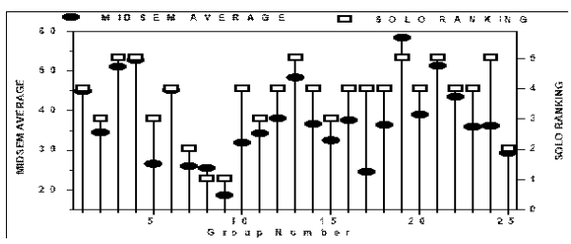

Figure 4. Comparison of student's performance during the SOLO taxonomy test vs. the Mid-semester exam (Source: computed by authors)

A separate feedback survey is conducted with 50 randomly selected students from the original sample of 100 students. For each question they were asked to put their opinion in the form of a 3-point Likert scale ranging from 1 (disagree) to 2 (neutral) and 3 (agree). Eight responses were observed to be acutely incomplete, and these were discarded from the final analysis.

Therefore, the feedback survey reports the findings from 42 responses. The feedback indicates that this new concept of learning and the scope of expressing their understanding challenge them to think more deeply about idea generation. From Table 1, it may be further inferred that SOLO taxonomy-oriented learning also helps to foster the creativity quotient in the students and helps them to think out of the box. Most of the students also acknowledged that SOLO based learning helped them inter-connect logic and basic principles across multiple chapters, which in turn helped them in developing a more well-rounded perspective about the subject. However, a significant number of students were not sure or were not appealed by the idea of introducing the learning taxonomy in other courses, citing that different courses have different flavours and this taxonomy should be incorporated in courses which required such blend of active learning with conventional classroom teaching.

Table 1. Student Feedback Survey Results

S. No.	Questions	Disagreement (%)	Neutral (%)	Agreement (%)
1	This method helps to understand the concept from simple to complex level.	19.1	25.5	55.4
2	This method helps us to link among the concepts of different chapters.	23.4	23.4	53.2
3	This method of developing the question module helps us to improve active learning.	23.4	25.5	51.1
4	This method of making question module as a group helps us to improve collaborative learning.	29.7	23.4	46.9
5	This method helps us to improve our analytical thinking.	21.3	21.3	57.4
6	This method helps us to improve our creative thinking.	19.2	17	63.8
7	This method helps us to motivate our self-learning.	27.6	21.3	51.1
8	This new method creates interest toward the course which increases our overall enjoyment.	23.4	34	42.6
9	This method is a useful and effective tool for teaching.	25.5	25.5	49
10	This method should be replicated in other courses.	31.9	29.8	38.8

Discussion

The tasks and goals were clearly defined that the group must make questions using SOLO taxonomy. The results show that the efforts of each team member benefit both the individual and the group and the commitment that gets developed among group members due to such an orientation helps them in generating both personal and group level success. From the teachers' perspective, SOLO based pedagogy is a powerful approach to engage generation Z students in the classroom because it helps students to be self-sufficient and develop a sense of ownership towards the course. The overall feedback regarding the impact of SOLO taxonomy from the students is that it is a great model to use in the classroom because it makes students realise that it helps in extending ideas into concrete application outcomes. By making the learning outcome clear, it improves students' understanding of the core reason for learning. It enables teachers to reflect at what they teach and map their teaching impact on the students' final learning outcomes. They successfully handled the accelerating nature of complexity in approach. While the

simplicity of uni-structural part of the question is evident, the students' level of conceptualisation at mid-level Multi-structural, higher level Relational, and more advanced level Extended Abstract is also appreciable.

The authors have further developed a template for curriculum design which can be used as a framework for incorporating changes specific to the preferences of generation Z students (Table 2). The findings from the experimental analysis and the qualitative feedback survey further validated the assumptions that today's post-millennial students appreciate being given the responsibility to self-learn fundamental concepts which is commensurate with the generic need for self-fulfillment and self-sufficiency.

Table 2 depicts this balance that needs to be created in the new-age curriculum design customised for post-millennial student preferences. The table also extends the implication of the changes recommended to the possible achievement of the different levels of SOLO taxonomy. It may be observed that the highest level of extended abstract can be achieved successfully using the curriculum interventions. To conclude, this study provides important insights on how to facilitate a higher level of classroom engagement by making the pedagogic approach inclusive and participative for the students.

Table 2. An Approach towards SOLO based Curriculum Framework

Name of component	Initiative	Level of synthesis achieved			
		Uni-structural	Multi-structural	Relational	Extended Abstract
Course content	To be partially self-learnt, giving Gen Z students a greater sense of self-fulfilment, teachers to take surprise evaluation of self-learnt components by asking questions to randomly selected students.	√	√	√	
	Group based and online mode of learning may be encouraged depending on interest	√	√	√	
	Students may be given the choice to suggest changes to the curriculum and if justified, the changes suggested should be considered for curriculum refinement		√	√	√
Quiz	Provision for students to decide level of difficulty of quiz, to continuously challenge each other by creating ad-hoc multiple-choice tests using Learning Management Systems or informal social network forums		√	√	√
	Students may be encouraged to host such tests on a dedicated inter-class website or app or through social network channels		√	√	√
Project / Assignment	To be decided by students in groups, and to be self-monitored by group members		√	√	√

Limitations and Future Directions

The research design of the study is experimental, which limits the external generalisations of the study. Future research may explore other possibilities in which the extended abstract version of learning synthesis can be made more mainstream.

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