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Use of Explicit Instructional Objectives to Achieve Program Outcomes and Facilitate Assessment: A Case Study*

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This paper describes an approach, based on common practices, for explicitly defining instructional objectives for university courses, mapping educational activities to those objectives, and using assessment tools that measure student proficiency in attaining the objectives. The advantages of implementing the approach are enhanced quality of instruction, increased student learning, and improved assessment. A case study in engineering demonstrates that data from the assessment can be used in several ways, including improvement of course instruction, supporting changes to educational activities, and supporting program objectives and accreditation. Student evaluation data for two instructors over several terms demonstrates that student perception of the course improved after implementing explicitly defined objectives.

INTRODUCTION

THE OBJECTIVE of this paper is to study the purposes and possible benefits of explicitly defined instructional objectives that are mapped to educational activities and assessment through the use of a case study and supporting data. A typical approach such as that presented in [1–3] is implemented where learning units are described that consist of an instructional objective, educational activities to support the objective, and assessment of student proficiency in attaining the objectives (see Fig. 1). Program objectives are decomposed to course objectives. At this level, course objectives are assessed. A case study is used to demonstrate how developing objectives can improve teaching and student learning.

BACKGROUND

Significant research has been done in the area of developing and assessing instructional objectives. Work by Carlson *et al.* [4] indicated that students benefit from explicitly stated outcomes in all coursework. These outcomes were expressed in terms of what the students should know and be able to do at the end of the course. This allowed the instructors to assess the course outcomes. Based on the assessments, revisions were made to the course.

At Western Washington University, the assessments of objectives were accomplished at the course level through student exit surveys that were linked to the objectives [5]. Similar types of surveys are being used at the DeVry Institute of Technology. Along with the surveys a senior project course is used to evaluate student competency in achieving program objectives based on direct observation.

According to Ewell [6], 'the ultimate point of contact is the curriculum.' He advocates assessment at the course-level to determine patterns of strengths and weaknesses. As part of an assessment strategy for an engineering design course [7], assessments were linked with achievement outcomes. Sims-Knight *et al.* [8] used this approach of assessing objectives at the course-level with the focus being to improve the quality of instruction based on the assessment results. Course-level objectives were linked to specific assessments. This approach proved useful in improving course instruction.

Ahlgren and Palladino [9] reported on the use of assessment tools to measure objectives at the Trinity College Department of Engineering. They defined program objectives which were then linked to assessment tools that took the form of various surveys. Feedback loops were incorporated to help identify needed course and curriculum changes.

Prior work has established a foundation for the use of instructional objectives. In 1956, Benjamin Bloom and a group of educational psychologists [10] developed a classification of levels of intellectual behavior important in learning. This became a taxonomy that included three overlapping domains; the cognitive, psychomotor, and affective. This taxonomy has been used to provide a technique for constructing instructional objectives. Kibler *et al.* [11], Tanner [12], and Armstron *et al.* [13] built on this to identify how instructional objectives can improve instruction. Mager [14] describes how to specify objectives. Gronlund [15, 16] addresses the construction of

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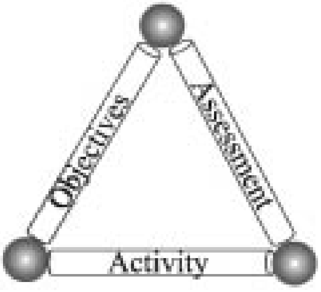

Fig. 1. A learning unit consisting of instructional objectives, educational activities, and assessment.

instructional objectives and the importance of considering a wide range of learning outcomes when developing instructional objectives. The work presented in this paper builds upon this foundation to include empirical data and a detailed process for linking objectives with assessments. Similar work is also taking place in the multi-university EC2000 project [17]. The objective of the project is to evaluate methodologies for assessing engineering education undergraduate program outcomes, and provide engineering educators with well documented, alternative methods, including protocols and instruments, for assessing specific outcomes.

In the paper, objectives are assessed at the course-level and linked to objectives at the program level. Furthermore, learning activities are linked to the objectives and empirical data from a case study is presented.

INSTRUCTIONAL OBJECTIVES

An instructor of a traditional university course usually has in mind what students should learn in the course. These often implicit objectives are supported with lectures, homework, and other learning activities. Exams and other graded materials are usually used to measure how well the students meet the learning objectives. It is not unusual, however, for these learning objectives to remain implicit in the instructor's mind. The instructor may have taught the course many times and be intimately familiar with the content and the intended outcomes. However, it is the students' first time through the course and, when implicit, they must infer the objectives from the lectures, assigned reading, homework, and other assignments.

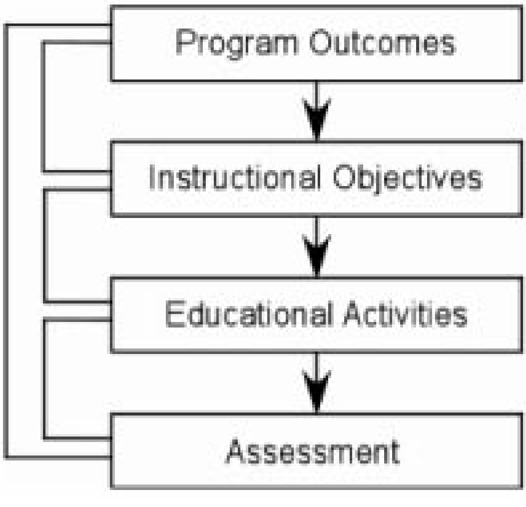

Fig. 2. A chart of the process.

There are a number of disadvantages with implicit course objectives. Students often feel frustrated because there appears to be a disconnect between what they thought they were supposed to learn and on what they are being assessed. This feeling of disconnect comes from the students making incorrect assumptions about the implicit objectives, or from the instructor not having structured the instructional activities to adequately reveal the objectives. Further, the instructor may not have written exam questions that accurately assess the implicit objectives.

Explicitly defining instructional objectives for a course serves several useful purposes. It can improve course organization by helping the instructor prioritize and implement educational activities that support desired competencies. It guides the selection or creation of valid assessment instruments. It provides a better mapping to the larger program objectives, ensuring that the course is doing its part in fulfilling the overall program objectives. Further, the students are better able to understand instructor expectations and thus focus their efforts. Finally, objectives confirm faculty success, increase their accountability, provide feedback to students, and respond to outcomes-based accreditation requirements.

APPROACH

An implementation approach is divided into two phases: the development phase and the operation phase. The development phase includes the definition of explicit instructional objectives for a course and their mapping onto learning activities and assessment tools. In the operation phase, the instructor continuously collects data and modifies the course based on the results. A flow chart of the process is shown in Fig. 2. A proactive effort to explicitly define instructional objectives can lead to structured approaches to achieving outcomes associated with higher levels of thinking that are otherwise difficult to address. It is also possible to include student input in the process to ensure their perspective and buy in.

The approach is illustrated by a case study that includes data from two instructors over several terms for a mechanical engineering course on kinematics (ME EN 337 at Brigham Young University). Because there is too much information to present here for an entire course, one topic will be illustrated in detail.

Identify topics

Major topics are identified for the course. These topics correspond roughly to chapters or major sections in a book. (Although the topics are analogous to major sections of a book, they are independent of the textbook and are defined based on the desired program goals.) Number these with Roman numerals.

Case Study. Eighteen topics were identified for this course, as listed below:

I. Introduction to Mechanisms
II. Graphical Position Analysis
III. Algebraic Position Analysis
IV. Complex Number Position Analysis
V. Relative Motion Velocity Analysis
VI. Graphical Velocity Analysis
VII. Instant Center Velocity Analysis
VIII. Complex Number Velocity Analysis
IX. Mechanical Advantage
X. Complex Number Acceleration Analysis
XI. Preliminary Dynamic Analysis
XII. Dynamic Analysis—Kinetostatic
XIII. Synthesis
XIV. Cams
XV. Gears
XVI. Balancing
XVII. Special Purpose and Advanced Mechanisms
XVIII. Computer Tools

Topics I through XVI correspond to major chapter sections of typical textbooks in the area. Topic XVII is specific to each instructor and topic XVIII is directly associated with a specific desired program outcome, as will be discussed later. The topic that will be illustrated in detail is 'TOPIC IV: Complex Number Position Analysis'.

Create explicit instructional objectives

The objectives [1] (student competencies, skills, attitudes, and/or outcomes) are expressed as 'The student should be able to . . . ' followed by an action verb (e.g. identify, calculate, derive, classify, recall, draw, create, determine, solve, recognize, apply, perform, construct, design). Note that these student behaviors are all measurable. The instructional objectives are identified by capital letters; thus, the second objective in the third topic would be III-B.

Case Study. The instructional objectives associated with Topic IV are: Students should be able to . . .

A. represent vector loops in the complex plane using polar and Cartesian representations.
B. create vector loops that model mechanisms.
C. determine the position of a mechanism using vector loops in the complex plane.
D. solve systems of nonlinear equations which result from vector loops.

Determine if the objective is required of all instructors teaching the course

The course committee will need to determine if the objective is required of all instructors teaching different sections of the course or is optional. This allows more flexibility for topics that may involve the integration of faculty research topics.

Case Study. The objectives for the above two example topics are required of all instructors because Topic IV is a fundamental part of the technical content of the course.

Map the course objectives back to the program objectives

Each specific course objective is a sub-objective of one or more program objectives [18–20]. Many of these program objectives are related to accreditation criteria (e.g. the ABET Engineering Criteria outcomes). List the specific program objective(s) that the course objective helps achieve.

Case Study. The intended outcomes of the program are listed below:

1. A basic understanding of fundamental physical phenomena and governing principles.
2. An ability to develop and solve mathematical models of fundamental physical phenomena.
3. An ability to design a system, component or process to meet desired needs.
4. The expertise to plan and conduct an experimental program and evaluate the results.
5. An ability to use modern engineering tools and techniques in engineering practice.
6. An understanding of fabrication processes and planning.
7. Effective oral and written communication skills.
8. An ability to work with others to accomplish common goals.
9. An appreciation of history, philosophy, literature, science, and the fine arts.
10. Personal behavior consistent with high moral and ethical standards.
11. An understanding of engineering in a global, societal context.
12. A desire and commitment for lifelong learning and service.

Objective IV-A is related to the first desired program outcome of: 1. A basic understanding of fundamental physical phenomena and governing principles, including sequences in thermal science, mechanics, materials, and system integration [18]. Topics IV-B to IV-D map to the second outcome of: 2. An ability to model physical systems to predict their behavior [18]. (Note that these program outcomes are closely related to the program outcomes listed in ABET Engineering Criteria [21].)

Topic XVIII 'Computer Tools' further illustrates the mapping between course and program objectives because its objectives are directly associated with the specific desired program outcome of: 5. An ability to use modern engineering tools and techniques in engineering practice [18]. The topic is discussed throughout the course and is integrated with other topics.

Select or create assessment tools for the objectives

Once the objectives are defined, it is important to select and/or create valid measures of them. In the particular course under study, less than sixty percent of the assessments were found to match the objectives during the mapping process. To insure content validity of the assessment (i.e. ensuring that the assessment tools, such as exams and grades, measure the extent to which the objectives were actually achieved), the behavior relative to the topic in the assessment must be the same or nearly the same as that stated in the objective.

Case Study. Exams were used as the primary assessment tool for the course because they were a valid assessment instrument. In creating an exam, each problem was mapped to its corresponding objective. The coverage of objectives was evaluated, resulting in redundant questions being eliminated and new problems created to ensure more representative coverage of important objectives. Often, inclusive problems can assess several objectives. This can be done with subproblems (such as part *a*, *b*, *c* of a problem), or grading can be done in a way that a certain number of points are assigned to each aspect of the problem.

The instructor will need to decide which graded materials are to be used in arriving at the final course grade. For example, homework problems are assessments because the students receive a grade; on the other hand, these problems may be considered instructional activities where the grade simply provides feedback on how to better reach the objective.

Develop educational activities that help students meet the objectives

Educational activities include lectures, demonstrations, assigned reading, labs, projects, and homework. Keeping the list of activities flexible allows students to achieve the objectives in ways that best fit their learning styles.

Currently existing courses already have educational activities that can now be mapped to the recently defined objectives. Each activity is tied into one or more objectives. The mapping is likely to identify gaps in meeting some of the objectives. It may also identify redundancy, along with too much or too little weight given a particular objective.

Case Study. The activities associated with Topic IV include approximately five lectures and the following reading, where the numbers following the objective identification represent the chapter and section:

IV-A, B; I-D.	4.3, 4.5
IV-B, C	4.6, 4.8
IV-C	4.9–4.12
IV-D	4.13

Note that the first reading assignment is related to an objective from an earlier topic (Topic I-D).

There is homework associated with Topic IV objectives, and it is listed as:

IV-A,B,C,D, I-D, 4.7b
IV-A,B,C,D , 4.10b, 4.12c, 4.17b
III-A, XVIII-A: 4.13

where the problem number in the book or a problem description follows the objective. Note that two problems are linked to objectives in other topics (I-D and XVIII-A). This illustrates how activities associated with Topic XVIII are integrated into other topics. The computer tools are not taught as individual units but rather are used in conjunction with other topics. The students are provided with a list of all the objectives and the corresponding reading and homework assignments along with mapping between the objectives and the activities in student packets at the beginning of the course.

Create a framework for collecting data

This may be as simple as a spreadsheet that records the student assessment performance on specific objectives, or it may summarize all the scores from various activities broken out by instructional objectives. When completed, this framework provides the instructor with scores that are associated with each objective.

Case Study. A spreadsheet was used to store the student scores that were mapped to specific objectives. This allowed for easy sorting and study of data.

Operation phase

The development phase described above provides a foundation that is built on and modified as more experience is gained with the course. Typical tasks required from term to term include mapping new assessment tools to objectives (this is because exams and other assessments are returned to students and new parallel problems are needed the following term), collecting data, evaluating data, and modifying the course to improve student learning as suggested by the data.

Case Study. Sample data gathered over a period of two years are presented to illustrate some types of data that can be gathered.

Table 1 contains data from three semesters for Topic IV: 'Complex Position Analysis.' These are class averages that illustrate that the first semester this new instructional approach was applied, a weakness in student learning was identified. Steps were then taken to address ways to improve student learning. After the first term the assessments and learning activities for Topic IV were

Table 1. Measuring learning effectiveness

Objective (Topic IV)	Term 1	Term 2	Term 3
IV-A represent vector loops	54	86	90
IV-B create vector loops	58	84	91
IV-C determine position of mechanism	60	83	90
IV-D solve nonlinear equations	66	81	98

reviewed. In reviewing homework problems for Topic IV, it was discovered that certain problems were not effective in teaching students the desired learning objectives. These problems were removed and replaced with more instructionally helpful problems. In some situations additional instruction time may be required. In this case, an extra day of lecture was added to provide more depth on the topic and to present and solve a more complex sample problem. The assessments of the Topic IV objectives were also reviewed, but were found to be adequately valid measures of the learning objectives so no changes were made. After the second term, the assessments were once again reviewed to identify areas where the majority of the students were struggling. The class lectures were adjusted to treat these areas more explicitly. The assessments were not changed. In subsequent semesters the learning effectiveness improved: students became more proficient in attaining the objectives. Over time, as weaknesses in student learning are identified and action is taken for improvement, proficiencies should become more consistent. Organizing the course in this manner allows the instructor to readily determine areas that need to be improved in order to benefit student learning.

When the assessments are mapped to the instructional objectives, students can receive continual feedback on their performance and their degree of mastery of the objectives. Table 2 contains possible data from three students in the course. Examination of the student averages for this unit shows that Student 1 with 89% and Student 2 with 93% could both receive an *A*- as a grade for this unit. This does not necessarily indicate that both are performing at the same level of proficiency with respect to the unit objectives. For example in objective 1-C (identify links), Student 2 is performing at an *A* level while Student 1 is performing at a *B* level. Yet in objective 1-B (draw kinematic diagrams), Student 1 is performing at an *A* level and Student 2 is performing at a *B* level. This type of information is valuable in advising students. Using these data, the instructor can easily ascertain those objectives where a student is struggling and can address them directly.

STUDENT EVALUATIONS

Student evaluations of the course provide insight into the use of instructional objectives. Table 3 lists student evaluations of the course for two instructors over several terms and is divided into terms before and after changes. The results are from a standardized course evaluation administered by the university. The evaluation asks for the students' overall evaluation of the course and instructor, followed by 13 specific statements on the course and 14 statements concerning the instructor. The students are asked to evaluate the overall course and instructor as (1) very poor, (2) poor, (3) fair, (4) good, (5) very good, (6) excellent, or (7) exceptional. On the specific questions, students are asked if they (1) strongly disagree, (2) disagree, (3) somewhat disagree, (4) somewhat agree, (5) agree, (6) strongly agree, or (7) very strongly agree with each statement.

The overall course evaluation and the first four statements about the course are most relevant to the material discussed in this paper. They are:

1. Course objectives are clear.
2. Course is well organized.
3. Student responsibilities are clearly defined.
4. Course content is relevant and useful.

Prior to implementation of the new approach, Instructor 1 taught the course 7 times with an average class size of 31 students and Instructor 2 taught twice with an average of 15 students. The mean student response for each question is listed in the 'Before' columns in Table 3 for each instructor. Data for the two instructors is summarized for two terms after the approach was implemented, as listed in the 'After' columns for each instructor.

The data suggest an improved student perception of the objectives and organization of the course as well as an improved feeling of the

Table 2. Student feedback

Objective (Topic IV)	Student 1	Student 2	Student 3
IV-A represent vector loops	87	91	91
IV-B create vector loops	98	82	61
IV-C determine position of mechanism	82	100	95
IV-D solve nonlinear equations	90	100	70
Student Average	89%	93%	79%

Table 3. Student evaluations before and after changes. Evaluation range is from 1 to 7

	Instructor 1 Evaluation Means		Instructor 2 Evaluation Means	
	Before (7 terms)	After (2 terms)	Before (2 terms)	After (3 terms)
Average enrollment	31	35	15	20
Overall course rating	5.5	5.9	5.5	5.6
1. Clear objectives	5.8	6.3	5.8	6.1
2. Well organized	5.9	6.5	4.9	6.1
3. Responsibilities defined	5.8	6.1	5.8	6.0
4. Content relevant	6.2	6.5	6.2	6.4

usefulness of the course. This positive trend occurred even with increases in class size over time. An increased mean was observed for both instructors in all areas.

A univariate t-test of the overall course rating revealed a 90% confidence that the 'After' mean is higher than the 'Before' mean.

A multivariate statistical analysis was performed to compare the 'After' and 'Before' means for the specific evaluation questions. This type of analysis was chosen to account for possible correlation between the different questions in a particular semester. The assumption that the means were normally distributed was statistically verified. The analysis yielded a 95% confidence that the means were different, based on a Hotelling's T^2-statistic. The data suggests that students perceived improved instruction after the implementation of the approach.

Considerable research studies have been done on student evaluations, including multisection studies with common final exams, that have shown a correlation between student achievement and course evaluations (for example, see [22] and [23]), and the validity of student ratings (for example [24] and [25]). Therefore, the data of Table 3 may be considered an indirect indication of improved student learning.

CONCLUSION

Advantages of using explicitly defined instructional objectives include: enhanced quality of instruction, increased student learning, and improved assessment. These are discussed below.

Enhanced quality of instruction

Instructional quality results, in part, from clarity of purpose for both students and instructor. Mapping of activities to objectives allows the instructor to identify weaknesses in instructional activities and gaps that may exist. Mapping assists in identifying redundancies and allowing replacement with other important topics.

Increased student learning

Several other factors are associated with increased student learning in addition to the improved quality of instruction. Because objectives are explicitly defined and understood, students can be more responsible for directing their own learning. The student perception of the course is improved and they feel that the course is more organized. The mapping of educational activities to objectives can motivate students when they see the purpose of the activities is to help them reach a specific objective—and they are free from busywork.

Student evaluations demonstrated an improvement in student perception of course instruction and were an indirect indication of improved student learning.

Improved assessment

Explicitly defining the objectives and mapping the measures to them facilitate valid course assessment. Everyone involved in the process, students and instructors, knows what will be assessed. The assessment tools are linked directly to the objectives, thus helping to ensure content validity of the measures. Assessment data can be used in numerous ways to improve the course. Poor student performance relative to a particular objective can reveal areas where more emphasis is needed, or where clearer and additional illustrations should be introduced. Assessment data can help instructors identify their own weaknesses and suggest ways to improve or compensate for those weaknesses. The assessment data can be used to track deficient students and insure that they meet acceptable levels of performance. Data collected from courses in a program can be used to support or justify program changes to the university.

When all courses in a program apply this approach, the objectives can be mapped to the program objectives to ensure proper coverage and assessment. When grades are explicitly mapped to the objectives they can be used as assessment tools evaluating student success in achieving the overall program objectives. Program constituencies can help define, review, or evaluate course objectives when they are explicitly defined.

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