A ‘continuous improvement’-based approach for the assessment of student learning

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Abstract: Student learning is primarily a function of teacher centric and institution centric processes. For sustained gains in student learning, it is important to have a feedback mechanism between ‘teaching’ and ‘assessment’, which we have addressed through the adoption of continuous improvement (CI) philosophy. In this paper, through assessment of student performance, we demonstrate the effectiveness of the application of CI theory for teacher centric processes particularly in attaining student learning related goals by the adoption of plan, do, check and act (PDCA) cycle to one of the quantitative methods courses that we teach. The demonstration of the application of CI theory for teacher centric processes could be easily extended to other facets of student learning not explicitly considered in this research paper for the holistic treatment of the issue of student learning.

Keywords: student learning; assessment; PDCA cycle; teacher centric processes; continuous improvement; institution centric processes; instructional design; instructional delivery; corrective action; first principles of instruction.


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1 Introduction

Over the last several decades, the quality of teaching and learning in colleges and universities has become an issue of growing concern and scrutiny in many countries around the world (Kehm, 2010). Pascarella et al. (2010) opine that beyond student related statistics, a growing segment of the population has become interested in knowing what students actually learn in college. According to Altbach et al. (2010), post secondary education has to prepare graduates with new skills, a broad knowledge base, and a range of competencies to enter a more complex and interdependent world.

It is an observable phenomenon all over the world that the focus is rapidly shifting from teacher controlled environment to student controlled environment and because of this, assessment of learning outcomes and teaching effectiveness is becoming the new norm at all the levels from K-12 to higher education. Buttressing the same view, Kehm (2010) opines that attention is shifting from what is taught to what the student is expected to know and be able to do at the end of the course, module, or programme. She also believes that the teacher is cast in the role of a facilitator of learning experiences who is expected to integrate opportunities for the acquisition of generic skills into the subject matter.

Holistic approach to student learning, which will enable the student to become a valuable asset to the society at large is slowly taking root all across America. Kuh et al. (2007) recommend that universities and colleges should focus their assessment efforts on factors that influence student success. Another concept that is gaining ground is what is called as ‘complex learning’. Complex learning has been defined as involving “the integration of knowledge, skills and attitudes, the coordination of qualitatively different constituent skills and the transfer of what is learned in school or training to daily life and work settings” [Van Merrienboer and Kirschner, (2007), p.4].

Altbach et al. (2010) emphasise the significance of linkages within the ‘triple helix’ of university-government-industry that contribute to important organisational changes within the university. They also believe that an increasingly diverse student body creates pressures to put in place new systems for academic support and innovative approaches to pedagogy.

In the context of student learning, the more important question involves understanding the different facets of the student learning process, which in turn allow us to identify the key elements that hinder the achievement of the desired level of quality.

The national survey of student engagement (NSSE, nsse.iub.edu) considers level of academic challenge, active and collaborative learning, student faculty interaction, enriching educational experiences and supporting campus environment as benchmarks of effective
educational practice that significantly contribute towards student learning and personal development. Kehm (2010) believes that internal quality management is complemented by external quality-assurance mechanisms, complete with quantifiable indicators. The five key dimensions for service industry namely, tangibles, reliability, responsiveness, assurance and empathy, which constitute the key elements of SERVQUAL model (Parasuraman et al., 1988) directly affect different facets of student learning.

In spite of the presence of voluminous research on ‘assessment’ in the context of student learning, we realised that there are avenues still open in the area of presentation of a simple, effective and generic feedback mechanism between ‘teaching’ and ‘assessment’ to improve student learning outcomes on a continuous basis. We propose the application of ‘continuous improvement (CI)’ theory to serve as the connecting mechanism between the important elements of teaching such as ‘instructional design and instructional delivery’ and the assessment efforts.

In the next section, in addition to discussing the key elements of student learning, we also demonstrate the effectiveness of the application of CI theory for achieving student learning related objectives based on the assessment of student performance on a controlled exam in two different semesters for a course taught by one of the authors. The CI techniques could be extended to other key ‘student learning’ related processes not explicitly considered in this paper to address the issue of improving the ‘quality of student learning’ holistically.

2 Improvement of the quality of ‘student learning’

Even though there could be a number of elements that define what ‘student learning’ is (as we are going to explain in sub-section 2.1), our primary focus is on the assessed performance of students on student learning objectives, which for the purpose of this paper we define as the ‘quality of student learning’. We demonstrate the effectiveness of ‘CI’ theory by assessing the performance of students on a controlled exam before and after the adoption of CI philosophy into the course design.

2.1 Role of assessment in student learning

At the strategic level, all the relevant aspects that have a bearing on student learning could be broadly divided into two categories, namely teacher centric and institution centric processes.

Institution centric processes primarily include student support services such as physical facilities, library holdings, student advising, financial support, etc., and faculty support services include teaching load, compensation, IT support, opportunities for professional development, etc. Teacher centric processes could be further sub-divided into two categories, namely, ‘subject matter related’ skills and ‘generic’ skills. Emphasis on generic skills such as communication abilities, team work skills, etc., in addition to subject matter knowledge is progressively increasing across the academic landscape. In an ideal context, all the elements of teacher and institution centric processes must be assessed to have a better understanding of the status of ‘student learning’.
Fardows (2011) defines assessment as a “systematic ongoing, interactive process of monitoring (recording and analysing) the student’s learning outcomes and processes in order to determine what we are doing well and what we need to improve”. Klein et al. (2010) opine that although many college professors have always been concerned with student learning, the formal focus on understanding and assessing learning outcomes is relatively new. Ried (2011) opines that among other things faculty members involved in curricular assessment should continually explore reliable and valid methods of assessing whether students have reached their learning goals. In addition to being a powerful tool for improving students’ learning and motivation, assessment also helps in developing a positive and supportive learning environment (Wanousa et al., 2009). In light of the significance of assessment activities on student learning and to address the need of establishing a link between assessment efforts and the teaching strategy, we advocate the use of ‘CI’ philosophy to improve the quality of student learning on a continuous basis.

Simultaneous assessment of ‘subject matter related’ and ‘generic’ skills is made difficult due to the lack of consensus on what specifically constitutes the so called generic skills. According to Kehm (2010), the assessment of mastery not only of the subject matter but of generic skills continues to be riddled with problems. In the context of this paper, we limit the scope of our research to ‘subject matter related skills’ primarily emphasising the assessment of student learning.

In the next sub-section, we demonstrate for a specific course how ‘CI’ techniques could be used to improve performance on ‘student learning’ objectives. Even though, we are presenting the ‘CI’ framework for improving ‘subject matter knowledge’ related aspects of student learning, same framework could be used with appropriate modifications to improve other aspects of student learning such as institution centric processes, generic skills, etc.
2.2 Attainment of student learning objectives through ‘CI’

With the emphasis shifting to student learning, it is becoming imperative that the students should be able to use their theoretical/conceptual knowledge in appropriate practical situations in the real world to derive the fullest benefit out of their education. Student learning quality can be enhanced only when there is a continuous feedback from assessment efforts, which is acted upon to make appropriate changes to ‘teaching’ on a continuous basis. The required link between ‘teaching’ and ‘assessment’ is missing in contemporary assessment studies. In this context, Chun (2010) states that “it is an empty exercise to assess student learning without providing a means to adjust teaching in response to deficiencies revealed through the information gleaned from that assessment”. Also, according to Kuh and Ewell (2010), “while there is considerable assessment activity going on, it does not appear that many institutions are using the results effectively to inform curricular modifications or otherwise to enhance teaching and learning”. Among other things, Hargreaves (2005) mentions monitoring pupils’ performance against targets or objectives and using assessment to inform next steps in teaching and learning as possible meanings for ‘assessment for learning’.

The proposed ‘CI’-based approach provides the missing link between teaching and assessment by the provision of a feedback mechanism to constantly update different elements of instructional design and delivery. The concept of ‘CI’ is not new to research in higher education. Mattis and Sinn (2009) refer to the fact that the Higher Learning Commission of North Central accreditation (HLC NCA) offered its member institutions an accreditation alternative – called the academic quality improvement process (AQIP)-based on continuous innovation and quality improvement principles. Kelly (2010) opines that CI is a necessity in today’s environment, and higher education is not immune to this phenomenon. She also believes that both planning and assessment are required to create successful improvement processes in higher education. Although the size of the education systems has increased enormously in recent decades, the quality has not (Stewart, 2010).

Even though student learning was assessed as a function of technology (Lei, 2010), peer assessment (Vickerman, 2009), etc., the novelty of this research lies in making use of the ‘CI’ theory in establishing the feedback loop between ‘teaching’ and ‘assessment’. For improving the quality of student learning, even though there are a number of survey-based models that consider teacher centric and/or institution centric processes (Chapman and Henderson, 2010; Frick et al., 2010), at the detail level, to the best of our knowledge, application of CI models is relatively sparse. Penn State’s IMPROVE model, which is an expansion of Shewhart (1939)/Deming (1986) ‘plan-do-check [study]-act’ model, demonstrates how to facilitate problem solving, decision making, and process improvement in higher education (Kelly, 2010). Peterson et al. (2011) have described a systematic assessment process that provides CI in the curriculum, supports faculty development, and enhances student learning outcomes and concluded that the curriculum assessment plan provides a structured method of monitoring and delivering continuous quality improvement. Haug and Keleman (1996) have discussed about CI concept and related tools in the context of introducing total quality management (TQM) into the process of teaching management.

The application of ‘CI’ philosophy and the associated tool kit facilitates the achievement of student learning related goals in a simple and effective manner. Simply
put ‘CI’ involves updating different aspects of teaching on a continuous basis by taking inputs from the students and the student related processes at regular intervals and proactively acting upon them.

The focus of this sub-section is to demonstrate the usage of CI philosophy for improving the quality of student learning particularly in subject matter related knowledge for a course selected based on the poor achievement of student learning objectives in a prior semester, which in turn will affect positively the ‘level of quality’ attainment for the department and the college in the grand scheme of things at the strategic level.

We have chosen ‘business statistics’ course as a test case for the improvement of student learning using CI philosophy. Business statistics is a required core course in the college of business for all majors. Typically there are around ten sections in a year consisting of 30–40 students in each section. Tools and techniques that the students are exposed to in this course are so versatile that all the business major students will have ample opportunities to actually use them both during their education and once they graduate and set foot in real world, thereby making this course an ideal choice not only for this research but also for further extensions of this research in future. Of course, the other important criterion for the selection of this course is the perceived need for improvement in the attainment of student learning objectives based on the past performance of the students.

As mentioned earlier, ‘CI’ framework and the associated tool kit could be used for improving other aspects of student learning not explicitly considered in this paper such as institution centric processes, etc. For example, communication ability as part of generic skills could be assessed based on presentation skills and team work ability could be assessed based on individual student’s contribution to a group-based project and the relevant data could be analysed for exploring the potential for improving the quality of student learning.

In this section, we specifically consider the application of CI theory and the relevant techniques for enhancing the quality of student learning that emphasise not only the identification of lagging students but also the topics/concepts majority of the students are struggling with. This will enable an instructor to achieve student learning related goals in an equitable fashion, which in turn will have a positive bearing on the quality of student learning.

Figure 2 PDCA cycle
The ‘CI’ methodology that we have adopted for managing and improving the course consists of the following four simple steps plan, do, check and act (PDCA).

We have considered instructional design (plan step), instructional delivery (do step), student performance assessment (check step) and the corrective action (act step) as the key elements that constitute the PDCA cycle. Course design is one of the most important activities that sets the ball in motion. Van Merrienboer et al. (2002, p.39) suggest that “inadequate [instructional] design may cause learning problems”.

Based on a synthesis of instructional design theories, Merrill (2002) claimed that student learning will be promoted when:

1. instruction is problem- or task-centred
2. student learning is activated by connecting what they already know or can do with what is to be newly learned
3. students are exposed to demonstrations of what they are to learn
4. they have opportunities to try out what they have learned with instructor coaching and feedback
5. they integrate what they have learned into their personal lives.

First principles of instruction (Merrill, 2002, 2008; Merrill et al., 2008) as postulated above could possibly serve as key performance metrics for teacher centric processes.

Figure 3 Cause and effect diagram for subject matter related student learning (see online version for colours)
Kelly (2010) opines that data-based decision making can be assisted by assessment, and assessment is directly related to quality improvement. We primarily analyse the data based on the first midterm exam scores of the students for two different semesters for this study before and after the adoption of the CI philosophy for improving student learning.

Cause and effect diagram also known as fishbone diagram or Ishikawa diagram (Figure 3) is typically used to search for the possible causes of a problem typically in manufacturing settings. We have used fishbone diagram in the present context to delineate different activities that will have an important bearing on student learning. The advantage of considering PDCA as the key components of the cause and effect diagram as shown in Figure 3, is that, it will force us to revisit all the activities starting from the planning phase to the act phase, if the student learning related targets are not met.

2.2.1 Plan phase: instructional design

‘Plan phase’ basically consists of the key activity of ‘instructional design’ that addresses ‘what and when’ with respect to the prescribed syllabus. Ruohoniemi and Lindblom-Ylanne (2009) through their survey of 132 veterinary students have identified ‘planning of teaching’ as one of the important factors in their research that contributes to the enhancement of student learning. The key emphasis is on equitable distribution of the topics in an appropriate order so that the student is not overburdened and at the same time required pace is maintained to cover the entire syllabus. It is essential that student learning objectives for each topic should be directly related to the course objectives, and the topics chosen for measuring the class performance (assessment) should in turn be related to learning objectives.

For this study, appropriate course objectives, relevant learning objectives and performance measurement topics are based on the prescribed syllabus (for the first midterm assessment) as shown in Figure 5.

Under the ‘plan’ phase, depending on the course, there could be a number of activities that need to be planned for in advance as shown in Figure 3. The addition of generic skill assessment components such as group projects or presentations or first principles of instruction assessment components is possible in this phase. Depending on the purpose of study, all appropriate elements that need to be planned for should be addressed during the ‘plan’ phase of the PDCA cycle.
2.2.2 *Do phase: instructional delivery*

‘Do phase’ basically consists of the key activity of ‘instructional delivery’ that addresses the question of ‘how’ with respect to what is planned during the ‘plan’ phase. The key emphasis is on maintaining the right tempo that sustains the interest of the students. Rocconi (2011) research results indicate that the relationship between learning community participation and learning outcomes are mediated by students’ levels of engagement. First principles of instruction (Merrill, 2002, 2008; Merrill et al., 2008) serve as a valuable guiding tool in this phase.

Even though we are not assessing the specific impact of each of the first principles of instruction individually in this study, it would make an interesting extension and would provide with valuable information on student learning and the effectiveness of teaching. In that case, appropriate elements for addressing the first principles of instruction should be considered during the plan phase. Even though we did not evaluate each of the first
principles of instruction individually, they were adopted in the classroom in a generic fashion to improve the quality of student learning. The first principle of authentic problem formulation can be better addressed for example by emphasising the application of the interpretation of the shape of a histogram in a business context rather than on the procedure that details how to construct it. As opposed to starting with a formula for arithmetic mean, a discussion about how it relates to a set of numbers followed by the relevant formula to calculate it would be well received by the students and be more in tune with the second principle of activation. In the context of explaining 'probability concepts’, development of a two way raw data matrix such as a contingency table by considering different major areas (finance, accounting, etc.) and the gender (male and female) for the class would facilitate immensely the understanding of the concepts such as union, intersection, complement and conditional probabilities for different events. Statistical simulation applets also serve as a wonderful aid in demonstrating various statistical concepts. Encouraging the students to work on a real world problem no matter how small or through a case study, that makes use of some of the statistical tools they have learnt would be a good strategy to make them appreciate the versatility of the decision making tool kit they are mastering, which ultimately leads to the possible integration of those concepts into their personal lives as well.

Some of the key activities to be considered under this phase are presented in Figure 3. Prior semester student evaluations of teaching are another important source of information for getting valuable feedback on ‘student learning’ and the quality of teaching that help in deciding the appropriate form of instructional delivery.

2.2.3 Check phase: student performance assessment

‘Check phase’ basically consists of the key activity of devising a measurement system for assessing the ‘student learning’ in subject matter knowledge at regular points of time during the semester to provide appropriate feedback on instructional design and delivery discussed in the previous two sections. Ellery (2008) in her research emphasises the importance of strategic and well-planned use of feedback in the assessment process for promoting learning. Generally, instructors tend to focus upon the lagging students with the idea of bringing up the class average and to reduce the number of students who fail. This approach misses the opportunity of improving the performance of the rest of the class. Through assessment of student performance, we show how we can use simple quality tools in not only identifying the students who are lagging significantly when compared to the rest of the class but also in identifying those concepts that majority of the students are struggling with. We specifically assessed the data for the combined performance of eighty one students of ‘business statistics’ course belonging to three different sections of Spring 2010 semester taught by one of the authors on their first midterm exam based on student learning assessment topics as identified in Figure 5. After assessing the performance of the students, appropriate corrective actions were planned for and put into effect in two different sections of ‘business statistics’ course consisting of forty seven students taught by the same instructor during Fall 2010. The exam was a controlled exam and was not given back to the students for keeping during Spring 10, hence the same exam was administered in both the semesters, thereby eliminating the potential bias that would arise if two different versions were used. We also assume that
the students taking the course in different semesters are equivalent on all other aspects not explicitly considered in this assessment. All the charts and graphs have been constructed using Minitab® 15 software.

**Figure 6** Exam scores vs. percentage of students (SP 10)

![Histogram for exam scores (Spring 10)](image)

**Figure 7** Exam scores vs. cumulative percentage of students (SP 10)

![Cumulative Histogram for exam scores (Spring 10)](image)
Figure 8  Cluster bar chart for SP 10 and FA 10 semesters

Figure 9  Pareto chart for SP 10 semester (see online version for colours)
2.2.4 Act phase: corrective action

‘Act phase’ basically consists of ‘addressing the key issues’ that were identified during the check phase. A histogram not only gives us an idea of the distribution of scores (symmetric, negative/positive skewness, etc.) but also gives an indication on the frequency of students with outlying scores and variability in the dataset.

Spring 10 exam score histogram (Figure 6) in our study is indicating that the exam score distribution is negatively skewed, which means that most of the scores are concentrated toward the higher end of the distribution, with a few very low scores. We have adopted a score of 70% as the minimum acceptable standard for meeting the learning objectives on the given topics. It can also be seen from the cumulative percent histogram (Figure 7) that approximately 41% of the students were getting a grade ‘D’ or lower, by not being able to reach the acceptable minimum standard. Appropriate corrective action in this case would be to pay extra attention to those students, suiting their individual circumstances to improve their performance. Providing opportunities for meeting outside of office hours, monitoring attendance, extra attention in the class room, etc., also would aid the students with poor scores to improve their performance. In addition to adopting these corrective actions in Spring 10, they were also implemented from the beginning of Fall 10 through the ‘plan’ step of PDCA cycle. Based on performance on the assignments leading to the first midterm and attendance, lagging students were identified and allowed additional opportunities to meet with the instructor suiting mutual convenience to clarify questions related to the relevant concepts. This facility was made available to other students as well. In addition, number of assignments leading to the first midterm was also increased compared to Spring 10 by incorporating additional home works to facilitate working on problems related to different concepts at their own pace.

Figure 10 Exam scores vs. percentage of students (Fall 10)
Figure 11  Exam scores vs. cumulative percentage of students (Fall 10)

Figure 12  Pareto chart for Fall 10 semester (see online version for colours)
As we mentioned previously, it is also essential to identify those concepts that majority of the students are struggling with. Pareto chart (named after an Italian economist Vilfredo Pareto), that works on the principle of ‘vital few and trivial many’ is another useful tool in identifying concepts in the order of their importance that majority of the students are struggling with. Based on Pareto chart for Spring 10 (Figure 9), it is clear that the students had a particular difficulty in mastering Z-score concept, intersection event probability, charts and graphs related concepts, conditional probability, combinations, etc., in that order. First five topics mentioned above together accounted for approximately 58% of all the wrong answers. Pareto chart is more useful than a regular bar chart, because it not only orders different topics according to their corresponding frequencies but also presents a cumulative percentage graph that aids in better understanding the cumulative contribution of different topics in a particular context.

Appropriate corrective action in this case would be to revisit the identified topics/concepts and also the appropriate learning objectives from Figure 5 (prioritised based on Pareto chart information) that students are struggling with in the class room and/or provide additional office hours to make sure that everybody understands those concepts in a clearer fashion. Based on student performance in Spring 10 semester, additional care was taken during Fall 10 semester by incorporating additional in-class practice problems for those learning objectives with the highest number of wrong answers. In addition, randomly chosen students were challenged to come up with the correct solution and the proper explanation for practice problems relevant to the identified learning objectives.

For some of the topics, simulation applets were also used as an additional aid to clarify different concepts. In addition, students were encouraged to make use of statistical software (Minitab® or MS Excel®) for routine calculations and in class hours were primarily spent on understanding different concepts related to relevant topics.

The effect of the corrective actions taken is clearly seen in Figures 8 and 10 to 12. It is clear from the histogram presented in Figure 10 that negative skewness is relatively less distinct compared to Figure 6 for Spring 10. Also, Figure 11 indicates that approximately 26% of the students are getting a grade D or less compared to 41% for Spring 10 semester, which is a significant improvement. Also from the cluster bar chart (Figure 8), it is clearly seen that the percentage of wrong answers for majority of the topics has come down significantly for Fall 10 compared to Spring 10. Pareto chart presented in Figure 12 indicates that there is also some change in the composition of the top five concepts contributing to the majority of the wrong answers, which is to be expected and those topics and the relevant learning objectives would warrant additional efforts for bringing down further the percentage of wrong answers in future semesters.

‘Plan-do-check-act’ cycle is again set into motion in the next semester by adopting the appropriate corrective actions from the current semester during the ‘plan’ phase itself, with the intention to prevent the same mistakes from recurring. With the incorporation of these corrective actions student learning will be impacted positively and the adoption of PDCA cycle in the next semester will offer additional opportunities for CI.

CI framework as demonstrated above should be applied to relevant aspects of all the student learning processes for attaining the desired level of quality as per the strategic mission statement for a specific educational institution for addressing the issue of ‘student learning’ in its totality. The proposed framework could be easily adopted for any other course in general and other quantitative methods courses such as operations management, management science, etc., in particular.
3 Conclusions

In our research we presented a model for the enhancement of the quality of student learning in a holistic manner and specifically advocated for the application of CI theory for teacher centric processes. Specifically, we presented the application of PDCA cycle along with several quality improvement tools for enhancing the quality of ‘subject matter related student learning’ by analysing the midterm exam score data for sophomore business students in two successive semesters. The key contribution of this paper is establishing the link between ‘teaching’ and ‘assessment’ through CI. In the process, we have also demonstrated the effectiveness of the application of CI theory for the enhancement of student learning in general and teacher centric processes in particular that not only aids in improving the performance of the lagging students but also facilitates the identification of the ‘learning objectives’ majority of the students are struggling with.

Even though we have confined the scope of this paper to subject matter related student learning processes, CI theory presented in this paper can be easily extended to other teacher centric processes, such as the development of generic skills, etc., if appropriate, and would serve as a possible extension for this line of research. Also by benchmarking ‘institution centric processes’ to the ‘best in class’ peer institutions, PDCA framework could be used to improve the quality of those processes as well, which in turn would constitute a potential research area for expanding the scope of the current model.

We believe ‘first principles of instruction’ to be an useful set of guidelines that promote student learning and tried to accommodate them in a generic fashion in our CI framework. We would love to see future research in this area to specifically investigate the effectiveness of the ‘first principles of instruction’ in a CI framework that would possibly shed more light on the real benefits that are accrued to the students as a result of their college education.

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