EXPERIENTIAL LEARNING OF MATHEMATICS FOR BIG DATA ANALYTICS

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Abstract - With the recent advancements in Information and Communication Technology (ICT) resulting in Industry 4.0 ,there is a major requirement for reskilling and upskilling the ICT workforce. Today, the buzz word in industry is'BigData' and thereis a need tofill the skill shortageinBig Data analytics. In this context, learning the basic skills of combining computer and mathematics capabilities is warranted in the workforce.Studies conducted internationally and by theAustralian Industry Group show the requirement for improvingnumeracy skills at workplace. In order to cater to this, the higher education curriculum requires reform. This paper takes a modest step to address this issue by introducing a renewed subject in an ICT higher education curriculum to upliftmathematics skills using innovative practices. We presentthe use of innovative methods such as experiential learning and assessments in a higher education program for developing the mathematical skills required for Big Data analytics. The results of such an improvised curriculum showa positive impactin student learning and development of numeracy skills required in this digital age.

Index Terms - Employability, Mathematics Skills, Big Data Analytics, Higher Education, Curriculum, Experiential Learning.

I. INTRODUCTION

In this globally advanced digitalera, Information and Communication Technology (ICT)skills need to be revisited among the workforce [1][2]. With the unprecedented explosion of huge data in both structured and unstructured forms, theresulting 'Big Data' in industry requirestrained workforce toeffectivelyderive value from itusing analytical skills [3][4]. ICT capabilities combined withmathematical skillsare inherent in managing Big Data and in performing variousdata analytics that aid in decision making. Apart from the ICT industry, there is a huge demand for such skillsacross a wide range of industries, including banking, manufacturing, media andentertainment. However, Big Data analytics requires mathematics skills integrated with computer skills which form a rare skill set [1][5][6]. Industries are encouraging the employees to reskill and upskill through further education[7]. Higher educationproviders are now required toreengineer the curriculum to address this skill shortage to prepare the workforce for Industry 4.0 [8][9]. Higher education systems are transforming to introduce lifelongemployability skills to enhance discipline-specific skills such as ICT skills. Among the employability skills identified within the Employability Skills Framework in Australia, the most important ones suiting the present digital age is Technology skills andlifelong learning skills [10][11].The National Research Council in the United Statesclassified the employability skills under three broad domains:Cognitive domain, Intrapersonal domain, and Interpersonal domain[12]. The programme for Basic Competencies in Working Life launched in Norway has identified Literacy, Numeracy and ICT skills as basic skills for adults [13]. Many countries worldwide have studied the workforce skill shortage and have reportedthe requirement to uplift the numeracy skillsfor betteremployability [14][15]. In Australia, numeracy or mathematical skills developmentis required to meet the skills shortage in the rising Big data analytics [16]. Students cannot be assumed to have the necessary mathematical skills inherently required for Big Data analytics. However, there are challenges in acquiring mathematics skills through didactic means. In order to have a lifelong learning skill development with the changing ICT landscape, innovative approaches in teaching and student learning are warranted. With a view to address this gap in practice, this research explores the impact of introducing experiential learning and assessment approaches to engage students in developing mathematics skillswithin a Bachelor degree program i in Australia. Over the past few decades, there has been great emphasis laid on innovative assessment methods in enhancing student learning in various academic levels [17][18].. This has resulted in an evolution of a wide range of assessment practices and strategies. This evolution is more evident in higher education due to the maturity of students and the degree of flexibility available in such an educational setting. Different courses in higher education adopt different combinations of such assessment methods. While assessment is only one side of a coin of education, learning is considered as the other side of the coin. The meaning attached to learning has also undergone various forms over a period of time and hence this work addresses the issue of matching the right set of assessment practices in the context of which form of learning is under consideration. Only such a perfect match can lead towards a positive and successful academic impact. A

spectrum of research work is continuously undertaken to study the impact of various learning and assessment methods [19][20][21]. In this paper, we explore experiential learning approach in the teaching and assessment formath skill development required for employability in Big Data analytics in the IT industry. Our research aims to study the impact of employing experiential learning pedagogies and assessment practices in a math subject taught withinthe Bachelor of Information Technology (BIT) curriculum in a higher education institute in Australia. The rest of the paper is organized as follows. Section II provides the research backgrounddescribing the need for this study, research aim and methodology. In Section III, we present the experiential learning framework with innovative practices adopted for learning and mathematical skills development in the BIT program. The student skill assessments and the research outcomes are discussed in Section IV and finally Section V summarises with concluding remarks and future work.

II. RESEARCH BACKGROUND

2.1.Need for the Study

In Australia, several industry surveys indicate that Science, Technology, Engineering and Mathematics (STEM) skills are considered fundamental to various jobs [7][9]. For today's digital era, these skills are more related to integrating the digital skills such as Big Data analyticsrequired to solve complex real world problems[22]. OECD's Programme for International Student Assessment (PISA)surveyfound a statistically significant relationship between direct exposure to the contemporary working world and higher student scores in the PISA mathematics assessments [23]. PISA survey indicates that Australia's performance in mathematics has declined over the past decadeand needs improvement [5][8].

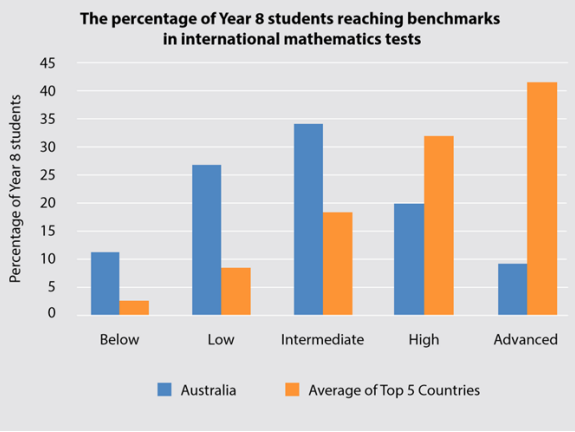


Fig. 1.Comparison of Mathematics Skills inAustralia –TIMSS

Fig. 1 indicates that more than a third of Australian Year 8 students do not have the skills to apply basic mathematical knowledge in straightforward situations according the Trends in International Mathematics and Science Study (TIMSS). Hence, TIMSS 2019 Assessment Frameworks emphasizes on assessing a range of problem solving situations within mathematics, with about two-thirds of the items requiring students to use applying and reasoning skills [21]. Table 1 shows the target percentages of TIMSS 2019 Mathematics assessment devoted to content and conginitive domains with increased emphasis on reason as the students develop their mathematics skills from fourth grade to eighth grade. Reasoning abilities go beyond the competency of arriving at a solution of routine problems so as to be able to analyse unfamiliar situations, complex contexts, and multistep problems. Hence, it is important to continue with this TIMSS framework to achieve improved analytical reasoning skill targets as students graduate and enter into workforce.

Table 1.Mathematics Assessment Framework Targets - TIMSS

Fourth Grade

Content Domains	Percentages
Number	50%
Measurement and Geometry	30%
Data	20%

Eighth Grade

Content Domains	Percentages
Number	30%
Algebra	30%
Geometry	20%
Data and Probability	20%

Cognitive Domains	Percentages	
	Fourth Grade	Eighth Grade
Knowing	40%	35%
Applying	40%	40%
Reasoning	20%	25%

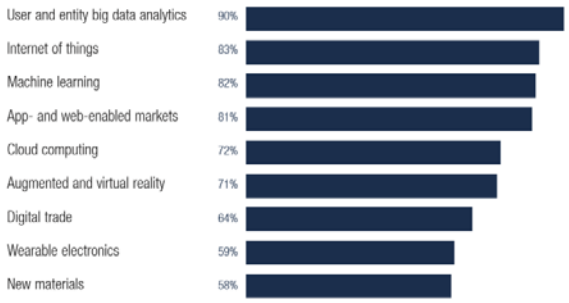


Fig. 2.Top Ten Future Jobs - World Economic Forum

Fig. 2.shows the survey results by the World Economic Forum indicating Big Data as the second among the top ten workforce skill sets having an impact on the future of jobs in a wide range of industries recent [4][8]. Overall, there is a need for the present day workforceto upskill in Big Data Analytics in order to meet the demand in industry. The Australian workforce is required to develop their math skills via formal education and training programs [8][9][10][11].Hence, research studies are investigating on innovative pedagogy in higher

education to uplift math skills [21][24]. This forms the motivation for this research to focus on developing mathematics skills in a higher education institution.

B. **Aim of the Study**

It has been a common practice for students to adopt rote learning, which would help only for recall of knowledge temporarily and does not aid in long-term benefits. Such learning practices do not help in applying knowledge for real world situations. In reality, surface-level learning habits, if continued to be cultivated in adults, leads to their low performance level at work place.In order to cater to the Big Data analytics skills shortage in Australian work place, a common core subject to developmath skills,as one of the generic skills,was introduced in the first-year curriculumof the Bachelor of Information Technology (BIT) in a higher education institute.The subject called 'Mathematics for IT' was designed to developthe students' numeracy skills that are relevant to IT discipline skills requirement, in particular the skills required for Big Data analytics. Previous research have studied and reported on the lack of motivation and student engagementin learning the math skills required for workplace [25][26]. In this research study, we explore the use of experiential learning approach to address this problem. This ongoing research project is based on a recent collaboration with industryto use their software tools for evaluating the impact of visual aids in incorporating the necessary experiential learning activitiestomotivate math skill developmentamong the BIT students. Based on these background details, we have developed the research aim and methodology to conduct this study.

C. Methods

We adopted a mixed method approach using survey based as well as student performance based outcomes to study the impact of introducing experiential learning theories to the design and delivery of the subject, Mathematics for IT in a higher education setting. We also conducted a self-assessment of students' confidence level in mathematical skill using standard methods from literature [27]. This was completed before the students underwent the experiential learning activities . Overall, we found that majority of the students coming from diverse background had difficulties in understanding mathematical concepts and their applications in real world. Many do not enjoy learning it. Despite the differences in student demographics and prior teaching methods adopted, in this new design of the subject delivery, we gave importance to the learning experience of the students in order to achieve life-longlearning skills in mathematics.Popular software tools that are used in industry were adopted to analyse and present data, to interpret the analysis and to apply findings in real-life situationsfor Big Data Analytics.With this view, we introduced experiential learning activities in the Mathematics for IT subject with appropriate software tool for visualization of data. We impact of experiential learning adopted in mathematics skill development was determined using students' performance in assessments through comparisons between last cohort and this cohort of students.

III. EXPERIENTIAL LEARNING OF MATHEMATICS FOR IT SKILLS

A. Role of Assessment in Experiential Learning

Assessment is an essential tool to measure the degree of learning achieved. Though assessment of student learning is always a major concern for the learners, it is also a complex procedure for the tutors to use it as a vehicle for enhancing student learning. There is always a concern from the learners' side regarding the purpose behind assessment and whether what they have learnt would be assessed and the experience gained can be applied to the real world. Additional aspects are about the nature of assessment, fairness of the assessment, and whether it is interesting or not. On the other hand, the lecturers try to set the objectives of student assessment mainly to measure the knowledge gained by the student and to guage thecapability of the students and thereby to enforce quality education. These perspectives of assessments were considered while designing the assessments through experiential learning activities in the subject, Mathematics for IT. Since learning and assessment go hand in hand, it is essential to first define learning as a basis for any assessment to be carried out in an educational setting. With this basis in mind, a definition of learning in the context of higher education is given below [28]:

Learning is a complex process of understanding and creating a knowledge base of the subject under study and integrating the concepts and experiences achieved so as to relate and apply them in a range of contexts and situations in any social setting.

This definition of learning is quite apt for higher education since the students need to adopt deep approaches to learning that would prepare them for a future of dynamic change. It is during higher education that students are in a good frame of mind to get themselves equipped with lifelong learning characteristics which will help them to become a self-directed as well as an active learner.

From literature, it is evident thateach person's learning style differs displaying different approaches to learningina higher education setting [29]. There are mainly four different learning modes: concrete experience (CE), reflective observation (RO), abstract conceptualisation (AC) and active experimentation (AE). Based on these four learning models, we propose an experiential learning framework to incorporate innovative learning activities using visual

aids available in the software tools.

B. Proposed Experiential Learning Framework

We adopt Kolb's experiential learning modelwith emphasis of "learning through reflection on doing".[29]. It consists of four stages in a cycle as given below:

1. Concrete Experience
2. Reflective Observation
3. Abstract Conceptualization
4. Active Experimentation

In experiential learning, it is important that the learner takes an initiative for active learning. In our proposed experiential learning framework, we motivate the students to engage in learning through active participation in various classroom activities that are linked to their continuous practical assessments. Assessment, when used creatively and appropriately, could simulatereal-life scenarios in workplace that facilitates students to take initiatives to learn.

We also consider Payne's theory of associating learning with cognitive, affective and psychomotor phenomena that takes place within each learner [30]. The cognitive domain of a learner can be categorised as: knowledge, comprehension, application, analysis, synthesis and evaluation. Payne strongly feels that assessment represents a wonderful opportunity to integrate the cognitive, affective and psychomotor aspects of instruction conveyed to a learner.

Our experiential learning framework introduces appropriate active learning activities within the Kolb's model by assessing the effectiveness of experiential learning in each of the three phases: a) a reflective learning phase, b) a phase of learning resulting from the actions inherent to experiential learning, and c) a further phase of learning from feedback [31][32].Overall, the successfactor associated in our experiential learning framework is that eachlearner is directly involved in the experience by doing tasks, and theneach learner is required to reflect on the experience gained using analytic skills as deep learning strategies, and finally take corrective action based on feedback provided.

C. Implementation

The proposed experiential learning framework was applied to the design and delivery of the new 'Mathematics for IT'subject with the aim to developmathematics skills in the specific context of IT discipline, in particular relating to Big Data analytics. Severalpractical software based exercises and embedded extra learning skills support by relevant specialists were introduced to provide a conducive learning environment.

In higher education, there is a wide spectrum of assessment situations ranging from very informal to very formal ones. There are many modes in which different assessment tasks are accomplished. Lecturers put in a lot of effort in moulding these assessment tasks from time to time in order to make them more effective. However, whatever be the method of assessment adopted, the underlying question is: what are the learning skills we wish to inculcate through this assessment task?

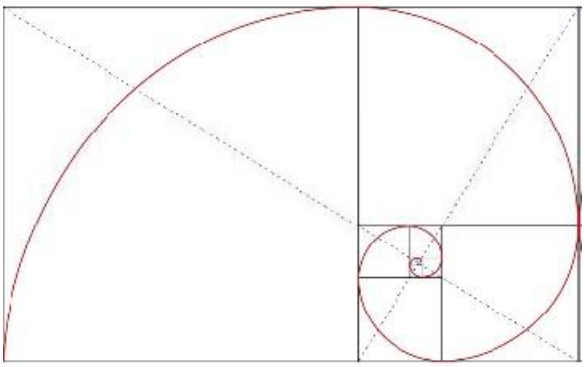


Fig. 3.Visual representations of Golden Ratio

An assessment task is used to evaluate one or more of the cognitive domains of learning in each student. But the basic underlying educational purpose is to impart some generic transferable learning skills to the students. There is a whole gamut of generic learning skills that students are desired to achieve in a higher education setting. Some of the common ones are problem-solving skills, communication skills (oral and written communication), reflective, analysing & thinking skills, deep-learning and researching skills, collaborative & team skills, time management skills, task management skills, creativity and innovation skills, etc. Among these, our main focus for the math subject were problem-solving skills, reflective, analysing & thinking skills, and researching skills.The subject lecturerdesignedthe learning activities hand-in-hand with appropriate assessment tasks to achieve these life-long learning skills. Innovative software tools and techniques were used to design the classroom activities. For example, the definition of Golden Ratio, which has wide applications in ITis usually expressed as a mathematical Fibonacci sequence given below:

$$\varphi = \lim_{i\to\infty} \frac{F_{i+1}}{F_i} \Longrightarrow \frac{F_{11}}{F_{10}} = \frac{89}{55} \approx 1.618$$

where the Fibonacci sequence is an infinite series of integers, with each term expressed as the sum of the two previous terms. It is defined by the following mathematical function:

$F(i) = F(i-1) + F(i-2)$ with $F(0) = 0$ and $F(1) = 1$

i	0	1	2	3	4	5	6	7	8	9	10	11
F_i	0	1	1	2	3	5	8	13	21	34	55	89

Golden ratio can be expressed in simple approximate form as follows:

$$\varphi = \frac{1}{\varphi - 1}$$

Fig 3. provides a visual representation of the above two equationsthat define Golden Ratioas the ratio of the hypotenuse of an isosceles triangle to its base. The Golden Ratio has many interesting properties as shown in Fig. 3. Such a visual representation facilitates in deep learning and retentionsince students can understand its implications visually when the size of data grows. For instance, as the value of$i$increases, the rate at which F_i increases can be projected as a graph for visual interpretation of the Fibonacci function. The teaching team employed suitable software tools for providing such visual representations of numerical concepts and data. These techniques helped the students to apply mathematics to Big Data analytics with data visualization. The impact of experiential learning much depends on the choice of assessment method used, the assessment process adopted and the reliability and validity of the assessment scheme. Certain learning skills are achieved through certain assessment methods and it is not possible to address all the learning skills through a single assessment method. Hence, for the assessment of learning arising from classroom activities inthe subject, we chose a combination of assessment methods that can collectively encompass the Mathematics for ITlearning objectives. In addition, a sound and reliable assessment rubricbased on clearly set criteria were devised. Since reflection is a crucial part of the experiential learning process, we incorporated this as one of the assessment components.

The implementation of our proposed experiential learning model involved designing classroom activities with visual representations as exemplified in Fig. 3 forthe weekly learning and assessment tasks of the subject, Mathematics for IT. The implementation model using Kolb's experiential learning cycle is given in Fig. 4. It is important to engage industry in education [33]. The continuous learning iterative cycle of Plan-Do-Reflect-Think promoted active learning by engaging students in using industry collaborated software tools such as Statistical Analytics Systems (SAS) and Excel graphs with heavy emphasis on visualisation of data, which. can help students gain deep understanding of the mathematical concepts and methods that can be applied to industry problems.

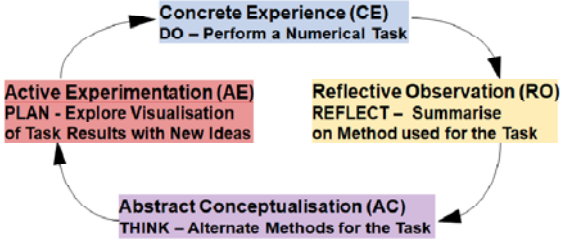


Fig. 4.Experiential Learning Implementation ofa Learning Activity

IV. STUDENT PERFORMANCE AND RESULTS

Wecollectedthe data of student performance from two cohorts to evaluate students' mathematics skills achievement as a result of the introduction of experiential learning in the renewedsubject, Mathematics for IT. Cohort 1 consisted of students studying in the first semester (S1) of the old version of the course(without the implementation of Experiential Learning inMathematics for IT subject)). Cohort 2 consisted of students in the renewed course (with Experiential Learning implemented in Mathematics for IT subject) offered in the second semester (S2).

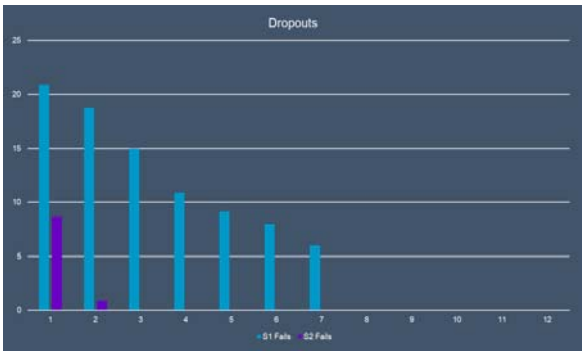


Fig. 5.Comparison of Student Dropouts (S1and S2)

Student performance in the subject was monitored and performance results at the end of each semester for Cohort 1 and Cohort 2 werecompared. Overall, there was an improvement in the grade results obtained by the Cohort 2 students (S2) as compared to Cohort 1 students (S1). These improvements in S2 as compared to S1 are summarized as follows:

– Higher percentage of students scored'High Distinction' grade

– Lower percentage of students scored'Fail' grade

– Lower percentage of student dropouts as shown in Fig 5.

The qualitative feedback and comments obtained from the two cohorts of students are summarized below:

– Students from S1 either liked or did not like mathematics with 50% ratio, while most of S2 students enjoyed it including those who started with some fear initially

– About 85% of the students (S2) submitted their assignments in time, which was a major improvement from S1

– Experiential learning visual exercises with SAS and 'Mathematician Stories' were engaging

– Additional tutorial support from Learning and Teaching/Academic Support team was helpful to the students

– Students' (S2) class participation was dynamic and entertaining.E.g. After completing activities for Proof of triangles using Pythagoras-Plato formula using visual approaches, the students' response was: "that's amazing".

The main areas of improvement in mathematical skills required for IT were in critical thinking and reasoning

for solving complex problems and data analysis. The introduction ofindustry collaborated software tools to aid in visualization of data helped students to understand the application of mathematical skills in Big Data analytics. In addition,cross-discipline collaboration among the facilitators aided in active learning and engagement of students in the experiential learning activities within the classroom environment.

CONCLUSIONS AND FUTURE WORK

Today's digital world has a skill shortage in Big Data analytics that motivated this research to study the effect of a renewed curriculum to uplift the mathematical skills required for complex data analysis and problem solving. This paper has proposed the adoption of experiential learning model in the design and delivery of a subject calledMathematics for ITand studied the performance of students as they progressed in their mathematics skill development. Appropriate industry collaborated software tools were employed to incorporate visualization of data to equip the students with the skills required for Big Data analytics. The performance of students were compared with the previous run of the subject without any experiential learning activities. There was a substantial improvement in the student engagement and motivation to learn in the renewed subject. There were very few dropouts and most of the students scored higher grades with lesser failures in the subject. Overall, the experiential learning framework proposed for this subject had a successful outcome and a positive impact on student learning and mathematics skill development. This ongoing research will study how the mathematical skill development has been applied to industry projects in Big Data analytics.

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