Global Journal of Engineering Education

Art of triangulation: an effective assessment validation strategy

Omar Ghrayeb, Purushhothaman Damodaran & Promod Vohra

Northern Illinois University
DeKalb, Illinois, United States of America

ABSTRACT: Assessment is a major topic in discussions about most accreditation and evaluation criteria. Collecting data and completing the feedback loop has been an implementation standard for many academic programmes. Like other universities, the College of Engineering and Engineering Technology at Northern Illinois University, DeKalb, Illinois, the United States of America, has been evaluating and assessing the level at which the academic objectives and outcomes are accomplished. Several measures and methods are used to collect and analyse data. It is critically important that all these measures converge to a strong conclusion in totality as indicated by all measures. The triangulation method has been used in the past to validate such iterative convergence. This article outlines the use of triangulation to validate assessment data and their convergence to a meaningful conclusion. Data collected from several sources have been analysed and statistically validated using the triangulation method. The article aims to inform readers of a validation technique to strengthen the observations of assessment methods.

Keywords: Triangulation, assessment, evaluation, learning outcomes, programme objectives

INTRODUCTION

The assessment of engineering programmes has been an evolving issue for the past two decades. Educators responsible for academic programmes have been debating the use of a range of assessment tools in evaluating learning outcomes. Usually, there are more assessment tools than necessary for educators to assess learning outcomes but the efficacy of a single assessment and its reliability are a new focus of attention. Educators are trying to find innovative methods to increase the efficiency and efficacy of the assessment methodology.

The process of triangulation discussed in this article involves multiple entities, assessing the same outcomes, using different methodologies to validate the findings. By definition, triangulation is a strategy used for the purpose of assessing and improving the validity of research findings. The method relies on using multiple data sources and approaches to *support a finding by showing that independent measures of it agree with it or, at least, don't contradict it* [1].

HISTORY OF TRIANGULATION

The concept of triangulation was first initiated in the social sciences field when Campbell and Fiske published a paper in 1952 that discussed the application of a multi-method matrix procedure to assess the validity of measures and traits in the psychological repertoire [2]. However, the use of this method as an assessment methodology is relatively recent and, therefore, has needed various types of scientific research and literature evaluation to affirm its validity.

The main features of triangulation in the assessment process are its utility as a method or tool to enhance the credibility of research work, eliminate bias, and to illustrate the differences between results to establish a valid well reasoned proposition. As detailed by Mathison, the concept of triangulation is carried out through four different processes: *a) data triangulation including time, space, and person; b) investigator triangulation; c) theory triangulation; and d) methodological triangulation* [3].

First, the data triangulation method consists of using several data sources to evaluate the same outcomes. Obviously, convergence to same outcomes establishes the validity of those outcomes. The data acquisition process may involve multiple human interventions in addition to spatial and temporal factors. This aspect addresses the multi source conditions and effects of a single phenomenon. An example discussed by Mathison to illustrate this evaluation approach

is if observations were made at different times of the day and at different times of the year to evaluate the learning outcomes in a school classroom setting [3]. If the outcomes were similar irrespective of the time and day, it could be concluded that the learning outcomes were valid.

In addition, the other form of triangulation used in research is investigator triangulation, which requires more than one investigator to be involved in the research process and fulfil the requirements of adequate data collection. This type of triangulation is subject to many questions regarding the choice of people designated to accomplish the investigation task and their assigned roles. In addition, it is essential to question the investigation process and to determine *how much hands-on data collecting the principal investigator needs to do in order to analyze the data, and how much data analysis is relegated to field workers because much of the analysis occurs as data are collected* [3]. On the other hand, the concept of triangulation theory refers to a simple, yet essential, component of studies and research assessment. The theoretical triangulation is nothing more than the statement of the necessary presence of theory perspectives in any performed study or research work.

Finally, methodological triangulation remains as one of the most prominent forms of triangulation and its value resides in the fact that it utilises different methods in the evaluation of scientific statements, research and proposals. Several research articles and publications have emphasised and supported the effectiveness of this approach in the assessment process and the establishment of valid and accurate statements and results. Denzin, in his book th*e Research Act: A Theoretical Introduction to Sociological Methods* highlights the benefits of using multi methodological triangulation by stating that *The rationale for this strategy is that the flaws of one method are often the strengths of another: and by combining methods, observers can achieve the best of each while overcoming their unique deficiencies* [4].

The research substantiates that triangulation is a pertinent tool and strategy in the assessment and evaluation of research work. The value of triangulation resides in its effective methodologies, which permit the use of multiple data sources, measures and investigations throughout to cancel out the inherent bias and establish a convergent proposition [3].

ABET CRITERIA AND TRIANGULATION

Under the strict ABET (Accreditation Board for Engineering and Technology) accreditation criteria, many engineering colleges and programmes are seeking pertinent methods and tools to assess specific engineering disciplines outcomes continuously. Triangulation can be used as one of the best and most effective approaches in engineering programmes and curriculum evaluation to provide multiple measures for a particular programme and establish valid and reliable outcomes [5].

For instance, the assessment of an engineering education learning application such as the ability to work in *multi-disciplinary teams* can be evaluated using the methodological triangulation approach through: *1) the student's self assessment of their enjoyment of working on teams via closed-form questionnaires; 2) ratings by a student's peers on the team; or 3) the direct observation of a team by a trained evaluator.* In this case, the triangulation process would enable the assessor to evaluate the accuracy of the methodologies chosen and the validity and accuracy of the outcome using that methodology. Once the results are obtained from the triangulation process, statistical methods may be used to investigate the relationship and patterns that exist among the measurements. Furthermore, after carrying out the statistical analysis and in the presence of strong correlation between variables and outcomes, the accuracy of the results can then be verified easily. Contrary to some beliefs, over-assessment using multiple triangulation measures is deemed unnecessary [6].

Engineering departments usually rely on at least two assessment tools (such as multi-source feedback systems and closed from surveys), to investigate the quality and outcomes of a specific programme or curriculum. In engineering curriculum assessment, the multisource feedback experience is implemented in a classroom setting using students to provide evaluation of peers for team-based projects, in addition to inputs from faculty members to determine the students' overall learning experience and interpersonal performance.

From historical trends, this approach has proven to be both an effective feedback tool and it has helped to improve engineering learning outcomes to a greater extent [6]. In addition, it is considered that closed form questionnaires serve as a classical method for obtaining feedback from individuals. This type of assessment source is used in engineering courses to evaluate the student's perspective and attitude toward the various engineering educational aspects, as well as obtaining a self-assessment of individual abilities and competencies [6].

In the above mentioned engineering programme assessment, triangulation can be used to evaluate and compare the results of the two metrics used in the process to find the method that yields more accurate results and consequently can be used to improve the engineering programme outcomes by completing the feedback loop.

USING TRIANGULATION

A non-traditional application of triangulation as an assessment tool may be used in some capstone design courses where unlike the conventional classroom environment, students are exposed to hands-on team work, through design projects in

their specific fields of study assigned by academic and industrial partnerships. In this case, the assessment process relies on the effective use of triangulation to evaluate the feedback and results obtained from three major sources.

First, from the industrial mentors assigned to each team to serve as an external source of evaluation of technical and engineering skills from a potential employer professional perspective; second, from the faculty advisors designated to work closely with small teams on sequential semesters of design project courses, and third, from the self-rating of the students. All three sources are critical in assessing the learning process and are used to determine student competence. In order to sustain coherence and validity of the results, the triangulation process may be used to assess outcomes from the several rating sources mentioned above to determine the learning outcomes associated with the capstone design course. Assessment of the capstone course is important as it establishes the claim that engineering students are *exiting the curriculum with the skills that match programme objectives* [7]. The data from the three sources may be used to converge to the final determination using the triangulation process.

In an implementation of the method, the students participating in the evaluation process were the ones enrolled in the course and were rated on technical knowledge, oral writing communicational skills, teamwork and project management skills. The analysis of the triangulation outcomes was processed in three different phases.

The first step involved the investigation of commonalities among the three different raters. The second phase of the triangulation results assessment resided in finding similarities between the open comments and additional explanations provided by raters from the surveys. Finally, the third step consisted of finding the inter-rating disagreements by looking up the differences in ratings. Eventually, statistical analysis was performed on the data using the *ANOVA Procedure,* which could test the ratings of one specific aspect of the design project and evaluate if the rating diverged significantly among feedback providers [7].

The results from the triangulation method were found to be an efficient way to determine the deficiencies in the course layout and illustrate the specific areas where personal and technical skills for students were lacking. In addition, they provided valid and reliable proposals and recommendations for rebuilding the course in order to assure improvement in students' skills and abilities, and achievement of academic objectives.

In most publications and articles, using triangulation as an assessment tool was considered a concept or tool to eliminate bias and improve the convergence of outcomes [1]. However, this approach is criticised by Mathison and categorised as being far from realistic. On a more practical stand as suggested by Mathison, triangulation provides evidence for the researcher *to make sense of some social phenomenon, but that the triangulation strategy does not, in and of itself, do this* [3]. The conventional approaches claim that the outcomes of a triangulation assessment would result solely in the convergence of results.

In addition, metrics investigated through several methods and sources would all support one proposal. On the other hand, a new practical perspective of triangulation as an assessment strategy would expect there to be inconsistency and contradiction between results. The presence of inconsistency in outcomes, while using different methods for the purpose of triangulation assessment, is a somewhat naturally expected result. It is possible that different approaches will lead to inconsistent and ambiguous perspectives instead of supporting a single source of evidence.

The third possible outcome of triangulation is to end up with contradictory data. Not only can inconsistency exist in results and provide ambiguous perspectives, but serious contradictions can also arise from using different methods. In some cases, triangulation may lead to contradictory statements, which may require further investigation to reach a reasonable conclusion. Inconsistencies and contradictions in the results should not affect the validity of the research or theory under question.

Restricting the outcomes of triangulation to the convergent outcomes approach lessens the potential and effectiveness of the research in progress. It is, therefore, deemed necessary to expect inconsistencies and contradictions to be present in the results of a triangulation assessment strategy. After all, triangulation is a tool to provide evidence and better explanations of social phenomena and not a mathematical process that allows room for only one solution as the ultimate truth.

A CASE STUDY

Programme outcomes are comprehensive learning statements that relate to the academic objectives and to the core skills and values that the students should acquire by the time of graduation. In order to investigate the level at which the outcomes are attained within the academic programme, comprehensive assessment and evaluation processes are implemented through the academic year. These evaluation and assessment measures help indicate and report the level at which the programme outcomes and objectives are achieved.

The College of Engineering and Engineering at Northern Illinois University has four departments. Like other departments, the Department of Industrial and Systems Engineering (ISYE) has a comprehensive assessment plan and

adheres to the ABET standards in meeting its learning and teaching obligations. The evaluation measures implemented by ISYE are divided into direct and indirect categories.

The direct assessment consists of two types of measure: *Course Embedded Assessment* and *Senior Design Performance Appraisal*.

To conduct the course assessment, an evaluation form is used. This assessment methodology requires professors to submit two separate evaluation forms: one at the beginning of the academic semester and the other at the end. The first form provides feedback on how the course-specific outcomes relate to the programme outcomes. The form used at the end of the semester provides an assessment of how various course assignments assess the learning outcomes associated with the course.

The senior design performance appraisal is an evaluation tool that was first implemented during the spring of 2007. The assessment process consists of providing feedback on the student's performance in the capstone design projects. Since local companies sponsor most of the design projects assigned to ISYE students, one or more representatives of the sponsoring company is part of the assessment team evaluating the ability of the student to apply technical, theoretical and communication skills to solve real industry problems. This forms the direct assessment category of the evaluation.

The indirect measures of the programme outcomes assessment can be addressed as follows. The first indirect assessment tool is the course student's survey. The survey is a self-assessment provided by the student of their own perception of learning in the courses offered by ISYE. Their feedback is then mapped on to the programme assessment matrix to assess programme level learning outcomes. Second, programme outcomes are indirectly measured through the graduating seniors exit surveys. Starting in spring 2007, ISYE students were asked to complete the graduating exit survey upon completion of their degree requirements.

The exit survey provides an effective assessment tool to obtain feedback from students on their overall experience at ISYE and their evaluation of the extent of knowledge gained by them to meet the programme goals and outcomes. The exit survey is an effective assessment tool that provides the department with good insights on possible curricular reform and a change in instructional strategies.

Co-op and internships surveys are another indirect outcome assessment measure. Co-op and internship surveys provide an insight into the ability of students to integrate in workforce environment, and how effectively they apply their personal and academic skills to contribute to the company welfare during the experience period. Supervisors from companies where students are engaged to acquire industrial experience perform the co-op and internship assessments.

However, the surveys are only obtained from students who officially enrol in internship courses and opt to receive academic credit for their work experience. These are the assessment tools used by the department to evaluate their learning outcomes and programme objectives. The direct and indirect programme outcome assessment measures data were gathered for years 2006 to 2009. The results obtained for each year, and each academic semester specifically were averaged across all outcomes for each assessment level as presented in Table 1 and Figure 1.

Data Analysis

Once all the necessary data were generated throughout the direct and indirect level assessment measures of the programme outcomes, it was deemed necessary to analyse the data and investigate the relationships between the outcomes and levels of assessments.

Table 1. Assessment results.

2006-2009 direct and indirect assessment of ABET outcomes for ISYE												
		Outcome A	**Outcome B**	**Outcome C**	**Outcome D**	**Outcome E**	**Outcome F**	**Outcome G**	**Outcome H**	**Outcome I**	**Outcome J**	**Outcome K**
2009	Direct	4.27	3.95	4.03	4.30	4.20	4.42	4.22	3.59	3.79	3.71	4.08
	Indirect	4.23	4.12	4.27	3.93	4.05	4.08	4.14	4.26	4.08	3.77	4.19
2008	Direct	3.88	4.10	3.83	4.32	3.92	3.75	3.84	4.15	4.20	4.01	4.14
	Indirect	4.32	4.24	4.18	4.32	4.30	4.28	4.18	4.21	4.27	3.91	4.15
2007	Direct	4.50	4.50	4.50	5.00	4.50	4.50	5.00	4.50	4.50	4.50	5.00
	Indirect	4.45	4.56	4.49	4.50	4.36	4.61	4.66	4.27	4.71	3.97	4.54
2006	Direct	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Indirect	4.33	4.37	4.25	4.46	4.44	4.29	4.47	4.39	4.37	4.22	4.33

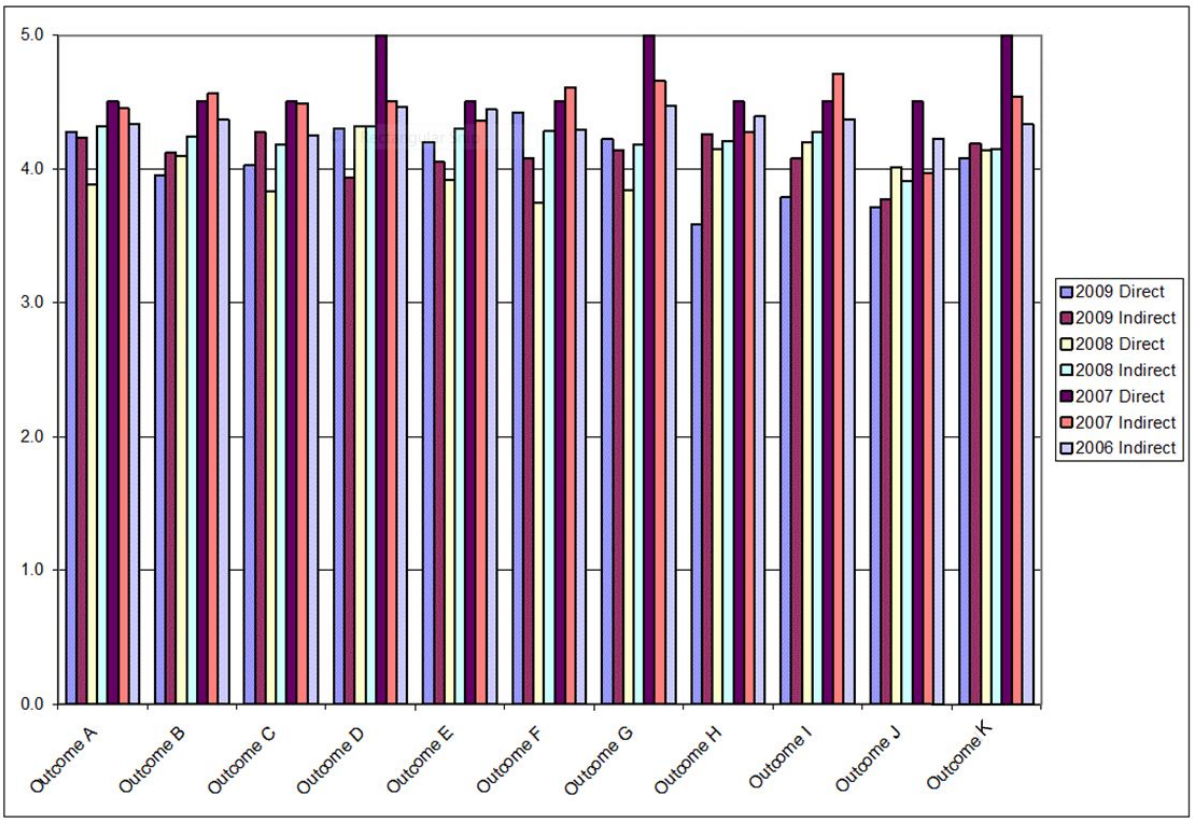

Figure 1. Assessment results.

Looking at the results, one cannot conclude that the different direct and indirect measures are measuring the same thing. In other words, are they giving the same results? Do they measure the same attainment levels? To answer these questions, the authors applied the concept of triangulation. Initially, a *t*-test was conducted on several paired two samples to compare the dependent data set and investigate, if the paired data sets had the same mean. The first *t*-test run was for the averaged direct levels of all years and all outcomes paired with the averaged indirect levels of all years and all outcomes combined. The results obtained from Minitab statistical *t*-test analysis are shown in Figure 2.

Paired T-Test and CI: Direct, Indirect

```
Paired T for Direct - Indirect

             N    Mean  St Dev  SE Mean
Direct      44  4.2306  0.3212   0.0484
Indirect    44  4.1835  0.2629   0.0396
Difference  44  0.0471  0.3087   0.0465


95% CI for mean difference: (-0.0468, 0.1409)
T-Test of mean difference = 0 (vs not = 0): T-Value = 1.01
P-Value = 0.317
```

Figure 2: The results obtained from Minitab statistical *t*-test analysis.

The results showed that both the direct and indirect samples have the same mean. In other words, this could be interpreted as indicating that both direct and indirect data samples were measuring the same outcomes.

Additional paired *t*-tests were performed, to investigate whether the direct and indirect levels for each outcome A to K individually have the same mean. The *t*- test analysis confirmed that the indirect and direct levels for each outcome A to K have the same mean and, thereby, are measuring the same thing.

CONCLUSIONS

From the literature research, triangulation was shown to be an effective tool to enhance outcomes credibility. The triangulation method relies upon the usage of several measurement tools to eliminate the bias within the data and establish convergent results.

For the purpose of evaluating and assessing the level at which the academic objectives and outcomes were achieved within ISYE, it was deemed necessary to implement the concept of triangulation to investigate and assess programme outcomes through the use of various assessment measures. The assessment forms were identified as direct and indirect with each type respectively having more than one measurement level.

The data collected from ISYE were analysed using statistical testing and hypothesis testing to verify the validity of the triangulation theory. When considering the significance of the data on a large scale, the results of the *t*-test supported propositions that both the direct and indirect assessment tools were converging to the same attainment level for the programme outcomes. The department finds triangulation theory to be promising and plans to use this in the future. The department will also share the results of this finding with the other departments and encourage them to substantiate their ABET assessment criterion using the theory of triangulation.

REFERENCES

1. Miles, M.B. and Huberrnan, A.M. *Qualitative Data Analysis.* Beverly Hills: Sage (1984).
2. Campbell, D.T. and Fiske, D.W., Convergent and discriminant validation by the multitrait-multimethod matrix. *Psychological Bulletin,* 56, **2**, 81-105 (1959).
3. Mathison, S., Why triangulate? *Educational Researcher*.17, **2**, 13-17 (1988).
4. Denzin, N.K., *The Research Act: A Theoretical Introduction to Sociological Methods.* New York: McGraw-Hill (1978).
5. Brent, R. and Felder, R., Designing and teaching courses to satisfy the ABET Engineering Criteria. *J. of Engng. Educ.,* 92, **1**, 7-25 (2003).
6. Besterfield-Sacre, M., Shuman, L. and Wolfe, H., Triangulating Assessments: Multi-Source Feedback Systems and Closed Form Surveys. University of Pittsburgh (2000) (me.pitt.edu).
7. Knight, D., Kotys-Schwartz, D. and Pawlas, G., Triangulation: an effective assessment tool for capstone design program evaluation. *Proc. Capstone Conference* (2010) (Capstone Conference Paper 2010).

BIOGRAPHIES

Dr Omar Ghrayeb is the Associate Dean of Outreach and Undergraduate Programmes of Northern Illinois University's College of Engineering and Engineering Technology. He works closely with the industrial sector and spearheads the EIR programme. He is committed to promoting experiential learning as part of engineering education and works with several companies in the area to bring real-life projects into the classroom. His expertise is in process innovation and production planning.

Dr Purushhothaman Damodaran is an Associate Professor in the Department of Industrial Engineering at Northern Illinois University's College of Engineering and Engineering Technology. His expertise is in the area of large-scale optimisation, logistics, simulation, scheduling and electronics manufacturing**.** He has worked closely with several industries on problems which are critical to their growth. He is interested in working on real-life, challenging problems that are in the critical path of an organisations growth.

Dr Promod Vohra is the Dean of Northern Illinois University's College of Engineering and Engineering Technology. His commitment to applied research and global engineering education is reflected in his work and philosophy. Dr Vohra has published widely and serves on several national and international committees and boards. He believes the engineering profession must act as an innovation catalyst and create a new economy for the globe.