Chapter 3 Conceptual Model

Learning theories suggest PBL is an instructional method with well-defined Input, Process and Output (IPO). PBL uses appropriate problems to increase knowledge and understanding. PBL in group learning facilitates gain of knowledge, enhancing of skills for example communication skills, teamwork, problem solving and builds attitude such as independent responsibility for learning, sharing information and respecting others. Hence PBL method that is implemented in small groups helps in acquiring knowledge and development of skills and attitudes (Wood, 2003).

The researcher has implemented PBL in Statistics and Operations research along with classroom teaching. In this chapter a conceptual model is proposed based on learning theories that can be used to experiment and evaluate the effect of PBL approach in Statistics and Operations research. Researchers have adopted problem-based taxonomy as suggested by Barrows (1986). In this chapter section 3.1 explains proposed conceptual model and as there are more than one latent variables such as Students’ Background, Student Engagement and Learning outcomes, structural equation modeling is appropriate, is mentioned in section 3.2. Section 3.3 presents the measurement model. Structural model is discussed in section 3.4. Summary and research directions are discussed in section 3.5.

3.1 Derived Conceptual Model for PBL in Learning Process

Students’ learning is affected by their background and engagement, (Coates, 2006; De Graaff et al., 2003; Gijselaers, 1996) as derived from literature review, forms the basis of study on the impact of PBL on students’ learning. Literature review also suggests that learning outcomes are knowledge, skill and attitude that student gains through learning experiences. Learning theories suggest that PBL in teaching learning system can be represented as IPO (input, output, process) method shown in figure 3.1
The Input-Output-equation then would be

\[(K, S, A)_{\text{output}} = (K, S, A)_{\text{initial}} + f(pbl, se, sb) \] ........................Eq(3.1)

Here \( pbl \) is a numerical variable taking values as discussed in Chapter 4, \( se, sb \) are vector measures to be defined in later Chapters.

The dotted lines in figure shows contribution of researchers. The impact of PBL would ultimately measure as **positive, negative or neutral**. The model uses latent independent and dependent variables, namely \( K, S, A, pbl, se, \) and \( sb \). Student background and Student engagement are independent latent variables and knowledge, skill and attitude are dependent latent variables. A latent construct or latent variable shown with oval shape is a hypothesized and unobserved concept that can be represented by observable or measurable variables. It is measured indirectly by examining consistency among multiple measured variables referred as manifest variables or indicators which can be gathered through various data collection.
methods like evaluation, tests, observational methods etc. As the study postulates relationship between several dependent and independent variables, Structural Equation Modeling is most appropriate (Hair et al, 2018).

### 3.2 Structural Equation Modeling

A complete conceptual model of Learning in general, and Learning with PBL in specific would constitute of following sub-models

{  
  A generic Input-Output model (Fig 3.1)  
  A detailed PBL process diagram (Ch 4, Fig 4.1)  
  A Transition diagram (Fig 3.2)  
  A SE Model (student engagement) (Fig 3.3, 3.4, 3.5)  
  A SB model (Student Background) (Fig 3.6)  
}

Deriving appropriate measurement equations between all concerned metrics, or appropriate connection rules between implied consequences would complete the description and lead to a comprehensive SEM. The following sections are devoted to discussion of these aspects. Hence, the first conceptual sub model is an IPO (input, output, process) method as shown in Fig. 3.1. Drawing on students' background knowledge and experiences, is an effective way to bridge gaps, provide connects, to make the content more accessible to learning process.

Hence SB is an **Input Resource** to be used. Student Engagement is a very important resource. It is an investment by learner. Could be in various forms, time being one of the most prominent ones.

Structural Equation Modeling (SEM) is a technique that allows to study a series of separate but interdependent multiple regression equations simultaneously by specifying structural model. SEM also incorporates latent variables into analysis.

SEM is characterized by two components (i) Structural Model and (ii) Measurement Model. The structural model is a path model which relates independent to dependent variables. The measurement model enables the researcher to use several variables (indicators) for a single independent or dependent variable.
The researcher proposes to study impact of students’ background (SB) and student engagement (SE) on learning of statistics and operations research when taught to undergraduate techno-management students by integrating PBL with traditional teaching. The researchers track dependence relationships on students pre admission attributes and students’ engagement attributes, with the transitions that take place through PBL from semester to semester enhancing knowledge(k), skill(s) and attitude(A) of the learned-product coming out of the student learning (SL) system. Figure 3.2 describes the transitions in Learning outcomes as PBL is administered to every batch semester wise.

\[
\begin{bmatrix}
K \\ S \\ A
\end{bmatrix} =
\begin{bmatrix}
t_{11} & t_{12} & t_{13} \\ t_{21} & t_{22} & t_{23} \\ t_{31} & t_{32} & t_{33}
\end{bmatrix}
\begin{bmatrix}
K \\ S \\ A
\end{bmatrix} \text{  } \ldots \ldots \text{Eq(3.2)}
\]

The equation Eq.(3.2) represents transition in learning outcomes.

The K, S and A gains for a single transition from above can be determined by following equations Eq(3.3-3.5) (Chapter 8, 8.15, 8.19):

K-gain=\[\sum_i(a_ip_i) \ldots \ldots \text{Eq(3.3)}\]

S-gain=\[\sum_i(b_ip_i) \ldots \ldots \text{Eq(3.4)}\]

A-gain=\[\sum_i(c_ip_i) \ldots \ldots \text{Eq(3.5)}\]
Where pi are the indicators of GPA and SE and ai, bi, ci are coefficients from Tables 8.15 and 8.19 respectively.

PBL has the potential to teach students self-directed study techniques for life-long learning, problem solving skills, better communication skills and the teamwork. As learning theories suggests that prior knowledge and social and contextual factors affect learning, the students’ background can become an input to the system. The success of instructional method also depends on the acceptance by students to change as defined by student engagement, which is the second input to the system. The measurement model for these two constructs and knowledge, skill and attitude is discussed in the next section.

3.3 Measurement Model

The first step in Structural Equation Modeling is to define the various constructs and then develop a good set of indicators for each construct. The characterization of the construct and selection of indicators is based on the successful previous research studies and the references associated with constructs used in present study are tabulated in Appendix A5.

3.3.1 Students’ Background

Student background is basically a column vector of measurements, where vi are the atomic level measurements given by

\[ \mathbf{sb} = \{v_1, v_2, v_3, \ldots\}^T \]

Student’s background is described through several characteristics that affects students’ learning or performance (Kargar, et al., 2010). Students’ prior academic performance is an indicator of future progress.

The four variables 10th Percent Marks, 12th Math marks, 12th Percent Marks, and Entrance score which represents the academic performance are considered as part of Student’s background in present study. Students’ demography (Kargar et al., 2010) represented as Course, Gender, Category, State, 12th Board, 12th Discipline, Math in 12th, Age, is considered for present study. The Fig 3.3 shows relation between Student’s background and measured indicator variables represented by square boxes. The relationship between latent variable and measured variable is indicated by the arrow.
The indicators for Student Demography and Student’s Prior Academic Performance are used for analysis in Chapters 5 to 8. The present study consists of students of two courses BBA(IT) and BCA hence to know difference in performance of student with respect to course, course is one variable affecting student’s background which affects students’ learning (Figure 3.1). The students’ background consists of two latent factors Student Demography and Students’ Prior Academic Performance. The variables gender (2 levels; M,F), category (10 levels), state (31 levels), 12th Board (53 levels), Math at 12th (2 levels), 12th Discipline (4 levels) are considered for Student Demography. Each demographic variable has various levels as mentioned in Appendix B7-B12. Hence for facilitating analysis, Category levels are reduced to 4 groups OP, Reserved (SC,ST), FN, Others (DA,DQ,DF,KM,NRI,OCI) and States levels are reduced to 5 groups MH, SOUTH, NORTH, NORTH-EAST, CENTRAL & WEST. Further Board levels are reduced to 3 categories namely State, Central & Foreign boards. The details of these variables are mentioned in Chapter 5, Descriptive Statistics (Table 5.2). The performances of students’ in 10th, 12th, 12th math marks and entrance scores are considered as Students’ Prior Academic Performance.
**3.3.2 Student Engagement**

Student engagement is independent or mediating variable and academic achievement are dependent variable respectively as mentioned by Coates (2006). The studies of researchers (NSSE, 2003) have revealed the relationship of engagement with academic achievement with respect to students’ learning and outcomes. Level of academic challenge, Active and collaborative learning, Student–faculty interaction, Enriching educational experiences and Supportive campus environment are five benchmarks of student engagement (NSSE,2003) as discussed in literature review (De Graaff and Kolmos, 2003; Woods, 1994; Hallinger & Bridges, 2016).

Again SE is a vector of measurements
\[ \mathbf{se} = \{ v_1, v_2, v_3, \ldots \}^T \]  \text{Eq}(4).

These measures surely will differ in values when cases of different levels of PBL are considered.
\[ \mathbf{se}_i = \{ v_1, v_2, v_3, \ldots \}_i^T \]  \text{Eq}(5).

Suffix \( i \) corresponds to the level of implementation of PBL in three semesters. Levels of implementation vary from Batch to Batch. Levels are defined in Chapter 4.

To measure the student engagement in PBL, the data is collected from students through an evaluation form and questions in the evaluation form acts as an indicator for student engagement.

The literature review suggests, the student engagement depends on students’ learning behavior and faculty characteristics as shown in Figure 3.4.

![Figure 3.4: Characteristics Affecting Student Engagement](image-url)
The indicators for students’ learning behavior and faculty characteristics are identified by various researchers are presented Figures 3.5 and 3.6 respectively.

Students’ characteristics determining students’ engagement include Attendance, No. of times and number of hours for Student faculty interaction, Timely Submissions by students as per deadlines, No. of hours for PBL and the extent to which they analyzed, synthesized, evaluated or applied information or knowledge (NSSE, 2003). Math fear/anxiety, Self-efficacy, Interest, Teamwork and Ability to apply the knowledge, also help in determining students’ engagement.

Further Students’ engagement is affected by Level of difficulty of Syllabus (Learning objectives), Pedagogy adopted by faculty (traditional method, ICT, Focus on math and No link to subject area in Traditional teaching), type of learning (active, collaborative) and Student’s background. The student engagement is related to (1) student/faculty contact; (2) cooperation among students; (3) active learning; (4) prompt feedback; (5) emphasizing time on task; (6) communicating high expectations; and (7) respecting diversity. Also Evaluations, carried out according to learning objectives facilitates the student learning.

PBL typically involves significant amounts of self-directed learning on the part of the student as cited by Prince(2004).

In order to compare students of different courses first syllabus are compared and accordingly decision regarding including students’ for research study is taken. The course contents should be delivered to students to achieve learning objectives defined in terms of learning outcomes. The students’ always willing to maximize their marks, their strategy for studying depends upon evaluations conducted. Hence, evaluations are one of important inputs to student learning.

The engagement is the acceptance by students to change, which determines attitude. The student engagement is measured through No. of hours spent by students. The different indicators for Students’ learning behavior, faculty characteristics and syllabus & evaluations presented in Figures 3.5, 3.6 and 3.7 respectively
Figure 3.5: Students’ Characteristics Affecting Student Engagement
The process and extraction of SE scores as defined in Figure 3.5 are discussed in Chapter 8.

Figure 3.6: Faculty Characteristics Affecting Student Engagement

Figure 3.7: Evaluations Affecting Students Engagement
The necessary and sufficient condition for learning is that students should be engaged in educationally purposeful activities (Coates, 2006). Hence in present study we have measured student engagement through following:

1. Students' learning behavior affecting Student Engagement variables considered are Attendance, students contacted facilitator (yes/no) (Student faculty interaction), Practicing problem in Statistics and OR, Mathematical background, Math fear, Self-efficacy, Interest (Learning Behavior Affective), Timely Submissions by students as per deadlines, No. of hours for PBL as shown in Figure 3.5.
2. Faculty characteristics affecting Student Engagement variables considered are teaching by traditional method, use of ICT, Use of spreadsheets in OR teaching, PBL, as shown in Figure 3.6.
3. Syllabus & Evaluations affecting Student Engagement variables considered are Level of difficulty of syllabus, Syllabus & Learning objectives and Evaluations. Evaluations consist of written exam, presentations, assignment, quiz, PBL report evaluation and post project feedback as shown in Figure 3.7.

Each of these indicators can be actually measured through posing one or more questions in the survey or the observation recorded as part of PBL process.

3.3.3 Knowledge, Skill and Attitude

One way of measuring knowledge is by marks obtained in different exams. One can choose knowledge indicator as GPA or average marks obtained in subject. The other indicators are obtained from survey data. In survey data each question can be binary with score of 0 or 1 or on three or five point Likert scale. 1 indicating enhancement in knowledge and 0 indicating no change. Thus these scores can be added to get a Knowledge score (K-score) (Figure 3.8)

![Figure 3.8: Measurement Model for Knowledge](Chapter 8, Sections 8.2.1 and 8.2.2)
Similarly Attitude can be measured by Math background, Attendance, evaluation and Survey questions to get Attitude score (A-score). Skill scores (S-score) can be obtained using Marks in specific subjects from Internal & External Evaluation and Survey questions. These relations are shown in following Figures 3.9-3.10

**Figure 3.9: Measurement Model for Skill**

(Chapter 8, Section 8.2.2)

**Figure 3.10: Measurement Model for Attitude**

(Chapter 8, Section 8.2.2)
3.3.3 Complete Measurement Model

The complete measurement model as discussed in sections 3.3.1-3.3.3 is given by figure 3.11.

Figure 3.11: Complete Measurement Model for K,S,A
3.3.4 Structural Model

In the previous section Measurement model described the various indicators for measuring both dependent and independent variables. The structural model will be described in this section which shows how different indicators for measuring the latent variables are associated with each other.

As there are large number of indicators for both dependent and independent variables the researcher have selectively chosen a set of indicators and derived dependency relationship between them. Also some variables are metric and others are non-metric in nature. In some cases data is readily available while in other cases the scores have to be compiled from survey data.

Six characteristics are chosen to represent Student demography which are qualitative in nature while the knowledge as learning outcome is represented by metric GPA. ANOVA is carried out for each characteristic (Chapter 6) of Student demography which is again a latent variable to study Student Background with respect to knowledge score GPA. The relationship is described in Figure 3.12 in presence or absence of PBL.

![Figure 3.12: ANOVA wrt Knowledge](image)
The methodology, results and inferences of ANOVA are discussed in Chapter 6. The classification technique is applied to classify students’ batch wise performance using Skew-kurt pattern of GPA, Math background and PBL treatment (Chapter 7, Figure 7.2, 7.4).

Further cluster analysis is applied to students’ of all batches together where GPA considered as knowledge score of all students. As data mining helps in identifying hidden patterns from data sets, it can be used to assess learning outcomes of PBL apart from statistical measures. The details of which are given in Chapter 7. Next relationship considered is with one indicator for each of the latent variable as depicted in Figure 3.13. GPA is considered as an indicator for knowledge while Math background is indicator of Student background and considering students’ batch as an engagement characteristic as presented in Figure 3.13.

The cluster analysis is also performed using link analysis. The cluster analysis helps in classifying students into optimum number of groups to trace their performances from Pre admission performance till semester 3. The impact of PBL is seen on the basis of important Student demographic characteristics, as observed from Chi-square tests and ANOVA, and academic performance indicators 12th marks, Entrance scores, and GPA of three semesters as knowledge scores of all students’ to see the impact of PBL treatment. These details are also given in (Chapter 7, Figure 7.15, 7.17) and the process is described in Figure 3.14.

**Figure 3.13: Pattern Analysis based on Shape Parameters**

Further cluster analysis is applied to students’ of all batches together where GPA considered as knowledge score of all students. As data mining helps in identifying hidden patterns from data sets, it can be used to assess learning outcomes of PBL apart from statistical measures. The details of which are given in Chapter 7. Next relationship considered is with one indicator for each of the latent variable as depicted in Figure 3.13. GPA is considered as an indicator for knowledge while Math background is indicator of Student background and considering students’ batch as an engagement characteristic as presented in Figure 3.13.

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The evaluation data consists of indicators related to knowledge, skill and attitude. The answers to these indicators are used to compute Knowledge-score (K-score), Skill-score (S-score) and Attitude-score (A-score). The K-scores are analyzed with respect to batch, using K-gain, as shown in Figure 3.15 (Chapter 8, Table 8.5,8.6).

The analysis of impact of PBL in semester 1 is studied using Cause effect model as represented in Figure 3.16 (for details refer Chapter 8, Figure 8.1).
The analysis of impact of PBL in semester 3 is studied using Cause effect model as represented in Figure 3.17 (for details refer Chapter 8, Figure 8.2).

Figure 3.16: Schema for Analysis of Statistics Performance with PBL

Figure 3.17: Schema for Analysis of OR Performance with PBL
3.4 Validating Structural Equation Modeling

The syllabus offered to techno-management students’ is designed by university on the basis of Bloom’s taxonomy. Hence Students’ learning outcomes will be measured in terms of knowledge, skill and attitude to see impact of PBL on students’ performance.

The measures used for student engagement draws its inspiration from the conceptual model framework to measure ASK at three levels as proposed by Nagendra et al. (2013) To find skill at first level the researchers have suggested parameters as Basic Skill Training in Finishing, Assembly. Knowledge at first level can be judged by understanding day-to-day, English Communication, Math, Science etc. The change in attitude can be judged by observing small improvement from Level 1 without supervision and get appreciation from teacher or seniors. The improvement in skills can be observed by work and improvement in specialized skill in the area of allotted trade through off and on-the job training. Further knowledge improvement in math, stats, OR, can be observed by improved problem solving and understanding results of these. The use of ICT helps the learning process to get experience within the limited time.

PBL has been used by many researchers. The relation between variables affecting student background, students’ engagement with respect to learning outcomes of PBL, and associated references from literature review are given in Appendix 5-8.

Student background and Student engagement leads to students’ learning which results in learning outcomes namely Knowledge, Skill and Attitude. The literature review suggests that effects of PBL in learning have not been found significant statistically, however improvement in students’ learning has been observed. Students’ learning in Statistics and Operations research through PBL along with traditional teaching can be measured in terms of knowledge, skill and attitude. Hence in present study researchers are assessing impact of PBL on students in terms of knowledge, skill and attitude using statistical and data mining techniques.
3.5 Summary

The PBL process has strong grounding in learning theories as it is widely used by researchers. The structural modeling is used because of Latent nature of input and output variables. Indicators used to measure these latent constructs are presented by emphasizing their relevance derived from literature. The student background is measured through student demography and students’ academic performances. The three components students’ learning behavior, faculty interaction characteristics and syllabus and evaluation characteristics are used to measure student engagement. Each of these components is further explored in detail bringing out clearly the ways of measuring them.

The learning outcomes in the form of knowledge, skill and attitude and their connections to various input parameters are described through measurement models. The conceptual model presented in this chapter forms the basis to research efforts described in subsequent chapters.