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The Potential of Active Demonstrations on Student Learning: A case from a Civil Engineering Classroom

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ABSTRACT

CONTEXT

Most engineering classes are traditionally classified into theoretical and practical. The theoretical classes mainly focus on transmission of the information and concepts from notes to provide a theoretical grounding regarding the course. Thus, lectures are often essentially expository with students in a passive role. However, there is some weakness with this approach.

PURPOSE OR GOAL

Difficult concepts taught in traditional lecturing environment may not be fully understood by students without providing students an opportunity to participate in discussions through demonstrations. Information from civil engineering course content with suitable strategy combined with active learning can be carefully introduced at crucial stages of lectures where students could have an extended opportunity to critically reflect on their previous learning. This study will explore the development and implementation of active learning strategies through In-class demonstrations that may be used at all stages of the learning process.

APPROACH OR METHODOLOGY/METHODS

The study will focus on some key events and reality constructed based on classroom observations, interviews (students and lecturer), classroom conversations, questionnaires, focus group interviews and document analysis.

ACTUAL OR ANTICIPATED OUTCOMES

This study will focus on how students demonstrated understanding of the course content which became possible through their active participation in the class through observations and active learning activities. Information from course content combined with suitable strategy for active learning can be carefully introduced at crucial stages of lectures where students could have an extended opportunity to critically reflect on their previous learning leading to deeper understanding and learning.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

The findings from this study will assist future civil classrooms to understand difficult concepts taught in lecturing environment to be better understood by students by providing opportunities for students to participate in active learning.

Keywords: Learning Effectiveness; Learning Assessment; Teaching Methods; Visualization; Practical Demonstration; Engineering Education

Introduction

Engineering education programs could be structured with an intention of providing rich conceptual knowledge integrated with practice so the tertiary education sector could make learning experience better suited for the learners. The lack of conceptual understanding and deeper insight into the consequences of phenomena is claimed to be a cause of failure in engineering subjects (Gabel & Bunce, 1994; Herron, 1996). It is not possible to achieve visual stimulations by just referring to textbooks or in a traditional lecturing environment. Most engineering classes are traditionally classified into theoretical and practical. The theoretical classes mainly focus on transmission of the information and concepts from notes to provide a theoretical grounding. Thus, lectures are often essentially expository with students in a passive role. There is some weakness with this approach.

The duration of theoretical classes, the amount of new information that is presented by the Lecturer and the gap that exists between classroom and practice, contribute to students entering workforce without the competences or practical grounding in the material necessary for autonomous work. So, the methodology and the objectives of the practical and visual demonstrations are undermined which affects learning, and in turn reflects high failure rates. Active learning approach is a way to address this problem as this encourages student engagement with the course content.

Demonstrations through Active Learning

Active Learning is any strategy "that involves students in doing things and thinking about the things they are doing" (Chickering & Gamson, 1987, p.2) and this broad definition can be taken to include a very wide range of teaching and learning activities. Active learning could be seen as an instructional activity which involves students engaging in discussions and thinking about previously learned concepts (Arthurs & Kreager, 2017). Some characteristics of active learning are as follows:

• Students are involved in more than listening.

• Less emphasis is placed on transmitting information and more on development of students' skills.

• Students are involved in higher order thinking (analysis, synthesis, evaluation).

• Students are engaged in activities (such as writing, reading, discussing, and observing); and

• Greater emphasis is placed on students' exploration of their attitudes and values. (Bonwell & Eison, 1991)

There is a mismatch between most engineering education and the styles of learning of most engineering students. There has been an increasing interest in developing teaching techniques to address all learning styles with a particular emphasis on the importance of active learning supported by pedagogies of engagement (Bahar, 2009; Cutolo and Rochford, 2007; Dzakiria, Razak and Mohammed, 2004; Heiman, 2006; Johnson and Johnson, 2006; Saroj Kumari, 2013; Freeman et al., 2014; Henderson et al., 2017). Studies has been carried out to study the effect of active learning techniques for different learning styles. Various authors have published studies which recognises active learning as an important element of course design in encouraging engagement of undergraduate students and contributing to active learning (Paulson, 1999; Johnson et al, 1991; Smith et al., 2011; Stains et al., 2018).

Proponents of active learning advocate the use of in class demonstrations as well and have shown that they may be used at all stages of the learning process (Chickering & Gamson, 1987; Bransford et al., 2000; Kuh, 2008) to motivate engineering topics by creating connections between theory and practice. A detailed review of literature shows numerous studies which elaborates on the benefits of demonstrations in helping students master concepts in technical fields such as physics and engineering (Marilla, 2004; Bransford, J. D., Brown, A. L., & Cocking, R. R, 1999; Shipley et al., 2017). Both Felder's (1988) and Arthurs & Kreager (2017) work on engineering pedagogy emphasises on the need for frequent use of demonstrations to balance abstract concepts and information in engineering which appeals to most students in terms of their learning style. The two-dimensional model for effective teaching proposed by Lowman (1984) supports the use of demonstrations to improve intellectual excitement during lectures which leads to potential improvement in interpersonal rapport between students and teachers (Gary et al, 2005; Ormrod, 2017). This study will report on the use of in class demonstrations to balance abstract concepts which leads to classroom engagement, discipline discourse and active learning. This study will focus on an instance in class where materials used for road surface/pavement construction was displaced and demonstrated by the lecturer which led to discussions and learning around road material properties, construction techniques and applications. While there is enough literature on theoretical justification of demonstrations in classrooms, the emphasis of this research will be to focus on how sample physical features makes them effective for student learning.

The paper will attempt to answer the following research question: Does physical demonstrations promote the understanding of engineering concepts in roading?

Research, Methodology and Educational Context

Surfacing Technology Course within a Level 7 New Zealand Qualification has posed number of challenges in previous years with its delivery and curricular structure. Feedback from students with no substantial industry experience was to alter the structure of the content and to present the course content to make learning more meaningful and manageable. There were fourteen student participants (11 international students and 3 domestic students) and one lecturer for this study who were selected based on their academic performance in an open book assessment for the surfacing course. There were 39 students in class and 14 student participants for this study were recruited. All participants were provided detailed information regarding the study and agreed to informed consents. A systematic random sampling technique was implemented to choose participants ensuring that the participants selection process captured students from varying academic ability in this class. Students in this study represented low, average, and high achievers. The researcher was not involved in any form with the students through academic teaching, tutorials or in offering other academic support activities throughout the duration of this study.

Data for this study was collected using two questionnaires, classroom observations, informal classroom discussions, interviews with students and lecturer of the course. Questionnaire 1 was collected before the demonstration and asked students to identify troublesome concepts and included Likert style survey statements. Questionnaire 2, student, and teacher interviews were conducted after sample demonstrations. Classroom observations and informal discussions were carried out during samples demonstration.

The teaching of Surfacing Technology course within the qualification traditionally takes place as theoretical classes and a field trip to a local Asphalt production plant. Theoretical classes are devoted to transmission of road surfacing content related to chipsealing and asphalt mixes. The learning outcome required students to critically evaluate testing and properties of pavement and wearing surface materials. The content is devoted in explaining basic road surfacing types and the type of aggregates (stones), binder, flux and adhesives used to construct various surfacing types. During these sessions, students are in a passive role. We received immediate feedback from the students that they found it difficult to both understand and visualise road aggregate types/grades, surfacing types and the binder (bitumen) which is used to bind or hold the aggregates together. The objectives of this learning outcome were undermined as a result, and this in turn was reflected in student feedback. This prompted a classroom intervention to demonstrate the various aggregate types, shapes, size, and the binder (bitumen) which holds them together for surfacing purposes. Samples of road seal types including chipsealing and hot mix asphalt types were sought from a local construction company (road works contractor). A tutorial was organised for all students where road surfacing samples were displayed.

The analysis and conclusions drawn from the study rested primarily with the researcher, as was recognized by the participants.

Findings

Following the sessions in the first three academic weeks there were student feedback (in collective) that it was difficult for them to understand the various surfacing seal types. The initial questionnaire 1 was distributed during Week 4 which collected feedback and required students to identify ‘difficult’ concepts from the surfacing course taught between Week 1 till Week 4 of the academic semester. A 5-point Likert scale was also used to understand student perceptions. The statements and their results are included in Appendix A. The results indicated a mixed response with 71.4% of the participants either being neutral or disagreeing with the first statement.

It was interesting to note that most students agreed that the lecturer encouraged discourse in class (Statement 3) but found that the lecturer was not effective in communicating the content (Statement 2). Nearly 42.9% disagreed and 35.7% were neutral with statement 2 while nearly 50% of the participants strongly felt that the Lecturer encouraged discussion and feedback in class (Statement 3). It was later identified that the one student who strongly agreed with all the three statements had prior field experience in the Civil roading sector. It was clear from questionnaire 1 that all students preferred a form of ‘lab visit’, ‘site visit’ or a more practical approach to help them understand road seal types.

In Questionnaire 1, students HJ and YJ identified properties of bitumen testing and its classification as problematic. PA, SA, GS, and NA wanted to know the difference between different surfacing types for various road conditions. NA and NS could not comprehend the topic ‘seal types’ as it was hard for the student to visualize aggregate types and ‘binder’ which hold them together. HY indicated that they initially found it hard to understand road engineering terminology and without a physical context or field trip, it was initially onerous.

Different grades of road aggregate and seal samples were collected from a local construction contractor who does maintenance contract works on State Highways in New Zealand. The stall display exercise was implemented for one full day in Week 8. A photograph taken of the sample stand is shown in Figure 1 and 2.

Figure 1. The sample display stand with Hot Mix Asphalt surfacing

Figure 2. The sample display stand with Chipseals and Bitumen samples

The samples were displayed to the class by the lecturer and students were invited to the stand in their respective groups. The lecturer explained the various aggregate sizes, shapes, bitumen grades and various road surfacing types used in New Zealand. Three containers filled with bitumen samples was also presented and discussed and students were asked to touch to see how bitumen 'felt'. Student response during the demonstrations were strong and inspired thinking and questioning.

There were students interested in 'poking their fingers' into bitumen to get a feel of the road binder. An excerpt discussion around the stall with the participant group 2 is presented below:

> L: Hot Mix Asphalt surfacing should be used especially if there are shear stresses as you would expect in urban roads. Observe the various Hot Mix types here like SMA and OGPA. Chipseals have been used satisfactorily if the traffic is free running in rural situations.

Texture depth is generally greater with Chip seals and increases with increasing aggregate size, provided the seal is in good condition.

HY: Why do we have more voids in this sample compared to others?

L: That is Open Graded Porous Asphalt, OGPA mixes, provide additional water disposal ability to protect pavements. It is a special mix type used for State Highways. It also allows for a smooth drive with minimal noise.

HY: (to AB) this feels so rough (pause)….. and look at the air voids for water dispersion.

HY: How much would be the percentage of stone (aggregate) by mass?

L: approximately 94% by mass of aggregate.

AB: Does the quality of stones need to be NZTA approved?

L: Yes, the design of OGPA is specified by meeting the criteria of NZTA P/11 standard in New Zealand. High quality stones are required to ensure vehicle loads can be distributed underlying layer. If you recall we discussed this in class, how do the chips allow for load distribution to happen?

HY: contact…? (Referring to high level of mechanical interlock of the aggregate skeleton),

L: Yes, high quality aggregate will allow to do so if properly compacted.

HS: Oh, so that is the reason why chipseals are not suitable to be used in tight intersections and bends or even roundabouts?.. Even OGPA does not have as much internal strength so not appropriate for tight intersections.

L: Right, here is an epoxy bitumen sample, feel it. This mixed with graded stones can be used as asphalt surfacing in roundabouts or signalized intersections. It helps prevents extensive rutting.

PA: So stone mastic asphalt surfacing is also suitable to prevent rutting resistance at signalized intersections. The high stone content may be the reason?

PC: Yes, it provides good shear strength due to stone-stone contact,

HY: But what about noise and water spray from SMA? Because we use it at low speed environment water spray might not be a problem.

L: Also because of its low texture and air void content.

It is interesting to observe how participants assisted in bringing classroom information into perspective as the samples were demonstrated. There were questions raised by this group of students regarding the use of various seal type for different road environments based on climate, traffic volumes and other factors. Students were clearly provided an opportunity to make contributions during discussion. This approach is critical in creating an active learning environment (Meyers & Jones, 1993; Henderson & Dancy, 2007; Shipley & Tikoff, 2017). The above instance shows how the lecturer used the opportunity to make students critically think regarding the practical application of various bitumen grades. However, the lecturer also mentioned that not all groups were interested in discussions but rather just observed and played with the samples.

A closed book Assessment related to this learning outcome was assessed in Week 9. In Week 10, the questionnaire 2 was administered which intended to capture student experience with the intervention. The scale implemented was a Likert style to rate agreements about demonstrations. These statements were intended to assess if such demonstrations added value and warranted continued use in future Surfacing classrooms.

The data from questionnaire 2 demonstrated that participants mostly agreed that the Lecturer was effective in communicating learning content during stall demonstration. Also of note is that questionnaire 2 was administered after their coursework assessment in week 10. The data demonstrated that majority of the participants in the class agreed that the demonstration improved their understanding of problematic concepts however not many participants were comfortable with 'chipsealing'. See Appendix B for the results. A possible reason could be lack of chipsealing surfacing samples however this was not confirmed by the students or was revealed in the dataset. The data revealed participants were confident with 'Hot Mix Asphalt' surfacing types and 'Bitumen Properties'. Students also claimed to have experienced improved performance in their closed book assessment after stall demonstration in the questionnaire. This paper will limit the findings on assessment improvement due to length constraints of this conference.

Face to face interview with participants were conducted in Week 12 and their experience on the sample display day were discussed. Student AB mentioned the following during the interview:

> *It was initially hard to visualise grades of bitumen. I kind of understood it when I read the notes, I was not sure about the RTFO test, but the lecturer displayed it in the class (demonstration). It was very helpful for me to understand the grades at that point. (AB, Interview).*

PC felt that the sample display was good for learning but would like to go to the 'field be shown live samples'. On further questioning, PC mentioned he wanted to view road construction process in real time. PA also mentioned the sample display stand was helpful to understand different asphalt types. For student YH, the sample stand helped to visually differentiate between chip sizes, chipseal and asphalt mixes (see Figure 2). YH also added that these samples should have been introduced to their course in the early teaching weeks while the topics on seal types were being covered.

CV recalled during the interview that the sample display was a good academic exercise.

> CV: I understood the differences between the various grades of bitumen.
>
> R: What did you learn that day?
>
> CV: If it penetrates more, it is 180/200 grade used in hot climates and the other different ones… the bitumen we saw was180/200 which was soft grade and good for warm climates.

The samples helped the student realize the true strength of asphalt seals and surface texture. CV also added during the interview:

It provided great examples like where could you use those samples, like for road intersections, which one would be more appropriate. Terms like 'void content' made sense. Sir explained it well in class (demonstration). (CV, Interview)

HS mentioned the following during the interview:

Before the session, I was not fully aware of the stone sizes, well the notes say 9.5 mm aggregate, but it was good to actually see it. Especially Grade 6 stones, stone size, its shape and angularity which gives good microtexture for skid resistance on the roads. The term microtexture is clearer to me now. It helped me to have more relevant discussions with the Lecturer. (HS, Interview)

The interview with the lecturer was conducted the following week 13 to capture their experience. An excerpt from the interview below:

Students are very good at remembering what is written in books, and I think most understand the concept, but I am not sure if they knew how seals look like and scenarios which require different seal applications. This may lead to students not comprehending the idea because they cannot visualise it and do not understand the right terminology in the first place. (Lecturer, Interview)

The Lecturer thinks one of the reasons for this is that they mainly tend to have a passive attitude in lectures instead of being active. The Lecturer experienced better communication and higher order questioning from the participants during demonstrations. These episodes support that demonstrations can follow the technical exposition of the topic in class. The Lecturer also advised:

Students need to be taken out on field trips or on the side of the road and watch the chipseal road and discuss defects. It is a good way of learning and discussion surfacing with the right roading terms. However, it is not easy these days due to Health and Safety considerations. (Lecturer, Interview)

The next section will discuss these findings and propose recommendations from this study.

Discussion and Recommendation

The findings from this study have implication for courses with similar epistemological position within any engineering curriculum which requires hands-on practical training. Active learning activities have been successfully incorporated in many engineering programmes to maintain a high level of commitment and excellence (Bowen et.al, 1997, Zumdahl, 1996; Freedman et al 2014). The approach taken by the Lecturer is consistent with active learning model with an emphasis on experience rather than merely listening as a means of acquiring knowledge (Bonwell & Eison, 1991; Coulshed, 1993; Felder & Brent, 2003; Henderson et.al 2012). When students were asked to comment on their experience with the sample display, their responses reflected an overall positive attitude towards this learning technique. Student engagement through this learning technique improved when the lecturer carefully recalled students prior experience, and reinforced learning through contextual discussions reinforcing engineering discourse. This strategy allows for cognitive internalisation through human perceptions, representation, and conception (Gang, 2000; Henderson et.al 2012).

A recommendation from this study would be to introduce demonstrations which helps address learning needs and styles. Demonstrations could be planned early in the semester, while topics are fundamental, pre or post topic demonstrations could be incorporated which may assist in addressing early misconceptions and enhance problem solving skills. Over the course of a semester, demonstrations should occur at various stages of topic presentations which has practical implications in field.

The various episodes on the day reveal that encouraging students to actively participate in dialogue and discussion help students to better understand the subject matter. The session incorporated explanations and discussions with students considering their current understanding and conceptions and allowing them to create satisfaction with their conflicting conceptions (if any). This study could not find any evidence of conflicting conceptions of any concepts within the limits of the collection data. However, discussions around the samples led to the modification of students' current views and, finally, to conceptual change and conceptual understanding.

Lecturer's expertise is significant for such discussions and discourse to happen and sustain in a class. Student understanding and discourse development happens gradually as students create a mental picture by physically feeling and observing the samples. Using heavy engineering and field discourse early in the course can prove to be insufficient to develop concept understanding and discipline language. This study has shown that concept understanding, engineering discourse and literacy can be improved through carefully planned demonstrations. Discussions around the stall has potential to include real-world context and authentic engineering/field terminologies to be introduced which facilitates students to internalise discipline discourse.

Lecturers are discipline and field experts and have been on the inside for so long that they must consider as Jacobs (2005, p.107) rightly said "what it's like to be outside of it". Lectures need to use active learning as means to conflate knowledge, practical skills and discipline discourse which would promote understanding of how students learn problematic concepts. Hence, Lecturers and students need to engage actively to develop discipline discourse and conceptual understanding.

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Copyright statement

Appendix A- Questionnaire 1 Likert statement results

Statement 1- The session related to chipsealing and hot mix increased my interest in the subject

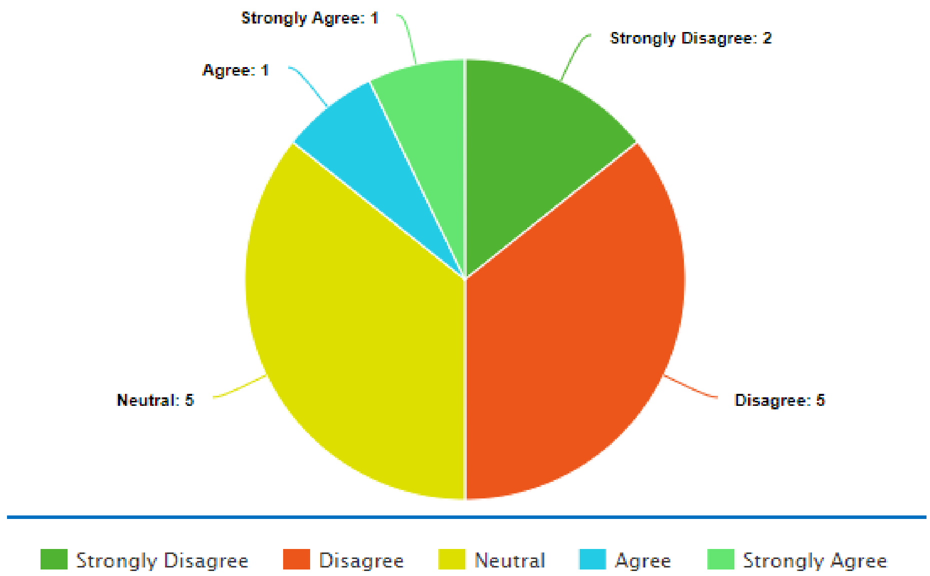

Figure 3. Pie chart showing response to Statement 1

Statement 2- Lecturer was effective in communicating the content of learning

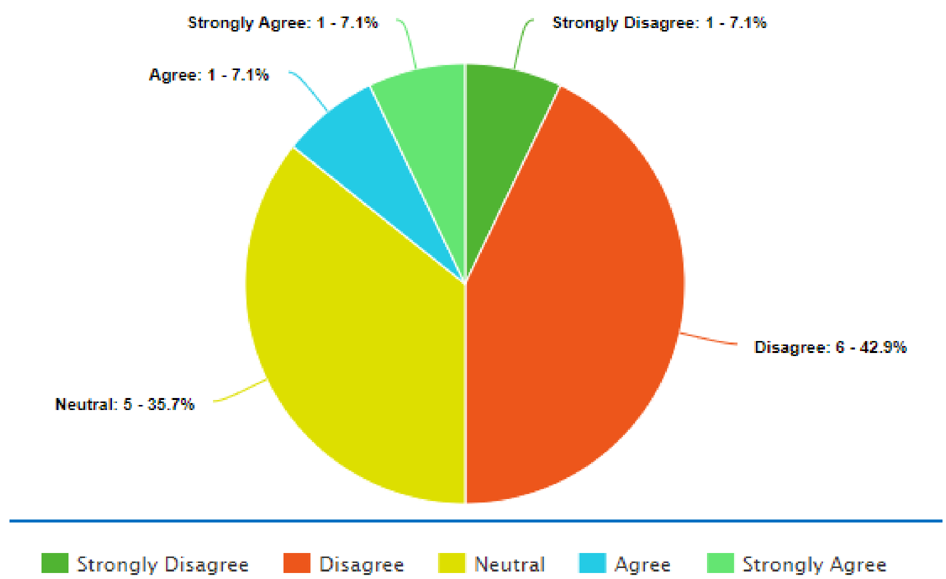

Figure 4. Pie chart showing response to Statement 2

Statement 3- The Lecturer encouraged classroom feedback

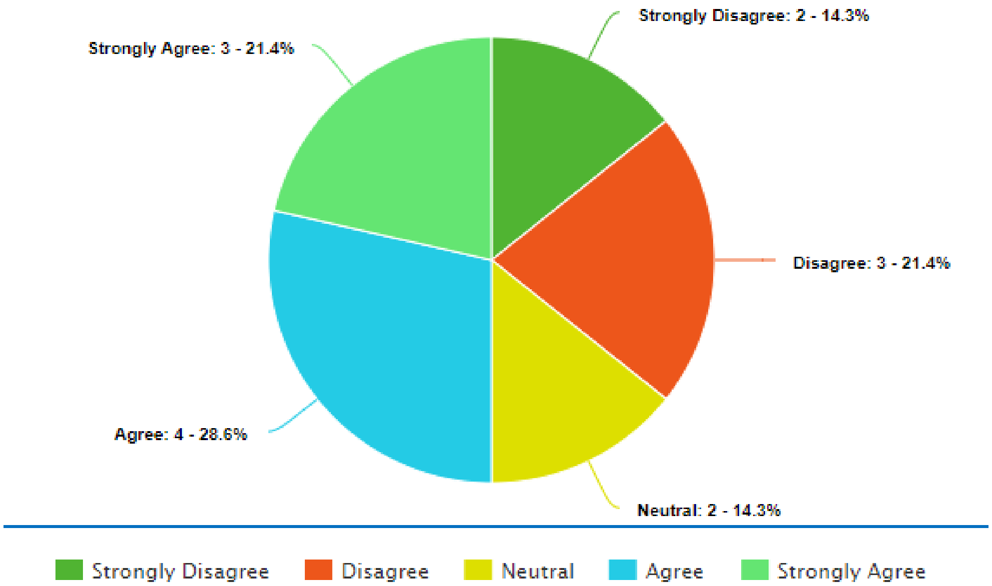

Figure 5. Pie chart showing response to Statement 3

Appendix B- Questionnaire 2 Likert statement results

Statement 1,2 and 3- The Sample demonstration helped me understand ‘Chipsealing’, ‘Hot Mix Asphalt’, ‘Bitumen Properties’.

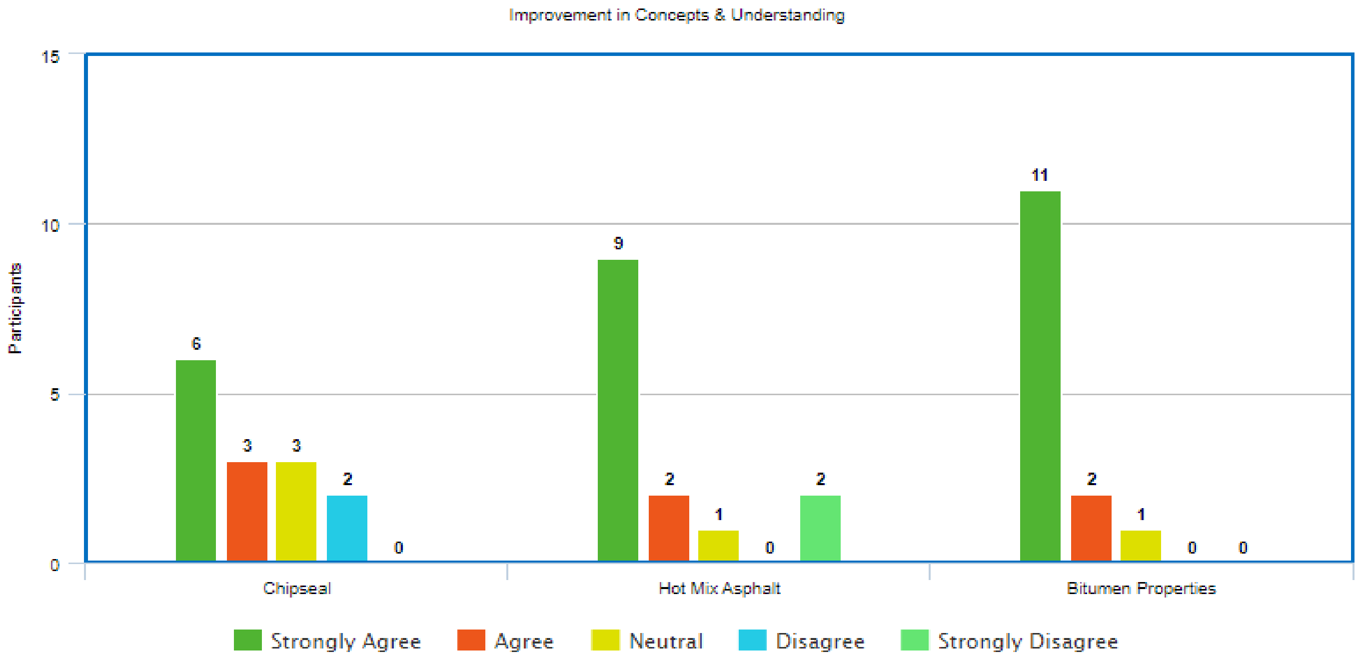

Figure 6. Pie chart showing response to Statement 3

Statement 4- Lecturer was effective in communicating the content of learning during sample demonstrations

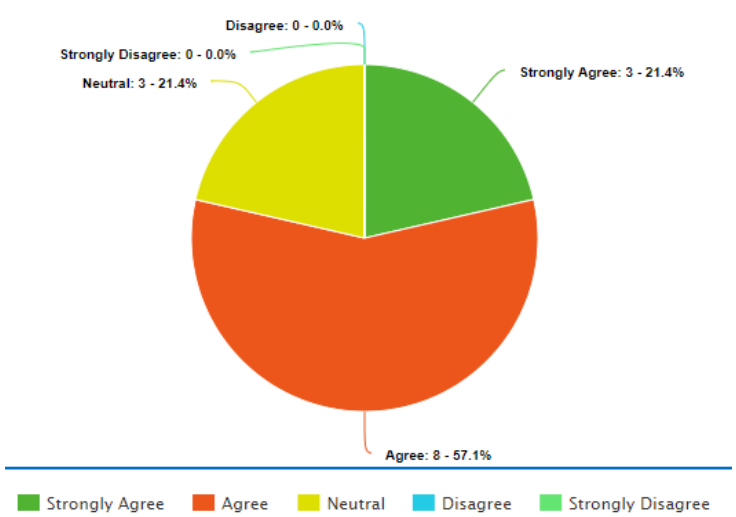

Figure 7. Pie chart showing response to Statement 3