Evaluation of Instructional Module Development System

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***Abstract*—This Research full paper addresses the challenge of creating an effective course design that has tight alignment between various course components and incorporates appropriate pedagogy and assessment techniques. Many systems have been proposed solely for the purpose of guiding instructors through the process of course design so as to achieve maximum student learning. One such system is the Instructional Module Development System (IMODS). IMODS is a web-based software system that has been developed to assist instructors in curriculum design based on the principles of Outcome-based Education (OBE) and Bloom's Taxonomy. It is not just enough to come up with a model that theoretically facilitates effective result-oriented course design. There should be facts, experiments and proof that any model succeeds in achieving what it aims to achieve. This paper focuses on testing and evaluation of the IMODS platform and deliver feedback to its development team. We present our methodology and instruments used for testing and evaluation of the tool. Data collection and analysis is described and the results of evaluation of IMODS are presented.**

Keywords—instruction design; outcome-based education; semantic web-based application; usability testing.

I. INTRODUCTION

Academia is not what it used to be. In today's fast-paced world, teaching requirements are constantly changing and adapting to these changes in an academic curriculum can be challenging. Given a specific aspect of a domain, there can be various levels of proficiency that can be achieved by the students. Considering the wide array of needs of learners, diverse groups need customized course curriculum.

There is a growing demand and interest in faculty professional development in areas such as Outcomes-based Education (OBE), curriculum design, and pedagogical and assessment strategies. According to Boice [8], 95% of the new instructors take three to five years to come up with an effective course plan. A very small percentage of 5 are able to do it in one to two years. Usually instructors go about teaching, the same way that they were taught. There was a need to come up with a structured methodology and design a model that would guide instructors through the process of developing a successful course design. An efficient way to help instructors have a lower margin for error is of utmost importance. And thus, educating the instructors on OBE is one of the major goals addressed in this paper.

One of the most widely used version of Outcome-based Education is by Spady. According to Spady [10], in order for the instructors to be able to successfully help the student achieve their goal, the objectives of the course pertaining to the outcomes expected has to be very clear. The following are the major steps to set up an effective curriculum: (i) defining a course objective and the Intended Learning Outcomes (ILO); (ii) designing assessments such that proof can be shown that the student did indeed learn what was intended; (iii) designing student-centered teaching and learning activities. One of the main reasons the use of OBE is rapidly increasing is because of its focus on the process of learning and the learning environment [9]. The principles of OBE have already inspired a few models for course design such as – Effective Course Model by Felder and Brent [4] and Integrated Course Design by Fink [5]. Not only is it important to come up with a course design methodology, it is also essential that be able to prove the efficiency of the proposed approach.

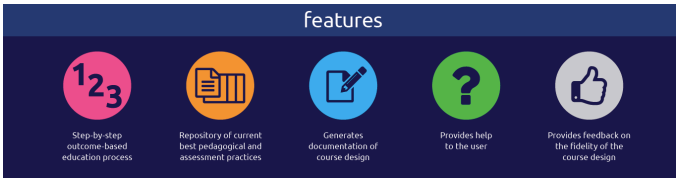

Figure 1: Features of IMODS

The need for having an archetype to design a course focusing on the outcomes, paved the way for Outcome-based Education (OBE). According to D. Clark, the major reason for the creation of Bloom's taxonomy was to stimulate and inspire a higher quality of thinking in academia – incorporating not just the basic fact learning and application, but also to evaluate and analyze the facts and its applications [7]. Instructional Module Development System (IMODS) is the culmination of both these models – Bloom's Taxonomy and OBE. The features of IMODS are shown in figure 1. It is an open-source web-based course design software that: (i) guides individual or collaborating users, step-by-step, through an outcome-based education process as they define learning objectives, select content to be covered, develop an instruction and assessment plan, and define the learning environment and context for their course(s); (ii) provides a repository of current best pedagogical and assessment practices, and based on selections the user makes when defining the learning objectives of the course, the

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system will present options for assessment and instruction that align with the type/level of student learning desired; (iii) generates documentation of course designs; (iv) provides just-in-time help to the user with explanations on how to perform course design tasks efficiently and accurately; (v) provides feedback to the user on the alignment of the course design components (i.e., content, assessment, and pedagogy) around the defined course objectives [15, 17, 18]. IMODS assists the instructor in creating well-defined learning objectives based on PC^3 model (with appropriate learning domain and domain category from Bloom's taxonomy) followed by appropriate choice of assessment and pedagogy techniques.

It is not just enough to come up with a model that theoretically facilitates effective result-oriented course design. There should be facts, experiments and proof that any model succeeds in achieving what it aims to achieve. And thus, the following is the main objective of the paper: evaluate the usefulness of a tool like IMODS on various aspects – (a) the effectiveness of the tool in educating instructors on OBE; (b) the effectiveness of the tool in providing appropriate pedagogy and assessment techniques; (c) the effectiveness of the tool in building the learning objectives; (d) effectiveness of the tool in document generation; (e) usability of the tool; (f) the effectiveness of OBE on course design and expected student outcomes. This paper presents the methodology and instruments used for evaluation of the tool, data collection and an analysis of the obtained results.

The rest of the paper is organized as follows. Background material and related work for this research project is presented in section 2. Section 3 presents the design and implementation of IMODS. Section 4 talks about the experimental study for evaluation of IMODS followed by the results and discussion in section 5. The paper concludes with future work and acknowledgements.

II. Background

A. Outcomes-based Education

The focus of Outcome-Based Education (OBE) is on the product and not on the process [9]. So, defining the goals and objectives clearly is very important, as the complete course design is dependent on them. Knowledge of Bloom's Taxonomy helps instructors compartmentalize various aspects of the course objectives and design each objective with specificity and precision. Learning is classified into three categories – cognitive (mental skills), affective (emotional growth), psychomotor (physical skills) [3, 11]. There are different levels of knowledge and excellence that can be obtained for each of the learning domains. Cognitive learning domain has six domain categories – remember, understand, apply, analyze, evaluate and create. Along with having domain categories, Bloom's taxonomy also has a mechanism of labeling the content with knowledge dimensions – factual, conceptual, procedural, metacognitive [11]. Any content topic can encompass a learning domain category with any combination of the knowledge dimensions.

B. Related Work

There are a few tools that have already been developed for course design that are based on OBE. All of them have considered the main components of the course design to be learning objectives, content, assessments and pedagogy [1, 5, 7, 12]. Not only should these elements be included while designing a course, it is also important to maintain a level of alignment between all the components. Keeping the existing useful elements from the other models, IMODS has added various other elements that make it different. It dives deep in the first step – defining the learning objectives.

Learning objectives are obviously one of the most important parts of designing a result-oriented course. Prior work was done on coming up with a theoretical model called PC^3 model as shown in figure 2 where PC^3 stands for Performance, Content, Criteria, Condition [15, 19]. It takes into consideration, the performance (expected from the course), content (things to be learnt), criteria (level of success to be achieved) and condition. An example learning objective with the breakup of performance, condition, content, and criteria is shown in figure 3. Assessment Criteria type can be chosen for each learning objective and can be quantified if needed, with statements such as 95% accuracy, complete a task within 10 minutes, etc.

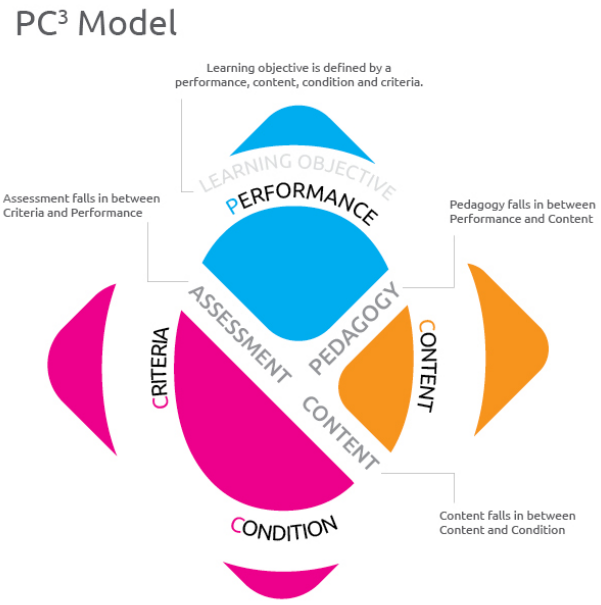

Figure 2: IMODS Framework - PC^3 model

Performance is the level of learning expected from the student; condition describes the conditions under which the specified learning is expected; criteria is the assessment criteria that is needed to ensure that the student has achieved the learning, for e.g., quality, quantity, speed or accuracy; and content is the description of the topics that need to be mastered at the specified level. Interactions of these elements are used to integrate the other components – Content, Pedagogy and Assessment. Performance and criteria are used for defining the corresponding appropriate assessment. Content and performance are used to define the corresponding pedagogy or

instructional techniques for a learning objective. The inclusion of additional components and the focus on the alignment among all aspects of course design makes IMODS highly effective.

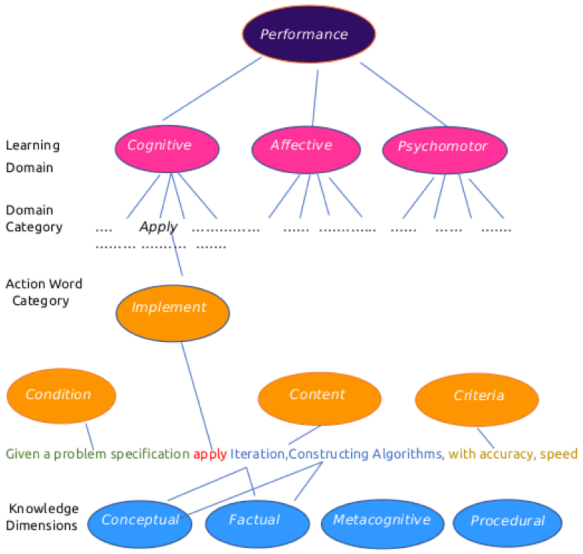

Figure 3: Example Learning Objective in PC^3 model

III. Design And Implementation Of IMODS

As mentioned above, IMODS is based on the PC3 model. The whole system is based on learning objectives, which is driven by Bloom's Taxonomy. Once the learning objectives are defined, the assessment and instructional techniques appropriate for each of the objectives are presented to the user so they can chose appropriate ones.

A. High-level Design

IMODS is a web application that assists instructors in curriculum design based on OBE. For users not familiar with OBE, the application acts as a tutorial. As OBE is result-oriented, IMODS first prompts the user to have a set of well-defined learning objectives (based on learning domains and domain categories from Bloom's taxonomy). After learning objectives are defined based on a unique technique (PC^3 model), assessment and pedagogy techniques need to be chosen. There is already a large database of techniques for assessments and pedagogy that are suitable for a large portion of STEM-related courses. Each learning objective is tied to one or more assessment and pedagogy techniques. A user can also create new techniques that uniquely satisfy the user's need. This can be saved in the database for future use as well.

B. Implementation

The system architecture for IMODS is the Model-View-Controller (MVC) model. Several technologies were considered and the best-suited technologies were chosen for the purpose of implementation. The framework for MVC was chosen to be Grails (Groovy on Rails) [14]. PostgreSQL, a relational database, is used to persist data. Jenkins, an extensible autonomous server, is used for continuous integration and continuous delivery [13] and Git for version control of source code [6]. An agile software development process called Scrum was used design and implementation of IMODS [16]. The entire system adheres to the PC^3 model, making sure that alignment is maintained between all course components – learning objectives, content, assessment and pedagogy.

IV. Experimental Study for Evaluation of IMODS

In this section, the research questions are further broken down into sub-questions, the study design and setup is presented in detail, the approaches to answer these questions are described and the results are discussed.

In order to evaluate the tool's performance, various aspects of the tool that needed to be evaluated had to be listed out. The following are the sub-questions in measuring the tool's effectiveness in achieving its purpose.

1) How effective is the tool in imparting knowledge on OBE?
2) How effective is the tool in providing a wide selection of appropriate pedagogy and assessment techniques?
3) How effective is the tool in the construction of learning objectives?
4) How effective is the tool with regards to the course documentation it generates?
5) How effective is OBE in course design and achieving student outcomes?
6) Is the tool user-friendly?

Our first study was conducted with 6 undergraduate STEM instructors (4 male; 2 female) were recruited from diverse backgrounds. These participants were given access to IMODS for the design of a course that they teach and deliver during the duration of the study. 2 out of 6 were new instructors, 2 had 1-2 years of teaching experience, and 2 of them had more than 5 years of teaching experience. A mixed-methods approach was taken for our research design to measure participants' understanding of the outcome-based course design process. A quantitative method comprising of a pre- and post-test was used along with a qualitative method comprising of interviews. Details of our instruments are presented in the following section.

Our second study was conducted with undergraduate STEM students in Software Engineering courses over multiple semesters with 20-50 students. Students use IMODS with a pre-defined list of course-design tasks to be performed with the tool in one-hour. This was conducted as an in-class activity. At the end of the session feedback was solicited from the participants through a Usability survey that is presented in following sections.

A. Evaluation Instruments

Pre/Post Test:

The pre- and post-test is a survey consisting of questions on OBE and Bloom's taxonomy in general. The participants are asked to complete the pre-test before they start using IMODS and the post-test after they have completed a course design. There needs to be a significant amount of time between both

the tests as recall has to be avoided as best as possible. These tests are useful in determining if there has been any increase in the participants' knowledge on outcomes-based education. The questions were objective questions as follows:

a) What are the three domains of learning as specified by Bloom's Taxonomy?

b) What are the different learning categories under the Cognitive Domain?

c) Which domain involves the recall or recognition of specific facts, procedural patterns, and concepts that serve in the development of intellectual abilities and skills?

d) Which domain includes the manner in which we deal with things emotionally, such as feelings, values, appreciation, enthusiasms, motivations, and attitudes?

e) Which domain includes physical movement, coordination, and use of the motor-skill areas?

f) What are the four types of knowledge that learners acquire?

g) List the two different kinds of Assessments.

h) Outcome-based education is a theory that is _____

- Process-based
- Product-based

i) Which of the following is NOT an outcome?

- Solve dynamic programming problems
- Design a neural network algorithm
- Attend four workshops
- None of the above

j) Which of the following is related to Outcome-based Education (OBE)?

- Exit outcomes are a critical factor
- Input based education
- Result oriented thinking
- Emphasis is on the educational process

Interviews:

One on one interview is an excellent method for getting a detailed account of their thoughts and opinions. The focus of the interviews was to get as much information as possible regarding the process of course design as a whole, the problems they faced while developing the course, their perspective of the tool's role in education, their opinion on all aspects of the process – with special focus on learning objectives and the selection of techniques for assessments and pedagogy. Also, information regarding participant's teaching experience was also collected. The general question list was as follows with further probing as needed:

a) What was the course that was designed? Is it new or a redesign?
b) Was the tool helpful in the course design process? How?
c) What are some of the strengths and weaknesses of the tool?
d) Can you elaborate on your understanding of OBE?
e) What is your understanding of the knowledge dimensions of the topics?
f) Do you think the choice of assessment/pedagogy techniques presented for your course are appropriate?
g) Did the Learning Objective feature force you to think about the level of learning for students? Elaborate.
h) Can you provide a reflection on how the course designed would help in achieving expected student outcomes?
i) Was it useful to have the Learning Objective feature connected to Bloom's Taxonomy?
j) Did you find this backward/reverse approach of designing a course was effective?
k) What do you think of the provided support and help documentation?
l) How many years of teaching experience do you have?
m) How many courses have you taught? How many of those did you build from scratch?
n) What is the average class size in the courses you have taught?
o) Additional feedback?

Document Comparison and Analysis:

Syllabus is one of the important documents in course design. It contains all the required information that students need regarding the course being taught – including the expected outcomes, the topics to be covered, rules/policies, etc. This document is what gives the student a first hand idea as to what the course entails. Thus it is very important for the document to be clear, concise, and consistent. Our aim is to compare – how helpful the tool is in covering all three aspects and also reducing the instructor's effort in writing the document from scratch.

Usability Survey*:*

For a software tool, no matter how amazing, to be truly successful, it has to be user-friendly. This questionnaire contains questions for the participant regarding usability of the tool. Persons on the research and development team have played a role in either coming up with the idea for the tool, brainstorming, designing, or implementing features for the tool. So their perspective tends to be biased. So it is important to get the prospective user's perspective about the tool. The questions are designed so that they can rate the tool on a Likert scale – Strongly agree, agree, neutral, disagree, strongly disagree.

The questions in the survey are as follows:

a) The organization of information on the screen for IMODS was clear.

b) The IMODS application gave error messages that told me how to fix problems.

c) The titles for assessment and pedagogy techniques were self-descriptive.

d) The description of the assessment and pedagogy techniques was clear.

e) The documentation produced (assessment plan and instruction plan) for assessments and pedagogy is satisfactory.

f) The selection available for the assessment and pedagogy techniques is satisfactory.

g) It is easy to define custom assessment and pedagogy techniques.

h) The application doesn't need a supporting document to use.

i) The application was easy to navigate.

j) The font size and style are easy to read.

k) The application is intuitive and easy to use.
l) The application looks aesthetically nice.
m) The overall satisfaction with the application is high.
n) I would recommend this application to my colleagues.
o) What additional improvements do you recommend?

User Testing:
Given a set of instructions for a software tool, it should be easy to follow. The user interface has to be intuitive enough for a naive user to navigate using the instruction set. In order to evaluate the tool on this front, user testing was done with a students in an undergraduate class. Never having had any teaching or course design experience, they simply had to follow the given instruction to create a complete course design. They were given one hour to complete all the tasks and at the end of the session, students responded to a Usability survey with the same questions mentioned above.

B. Effectiveness of IMODS in educating instructors on OBE

One of the major goals the tool tries to achieve is to build faculty expertise in OBE among instructors.
Literature shows that newly appointed instructors take about five years to perfect the process of effective course design through trial and error [8]. The students are most affected during this time. Coming up with an efficient way to help the instructors have a lower margin for error is of utmost importance. And thus, educating the instructors on OBE is one of the goals of the IMODS tool.
The pre/post tests, as well as interviews are used to measure this particular aspect.

C. Evaluation of the repository of techniques

It is important to employ appropriate assessment and pedagogical techniques that align with the level of learning that is expected out of a target audience. Let's say for example that a student cannot be expected to create or evaluate a course-specific subject when the level of learning expected is that of understanding a particular topic. Using the learning domains, domain category and knowledge dimensions, it is important to check that the assessment and pedagogy techniques suggested by IMODS really do match up with the level of expertise chosen by the instructor. Thus, it is important to evaluate the selection of techniques presented to the user. The usability questionnaire contains questions regarding the repository of techniques. Interviews have also been used as a mechanism to get the opinion of the participants regarding the techniques.

D. Effectiveness of the tool in building learning objectives

The tool uses principles of Bloom's taxonomy for the construction of the learning objectives. In order to understand this part, we will present the process of constructing a learning objective using IMODS. The first step is to choose the learning domain – Cognitive, Affective or Psychomotor. Based on the selection of the learning domain, the user will be presented with a drop down box, using which a selection for the domain category has to be made. If, say, the learning domain is cognitive, the domain categories presented will be Remember, Understand, Apply, Analyze, Evaluate and Create. With this, the level of learning expected in the learning objective is chosen. A specific action word representing the performance is then chosen using action word category and action word selections provided by the tool. In the next step, content with respect to the learning objective is created and/or chosen. Each content topic is associated with a knowledge dimension – conceptual, factual, procedural or metacognitive. Next the criteria that can be defined as the level of competence, has to be decided followed by the conditions under which the learning happens. This constructs an initial sentence for the learning objective. The entire process is outlined in the figure 3. The user is given the option of making changes and refining the resultant learning objective. This part of study is aimed at understanding how good are the tool-generated learning objectives. Interviews are the main source for this information to be collected.

E. Evaluation of documents generated by the tool

After all the steps of course design are completed, a complete syllabus, an assessment plan, and an instruction plan is generated by the tool based on the various selections made by the user. These documents are ready for direct distribution to students, for use by instructor in aiding instruction, or in documenting course design process. An option of hiding certain aspects of the syllabus is provided if the instructor wishes to do so. Evaluating the auto-generated documents is yet another way of establishing that the tools is useful and reduces extra effort from the instructor's point of view. Interviews are used to evaluate this aspect along with actual comparison of documents obtained using IMODS and any existing documentation prior to use of tool.

F. Effectiveness of OBE course design and achieving student outcomes

One way of measuring this particular aspect would be to analyze two consecutive offerings of the same course – the first being designed traditionally, without the tool and the next using the tool and comparing the student feedback for the course as well the achieved student results. But in an ideal scenario it would also require the same set of students, along with the same level of knowledge while entering the class. This is, however, not possible. So instead, a discussion with the participants on their thoughts about the student performance based on their experience is used for evaluating this particular aspect. Interview is the method used for collecting data about perceived student performance and the influence of OBE on it.

G. Evaluation of tool's usability

Usability is one of the core qualities that is expected from a software. Along with being functionally effective, tools also need to be easy to use as otherwise, not many will be inclined to use a tool that requires more effort in just navigating through it. Not only should it be aesthetically pleasing, it should also be intuitive. The user shouldn't have to read through a ton of documentation to understand its working.

Thus, usability was chosen as one of the aspects to evaluate the tool on.

H. Study setup

The study has been conducted with diverse groups of participants using a different process for each group.

1) *Students* – The tool was given to a class of students with a set of very specific instructions and a sample syllabus. The goal of this was for the students to be able to follow simple instructions and be able to design a course that was 100% complete.

2) *Instructors* – A group of six instructors were recruited. The first step for this group was to give a pre-test prior to any exposure to the tool. The pre-test consists of a set of questions focussing on Outcome-based education. After the completion of this step, the participants are given ample amount of time to explore the tool, go through the documentation, help videos and seek any further help required from the research team in order to build either a previously taught course or a brand new one. An interview is conducted after the successful completion of course design, with a focus on gathering information on their experience, their prior expectations, acquired knowledge about OBE, their perceptions on expected student outcomes, any challenges faced during the process and feedback for further improving the tool. Then, a post-test was conducted followed by a usability survey.

3) *Off-site Participants* – A webinar was conducted to introduce the tool to STEM undergraduate educators in International institutions outside of US. Each webinar consisted of 15-60 participants. 3 webinars were conducted. OBE-based pre-test survey was administered. A week's time was given for them to explore and design using the tool and build a course. As a last step, the participants had to complete the post-test and usability survey.

V. Results and Discussion

For evaluating the Instructional Module Development System, various aspects have been considered and different criteria has been chosen to evaluate each of the aspects. The results for each of the aspects are discussed below.

A. Educating instructors on OBE

A combination of pre and post tests was used for this particular evaluation, in combination with in-person interviews. There were six participants in the study and their results (scores out 100) are shown in the table below.

Participant	Pre-test Score	Post-test Score
1	47.5	69.17
2	47.5	72.5
3	50	98.33
4	75	75
5	69.17	75
6	70	85

There is an overall increase of 23.16% in the knowledge of the instructors after using the tool.

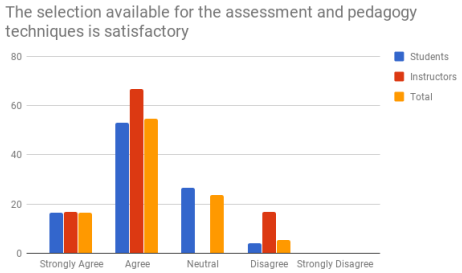

Figure 4: Availability of Assessment and Pedagogy techniques

B. Repository of Techniques

From the data collected from 54 participants this year, 72.3% agreed that the selection of techniques available for both pedagogy and assessment was satisfactory (figure 4) and 61.1% agreed that the titles used for the techniques are self-explanatory (figure 5). But only 57.4% of the total participants agreed the description of the techniques to be clear (figure 6).

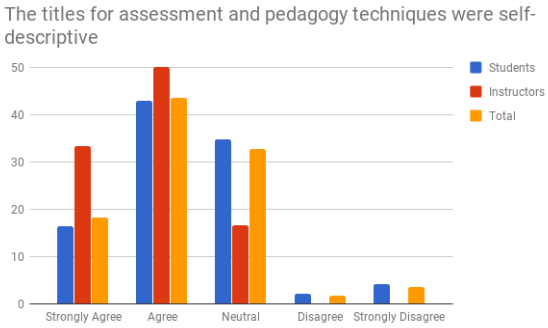

Figure 5: Titles of assessment and pedagogy techniques

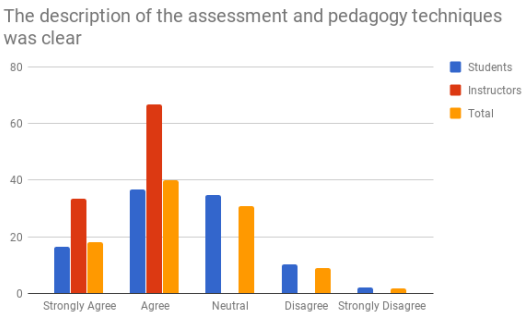

Figure 6: Description of assessment and pedagogy techniques

C. Building Learning Objectives

Three different learning objectives are considered from the courses designed with and without the tool.

i. Sample Learning Objective 1

With IMODS:

Given an algorithm, apply Analytical Analysis and Empirical Analysis.

- Assessments – Midterm Test
- Instructional Techniques – Lecture

Without IMODS:

Students can analyze existing algorithms and use these techniques in designing algorithms.

ii. Sample Learning Objective 2

With IMODS:

After completing the course, the student will be able to analyze Number Representation with 95 accuracy.

- Assessments – Assignment
- Instructional Techniques – Lecture

Without IMODS:

Convert between common number systems (including: Binary, Decimal, and Hexadecimal), in support of program outcome Technical Competence.

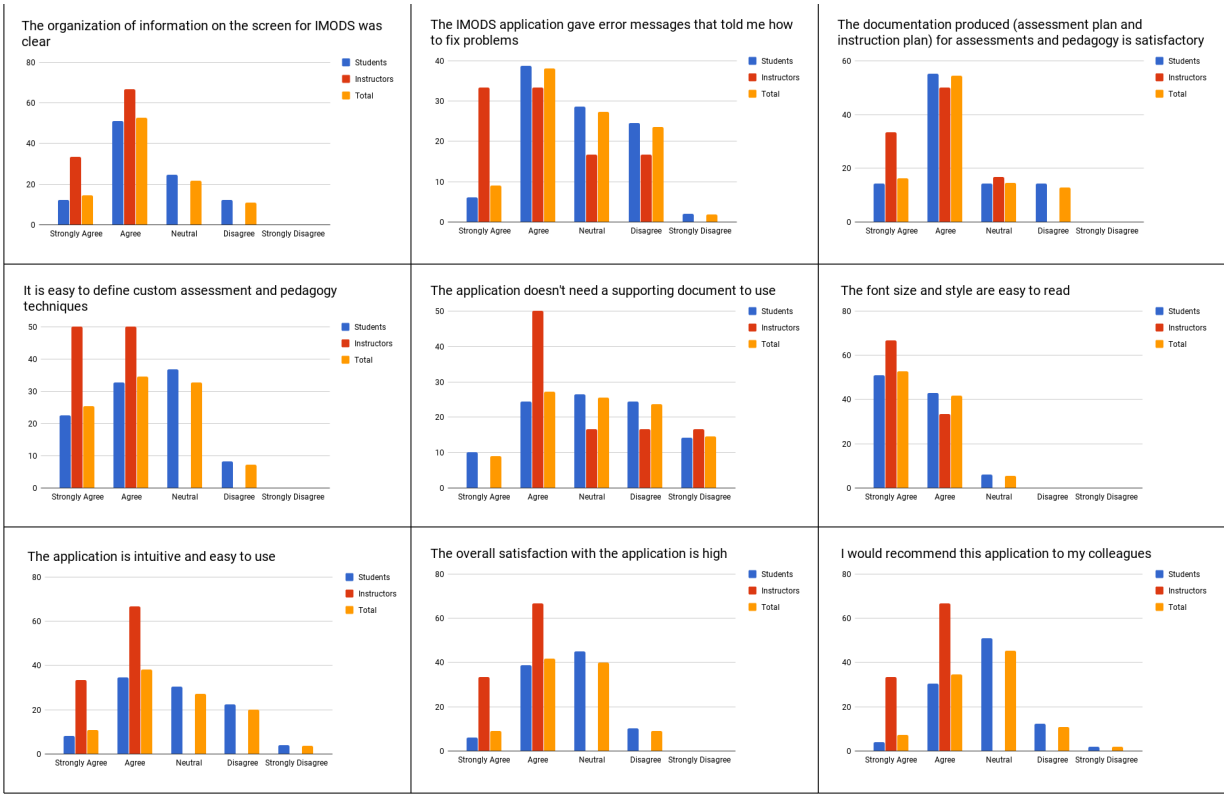

Figure 7: Usability Survey data

iii. Sample Learning Objective 3

With IMODS:

After completing the course, the student will be able to apply user interaction models and prototypes with accuracy

- Assessments – Assignments, Final, Semester project.
- Instructional Techniques – Critical Debate, Thinking aloud pair problem solving

Without IMODS:

After successfully completing SER315, the student will, construct user interaction models and prototype,

- in support of SER student outcome Technical Competence
- in support of SER student outcome Design

The above objectives are part of the results obtained from the study. Prior to the use of the tool, the learning objectives defined were either vague or specific to the content topics. But there was no mention of the either instructional or assessment techniques that would be employed to achieve or measure the outcome. The process of defining the learning objectives using the tool basically forces the instructor to put some thought into the assessments and instruction of content to assure that the alignment between these components is maintained.

C. Document Generation

The syllabus generated by the tool follows a specific format. If the tool is employed at all levels, the consistency provided by these documents will be very high. Referring to a pre-requisite course while in the process of designing an advanced course becomes significantly more insightful, providing the instructor with the general level of knowledge in the incoming class.

The syllabus generated by the tool also maintains the alignment in learning objectives, giving the student a clearer picture of the course and instructor expectations. Also, a nifty

feature called the time ratio gives the students an idea of the amount of time they are expected to spend in class to out of class.

D. Usability

In the previous section, the questions for the Usability Survey have been listed. Students took this survey as a part of user testing, as well as the instructors who built their own courses using the tool.

Bar charts (shown in figure 7) has been used as a way to represent the results. The blue bars represent the students, the red bars represent the instructors and the yellow bars represent the total – combination of both. The horizontal axis shows the Likert scale – and the vertical axis shows the percentage of participants. Data collected over last few years was compared to look for improvement with incorporation of user feedback. Figures 8-10 show this progression.

VI. Conclusions and Future Work

The results of the study demonstrate that IMODS achieves the goals that it has aimed to since its inception and has improved over the years. The study also helped identify a list of improvements to the system that would go a long way in increasing its effectiveness. The evaluation has shed light on some of the issues that escaped the development team's notice. The system offers a fairly limited number of sections for the syllabus. The repository of assessment and pedagogy techniques needs to grow and a variety of techniques for various subject areas have to be added. Making this software more flexible is one of the future goals for improvement. The study was conducted with a small group of participants and conducting this study with improved questionnaire with a larger group can have more promising results.

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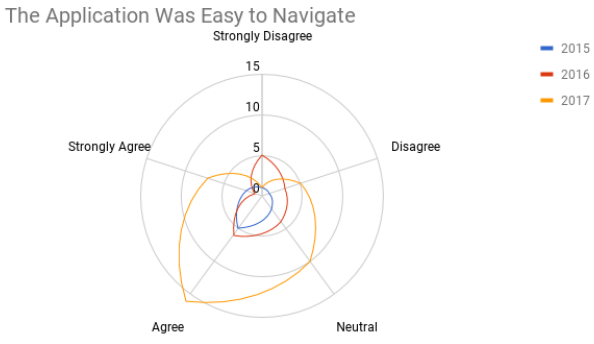

Figure 8: Usability Question on Easy navigation

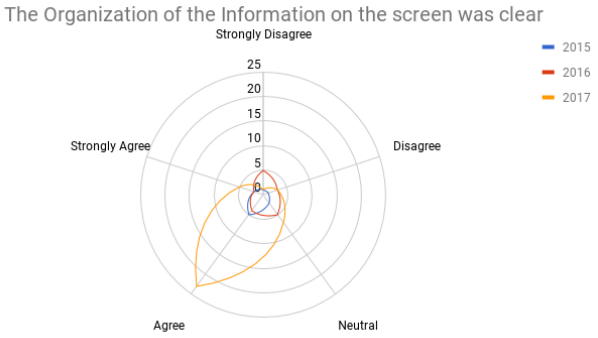

Figure 9: Usability Question on Organization of information

Figure 10: Usability Question on Error messages

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