International Journal of Business, Human and Social Sciences
ISSN: 2517-9411
Vol:6, No:5, 2012

Virtual Learning Process Environment: Cohort Analytics for learning and learning processes

Ayodeji Adesina, Derek Molloy

Abstract**—**Traditional higher-education classrooms allow lecturers to observe students' behaviours and responses to a particular pedagogy during learning in a way that can influence changes to the pedagogical approach. Within current e-learning systems it is difficult to perform continuous analysis of the cohort's behavioural tendency, making real-time pedagogical decisions difficult. This paper presents a Virtual Learning Process Environment (VLPE) based on the Business Process Management (BPM) conceptual framework. Within the VLPE, course designers can model various education pedagogies in the form of learning process workflows using an intuitive flow diagram interface. These diagrams are used to visually track the learning progresses of a cohort of students. This helps assess the effectiveness of the chosen pedagogy, providing the information required to improve course design. A case scenario of a cohort of students is presented and quantitative statistical analysis of their learning process performance is gathered and displayed in real-time using dashboards.

Keywords**—**Business Process Management, Cohort Analytics, Learning Processes, Virtual Learning Environment.

I. Introduction

IN a formal higher education setting for "traditional classroom" or "online" undergraduate studies (especially for distance students), the desired learning outcomes are part of the broader context of pedagogical reform [1]. Pedagogy, though a concept, is crucial to learning because it endows the relevance of the process through which knowledge-gain is achieved upon the lecturer. The collective means involve: the contents to be delivered through the rigorous analysis of the contents; the students' needs through a proper analysis of the entire audience; and, the learning outcomes or objectives in form of the goal analysis [2].

In the traditional classroom environment, lecturers – although bound by time constraints – are naturally predisposed to a more flexible pedagogy [3]. Lecturers may or may not expand on a topic, change learning contents, emphasis on a broader participation in class discussions, adopt a new formative approach based their pedagogical tendency. Most of the observable students' activities in the classroom that influence pedagogical shift are not based on cognitive learning processes, but behavioural ones - albeit, learning is related to both processes [4], [5].

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In an asynchronous e-learning environment, where structured course materials are delivered to online undergraduate students, Virtual Learning Environments (VLEs) such as Moodle, WebCT, Blackboard etc. provide the platform that many third-level online educations are implemented [6]. However, runtime pedagogical adjustments can be difficult to make [7].

In contrast to the classroom environment, behavioural learning process is difficult to measure within the current VLEs [8]. More often than not, accounts of competency or desired learning outcomes are often apparent to lecturers during a summative process; and the areas of difficulties faced by the cohort are often blurred as continuous learning process information in a real-time manner are not available [9]. In fact according to [8], the basic data provide by VLEs about students' activities are the frequency of login; visit history; message post on the discussion board; etc. However, if lecturers are afforded the necessary learning process information that could provide the means to observe, monitor, track and analyse students' online learning behaviours continuously, then lecturers' runtime pedagogical approaches might be dynamic (i.e. customised assessment, prompt feedback, and more personalised attention) as needed [10]. Therefore, it is necessary to devise an analytical means within the online environment, beyond the summative process, in such a way that would allow behavioural learning processes of the cohort of students – right from the inception of the teaching and learning process – to be continuously monitored and analysed until completion [11], [7]. Such systems will be productive and timesaving for the management of a cohort learning process by the lecturers [7].

The aim of this paper is to present a BPM-based e-learning system (VLPE) that focuses on learning processes management through the modelling of a learning process workflow around structured course materials based on a desired pedagogy. The automated agents associated with the BPM technology are employed to perform the learning process information gathering. Consequently, allowing for the behavioural learning process information of up to a very large cohort of students to be captured and presented on a learning process dashboard for continuous monitoring and analysis in a way that could prompt lecturers to intervene early enough in the learning process where and when necessary. The analytical results of the cohort of students that are presented in this paper are made up of ten first-year students selected to take part in a three-week foundation Mathematics course (Mathematic-EE101). Although the cohort of students is made up of ten students in total, the system analytical dashboard can be applied to up a very large cohort.

II. Learning and Learning Process

In many undergraduate education programs, much focus has been on the pedagogy of passing knowledge from lectures to students. Focus on students' learning process has received lesser recognition [12] and the current VLEs are not exempt from this conventional pedagogical approach. The impact of this approach on learning is often measured against a set of learning outcomes and/or students' overall performance during a summative process. However, the full appreciation of the pedagogy employed is hard to gauge.

Learning has been defined by numerous researchers, and from academic point of view, they unequivocally emphasised on "knowledge gain" as opposed to information regurgitation. More importantly, knowledge is gained through one form of a process or another. Therefore, an insight into the process of learning can advance the online management of learning by both the lecturers and students. Understanding the ways in which a student exhibits the characteristics of learning constitute learning theories [13]. Although, learning theories have been around long before technology began to influence learning [14], its concept in understanding the complexity of learning and learning process are still relevant. The most widely used models of learning theory are behaviourism, cognitivism, and constructivism. Evidence in the literature has shown that constructivism learning theory is compatible with the e-learning didactic ethics since it ensures learning among learners in a more critical and engaging manner that could only spur motivation [15], [16], [17]. Nevertheless, an in-depth knowledge into the complex nature of learning and learning process within an e-learning environment would require more than the implementation of a single part of the learning theories and/or one single pedagogy [18].

The paper argues that since learning is a process, a balanced account of learning theories (cognitive learning process, behavioural learning process and constructive learning process) within an online learning environment is desirable if students' learning is to be managed. A behavioural learning process involves, according to [19], "... a retention or remembrance of observed behaviour, reproduction or acting, as like the observed behaviour and motivational outcomes or a positive reason for adapted behaviour". The ability to observe students' learning styles, paths and choices can influence a shift in pedagogical approach. The traditional classroom environments strive in this process. Kesici [20] defined cognitive learning process as "a planning process used for administering cognitive sources, such as attention and long term memory, which help the learner reach his/her learning targets." Observation of cognitive learning strategies would be significant in learning process management. Bramming [21] stated that "In the learning-based system, a constructive learning process is understood as the students being actively involved in transformative processes driven by problem solving". Records on the level of collaborations amongst the participant (students, lecturers and tutors) during a constructive dialogue can also help in the management of students' learning process. Inspired by the benefits of BPM technology in the enterprise domain, this paper presents an e-learning system (VLPE) that allows for the management of learning process to be the focus of attention. It embodies the characteristic of the most used learning theories that is discussed above through the modelling/orchestration of learning process workflows around course materials. Effective pedagogy and learning theories can help students' development in learning and attention to their learning characteristics, behaviours, needs, uniqueness, and experiences is essential to the effective management of teaching and learning [22].

III. Learning process analytics

When lecturers use VLEs to create, manage and deliver online course materials, students login and download the course materials. In some cases, lecturers upload course materials periodically in an effort to prevent information overload that may de-motivate students learning. In any case, whatever the pedagogical approach adopted within the VLEs, many questions still remain [23]: How effective is the online course materials? Do they sufficiently meet the students' needs? How can the students' needs be better supported? To What extent are the students' interactions with the course materials, tutors, lecturers and their peers effective? How can the online course materials be improved? Answers to these questions would have a profound effective on teaching, learning and pedagogical reforms.

Since different students browsing and studying the same online course materials will usually show different learning behaviours according to their personal characteristics [24], deeper analysis on their learning process would required advance technique beyond the simple upload and download histories. According to [23], there is a growing interest in how the data in an online learning environment can be used to enhance teaching and learning; hence, the emergence of a new field of learning analytics. The emergence of learning analytics to improved teaching and learning is inspired by the existence of many analytic tools such as web analytics, business intelligence, business activity monitoring (BAM) etc. These tools have advanced within the commercial sphere and the academic environments are beginning to catch up with analytical tools such as academic analytics, action analytics and educational data mining [23]. Nevertheless, [25] observed that though the growing need for educational data mining for intelligent report are beginning to gain traction, the access to this data still falls short of been used to address learning and teaching.

Understanding the nature of students' interaction with course materials can further enhance learning process analysis. Chuang [24] categorised the engagement of students' interaction with course materials as follows: (1) Sequential: Students follow the instructed ways of learning. Sometimes they jump out the recommended paths, but turn back to them soon after; (2) Challenging: Students will browse pages related to course summaries and unit tests first. When they fail such tests, they go back to find related detail course materials and iteratively perform the tests until passed; (3) Free:

Students browse the pages randomly without specific rules or sequences, often due to their interest toward different course subjects; and (4) Iterative: Students have hybrid learning paths of those mentioned above, often browsing the same course webpage iteratively. How these scenarios occurred is difficult to observe within the current VLEs as the data on the interactions with these learning materials is often no more than student's login profile and downloads histories. There are not sufficient learning activity captured data for lecturers to adequately personalise learning needs for their students [26]. Consequently, intelligent decisions on the effectiveness of the online course materials, pedagogical approach and students' learning progressions and performances are difficult to make.

One of the challenging areas in learning analytics according to [27] is "scaling the collection and real-time use of learner analytics by students, instructors, and advisors, in order to improve student success". This challenge is one of the motivations for the research and implementation of a learning-process-focused e-learning system (VLPE). It provides a mechanism that allows for the analysis of up to a very large cohort of students to be made possible within a virtual learning environment.

Part of the design and implementation strategies of the VLPE that is presented in this paper is based on the use of BPM automated agents to aggregate the auto-generated learning data. Analysis can then be performed through a visual learning process analytics dashboard. This provides real-time learning process performance details to all the e-learning participants (lecturers, students and tutors) that are involved in the entire lifecycle of a learning process. The aims are to: prevent delay in early identification and provision of much needed support for the students until the end of the semester or during a major summative stage; capture feedback from the cohort satisfactory and competent level of achievements; and, adapt runtime pedagogy based on learning process performances.

IV. Pedagogical Modelling in Business Process Management (BPM) Tool

With pedagogy at the heart of our VLPE implementation, a pedagogical modelling tool that is based on BPM technologies has been designed and developed. One of the backbones to the successful implementation of this tool is the adoption of, among many others, a BPM technology called Business Process Management Notation (BPMN).

BPMN is the core driving force or promoter of BPM. It is a standardised notation for modelling business processes using graphic symbols in the workflow system. BPMN was developed by the Business Process Management Initiative (BPMI) to allow business users to understand graphical representation of the development of their business processes [28]. BPMN elements are made up of simple intuitive flow diagrams that use a small set of graphical elements. Fig. 1 shows the core sets of BPMN elements, which fall into four categories: 1) Flow objects: These include events (i.e. start, end and intermediate events) activity (i.e. tasks) and gateway (i.e. a diamond shape and will determine different decisions). 2) Connection objects: This allows flow objects to be connected together. 3) Swimlanes: These serve as a mechanism to organise activities and responsibilities on a process diagram. 4) Artifacts: These allow developers to bring some more information into the model/diagram. In this way the model/diagram becomes more readable [29]. Fig. 2 shows a snapshot of the standalone pedagogical modelling application tool.

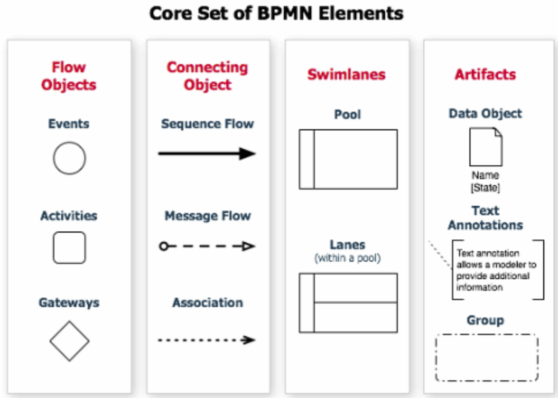

Fig. 1 Core set of BPMN elements

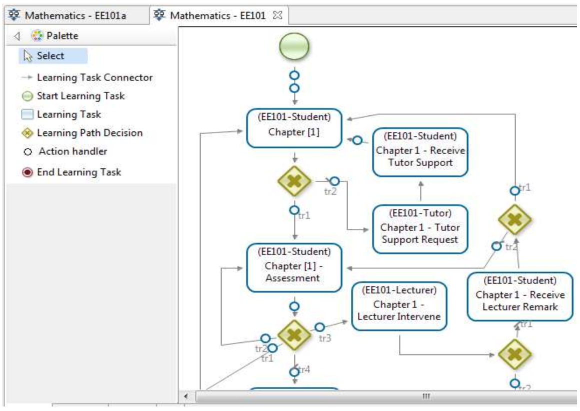

Fig. 2 Pedagogical modelling tool based on BPM technologies

Using the modelling tool shown in Fig. 2, course designers can model various education pedagogies in the form of learning process workflows using intuitive flow diagrams associated with the BPMN elements. The modelled pedagogy can then be deployed unto the VLPE (web-based BPM e-learning system). A sampled designed learning process that is designed around a Mathematics module course (Mathematics-EE101) based on a non-linear pedagogical structure is shown in Fig. 3.

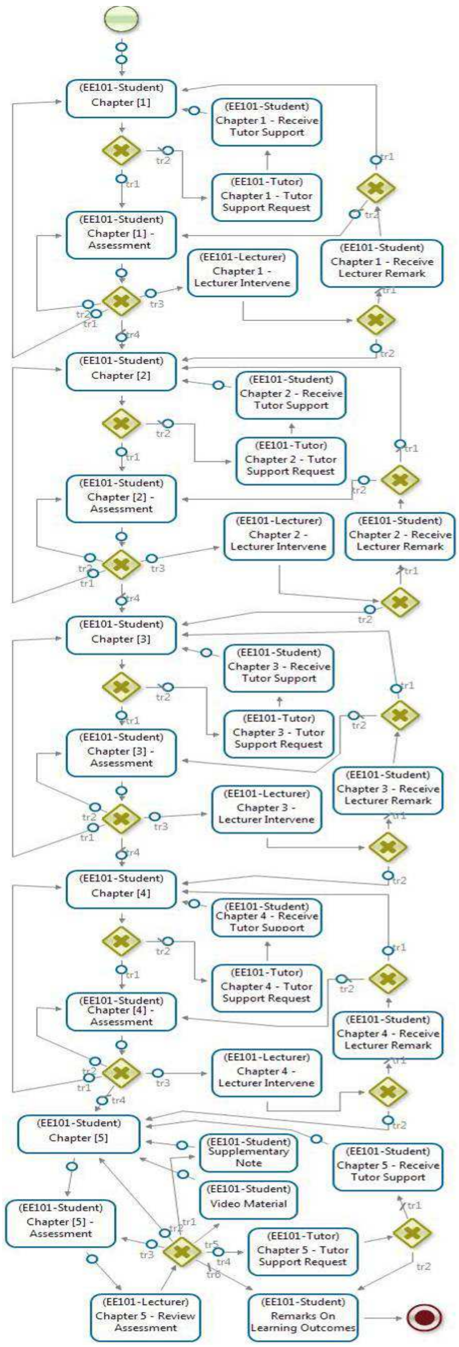

Fig. 3 Learning process designed around Mathematics-EE101 module course

The same diagrams shown in Fig. 3 can be instantiated by as many as possible students that are enrolled for the module, with each instantiation representing the learning process of an individual student. Consequently, all instances can be used to visually track the learning processes and progressions of a cohort of students as they learn through the course materials. Furthermore, the ability to visually track these learning processes would allow for the effectiveness of any adopted pedagogy to be re-assessed with the potential to improve course design based on the analytical results. The overarching benefit of using BPM technologies is the volume of quantitative learning process data that can be auto-generated during the process of learning. These data can be captured and processed for the Key Performance Indicators (KPIs) analysis on the cohort learning processes. KPIs are quantitative or qualitative measurements and evaluations of the effectiveness, efficiency and quality of a business process, which reflect the overall process success factors or success of a particular activity within the entire process and address the performance of the business process [30]. Within the designed learning process in Figure 3, the non-linear pedagogical approach is such that the KPIs are measured against the students': successful learning outcomes through the formative process of assessing their competencies on every chapter; attrition rate; progression rate; mathematical problem solving skills; frequency of supports; feedback; and, completion rate. While these KPIs are applicable to the modelled pedagogy shown in Fig. 3, they may or may not apply to a different pedagogical construct. In other words, KPIs measurements are dependent of the pedagogical choice by the lecturer. This paper presents the analytical results of the learning processes of the cohort of students who were enrolled in a Mathematics-EE101 module. The results are based on three weeks of analysis in which the cohort learning progressions and performances were closely monitored within a cohort analytics dashboard.

V. Cohort Analytics Dashboard: Analytical Results for Learning Process on Mathematics-EE101Module

In this section, the analytical results of the learning process of the cohort of students (10 students in total) are presented. Within the VLPE system, there are several features (learning process interfaces) that are designed specifically for the management of learning processes. However, for the purpose of the analytical results that are presented in this section, 2 key-features are highlighted – Learning Process Interface and Cohort Analytics Dashboard.

A. Learning Process Interface (LPI)

The LPI shown in Fig. 4 is the demonstration a learning process workspace that contains learning objects and tools for accessing heterogeneous learning resources (i.e. Google, YouTube, Dictionary Services etc.). The LPI is available to all the e-learning participants that have been pre-defined and assigned a role within the learning process orchestration. Once the learning process on any course is instantiated, course contents are systematically displayed as a task list (i.e. "read this topic", "answer that question", "validate assessment", "approve or reject progression" etc.) and interaction with the learning objects by the e-learning participants can take place within the LPI. Therefore, course materials or learning objects are not made readily available for immediate download. Instead, learning objects are an integral part of the learning process workflow designed shown in Fig. 3; learning objects are embedded into the process as a task list. Student has to go through each part of the learning activities within the process as shown in Fig. 4. This way the student's digital learning footprints can be tracked and monitored. Download of course material is automatically made available to student who has gone through the lifecycle of a learning process.

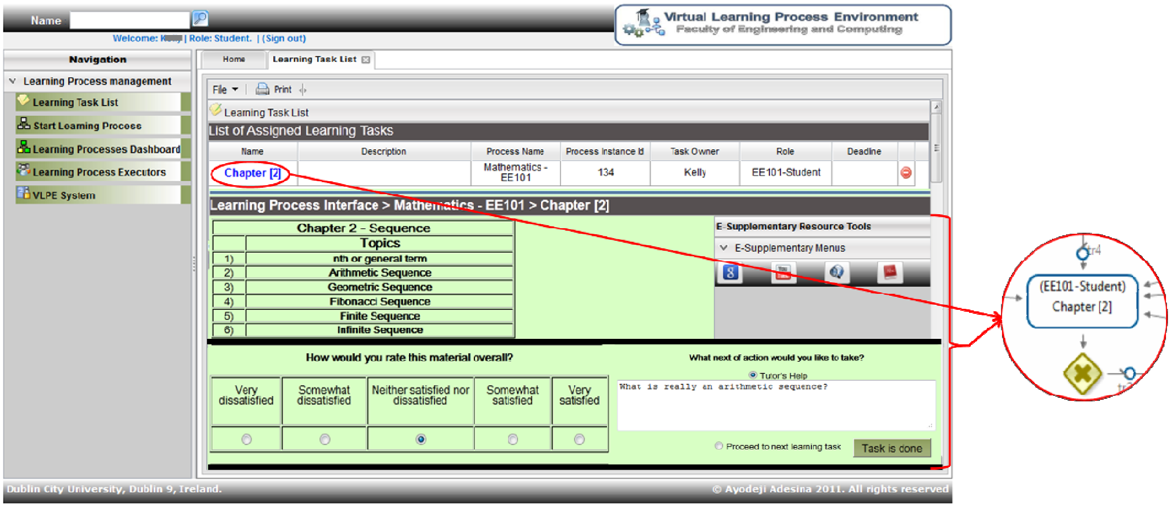

Fig. 4 VLPE Learning process interface showing student accessing chapter 2 which corresponds to the modelled part of the learning process

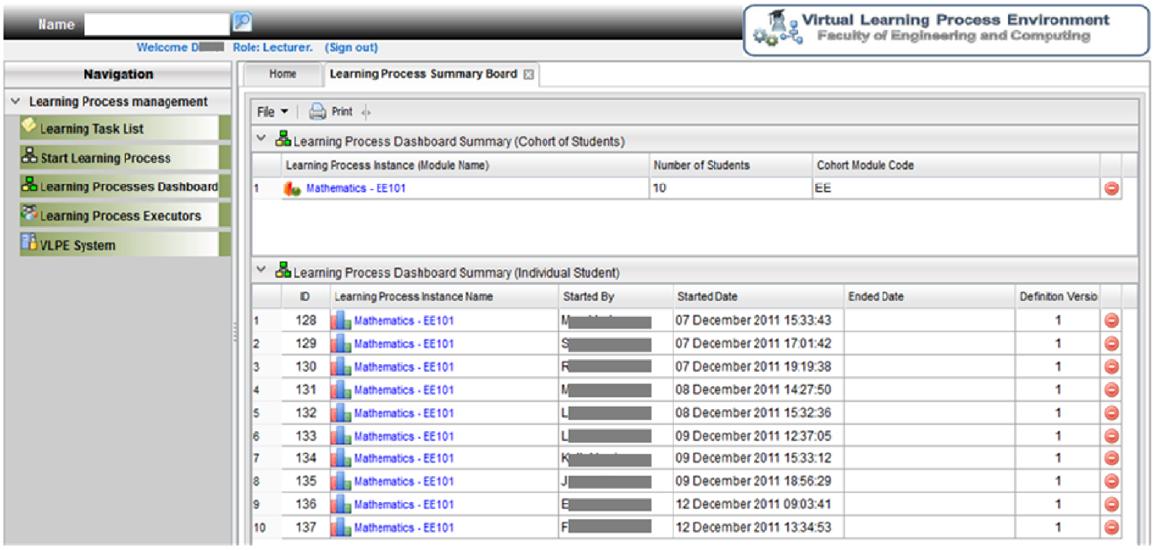

Fig. 5 Summary panel of VLPE learning process dashboard

Fig. 6 Cohort Learning Process Dashboard (CLPD)

B. Cohort Analytics Dashboard (CAD)

What cannot be measured can neither be improved, nor managed. Therefore, measuring the cohorts of students learning processes in a real-time manner provides the monitor-ability, manageability and improvability of students' learning experiences through evaluation and intervention by the lecturer and/or tutors where and when necessary, based on the monitored data as students learn through course material. The capturing, monitoring and measuring of the cohort learning processes lifecycle in a transparent manner would require a learning process dashboard. Within the VLPE, Cohort Analytics Dashboard (CAD) was implemented to do just that. CAD is the marriage between data mining for learning activities and learning process intelligence gathering. The major benefit of CAD is that it provides real-time alerts based on statistical metrics when learning process are in need of intervention and lecturers and/tutors can analyse and detect in real-time the: rate or lack of progressions; learning performances; frequency of supports; live feedbacks and completion rate.

There are two sections to the CAD and the summary panel to the CAD sections is shown in Fig. 5. The first section, shown in Fig. 6, is the aggregated *Cohort Learning Process Dashboard* (CLPD) which provides the analytical means to view the entire cohort learning processes. CLPD is the analytical tool of interest in the paper. The second section is the *Individual Learning Process Dashboard* which provides the analytical means to drill into an individual student's learning process.

For effective analysis of cohort learning processes, CLPD is made up of several analytical components: Learning Task Progression Chart; Learning Task Progression Level Gauge; Learning Process Instance Graph for Learning Paths; Number of Request for Tutor's Support Chart; Number of Request for Lecturer's Support Chart; Number of Attempts On Chapters Chart; Number of Attempts On Assessments Chart and Student's Satisfaction Level Chart. Each of these components provides different statistical and graphical information on how the cohort learning progressions and performances can be intuitively comprehended by the lecturers and/or tutors. The analysis can be performed at any stage of an instantiated learning process. For example, this paper presents two sets of analytical results collected using the CLPD shown in Fig. 6: The first set is based on the cohort learning processes into the second week of starting the three-week online Mathematics-EE101 course. The second set is based on cohort learning processes into the third week (the normal course duration) of the cohort learning processes. Although, while the lecturer can set the course duration with the VLPE, and the short course presented in this paper is set for a duration of three weeks with 24/7 access to the online course; there is the option for student who has not completed the learning process to resume learning as normal. However, the second set of learning process analyses that is presented in this paper accounts for all students' learning processes and performances within the normal course duration – three weeks.

1. Analytical results based on the cohort learning processes into the second week of starting the online Mathematics-EE101 course

Analysis on the cohort learning experience, progressions and performances were observed on the CLPD components and charts are as follow:

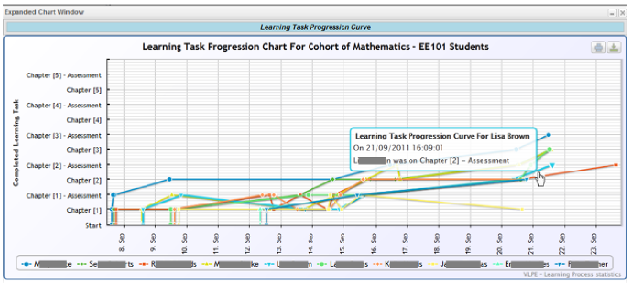

Fig. 7 Cohort Learning Task Progression Chart in week 2

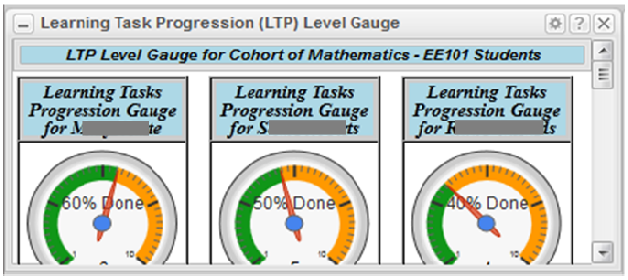

Fig. 8 Cohort Learning Task Progression Level Gauge in week 2

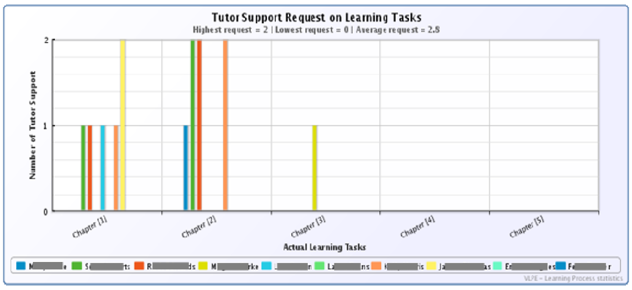

Fig. 9 Number of tutor supports requested by the cohort in week 2

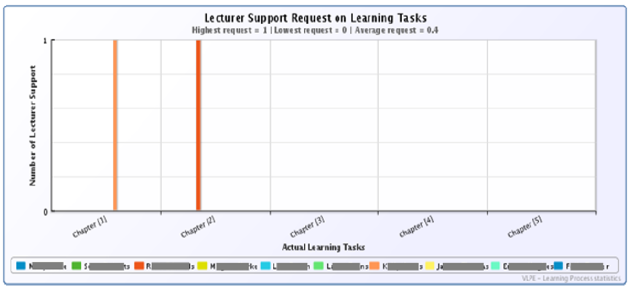

Fig. 10 Number of lecturer supports requested in week 2

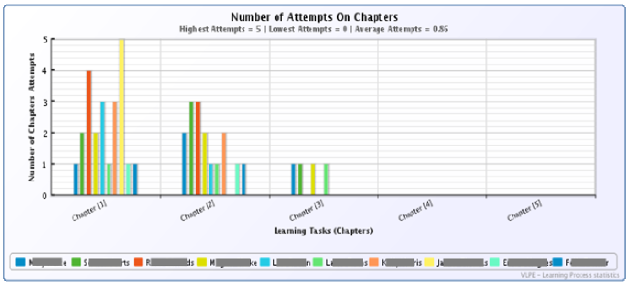

Fig. 11 Number of times cohort attempt reading chapters in week 2

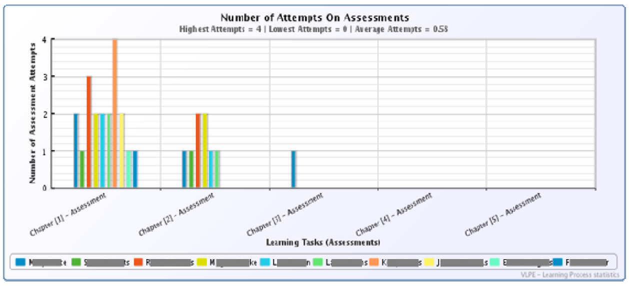

Fig. 12 Number of times cohort attempt the assessments on chapters in week 2

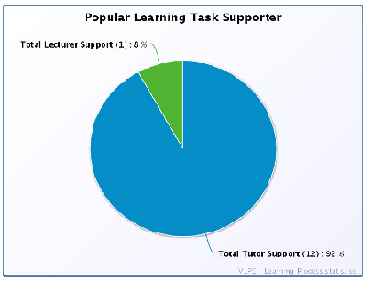

Fig. 13 The popular supporter sought after by the cohort in week 2

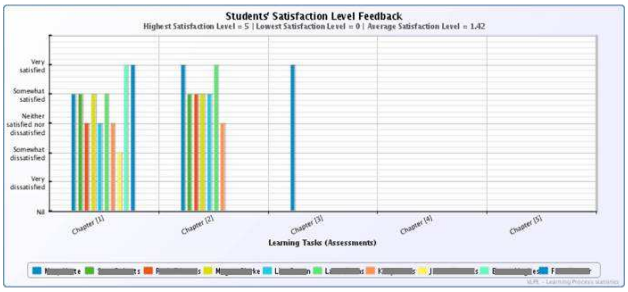

Fig. 14 Cohort feedback on satisfaction level on chapters in week 2

Based on the real-time monitored learning information on the CLPD, the following observations and analyses were made: Fig. 7 indicates that majority of the students were struggling to get through the first chapter and the assessments that follow. Fig. 8 gives an accurate account of the level of advancement each student was making on the entire course material. Some had covered 60% of the material, few had only cover 30% and only one student had actually cover 10%. Fig. 9 shows that the tutor received much request for support from the cohort. Conversely, just 2 requests for support were made directly to the lecturer as shown in Fig. 10. The number of times the students had to read through the chapters was captured in Fig. 11 and Fig. 12 shows the number of times the student had to attempt the assessments that follow each of the chapter. Fig. 13 confirms the percentage of support given by the lecturer and tutor thus far. Fig. 14 presents the students' satisfaction level with each of the chapter, prompting a real-time feedback on the effectiveness of each learning object structure to the lecturer.

The analyses were conducted on a continuous bases and interventions were made where and when needed accordingly since the cohort digital learning footprints were been monitored live. This mimics and provides a similar experience that would normally be experience in the classroom settings.

2. Analytical results based on the cohort learning processes at the end of the three weeks of the normal course duration of the online Mathematics-EE101 course

To be conclusive on the effect of the pedagogical approach and course design structure, it was important to observe the overall learning processes at the end for the cohort learning experiences. This way the course coordinator/lecturer can re-assess, re-evaluate the entire cohort performances with the view to reform the modelled pedagogy if need be. At the end of the three weeks of the normal course duration of the online Mathematics-EE101 module, analyses were conducted based on the monitored learning information shown in the Fig 15 to Fig. 21.

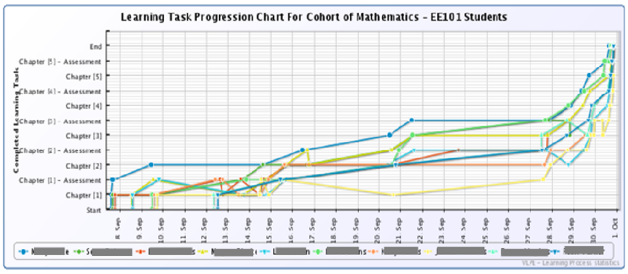

Fig. 15 Complete cohort Learning Task Progression Chart

Based on the observed learning information on the CLPD upon three week completion of the learning processes, the following analyses were concluded: 70% of the cohort completed the entire learning process lifecycle. Fig. 15 indicates that chapter 1 was the most difficult chapter even though it happens to be the less difficult topics. This suggests that chapter 1 will need to be revamped in the future. Fig. 16 provides an example of how each student's learning styles and paths can be different. The resources, supports sought, repetitions made and most popular paths taken by a student can inform on the student's learning behaviour. Fig. 17 shows the overall number of support requests received by the tutor. Judging by the amount of requests, course material will either need to be overhauled or number of tutors will need to be increase in future so as to accommodate demands. Although it is the system (VLPE) that automatically alert lecturer when progression is anemic or stalled, Fig. 18 shows that overall the lecturer had had to make significant interventions where needed – the last chapter in particular.

International Journal of Business, Human and Social Sciences
ISSN: 2517-9411
Vol:6, No:5, 2012

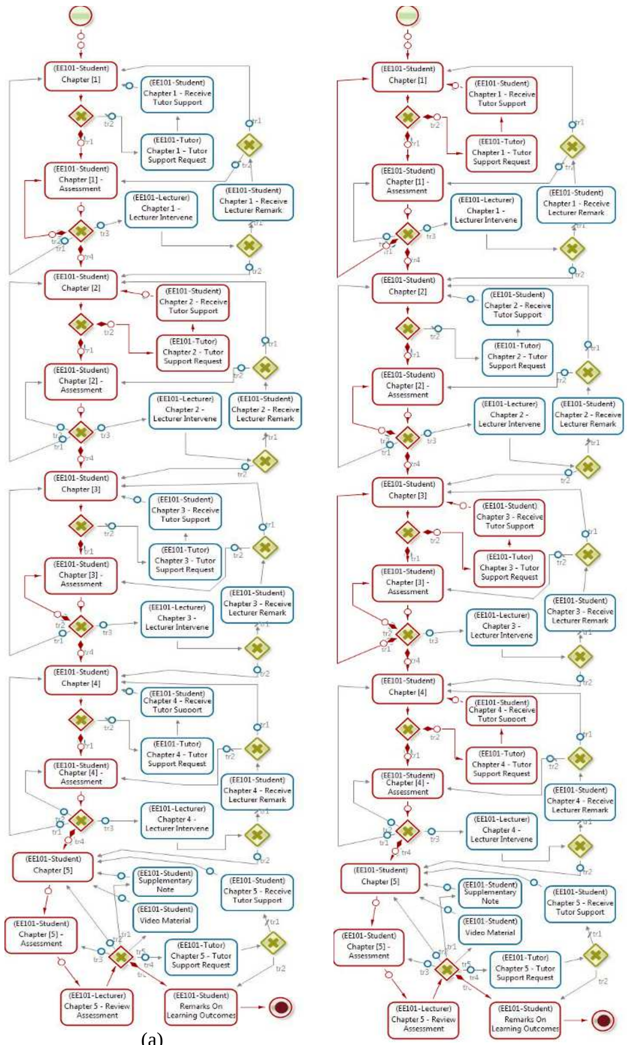
(a) (b)

Fig. 16 (a) The learning paths of a particular students throughout the entire learning process (b) The learning paths by another student – path taken is marked in red

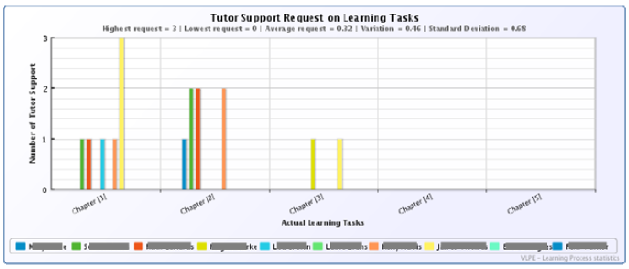

Fig. 17 Number of tutor supports requested by the cohort

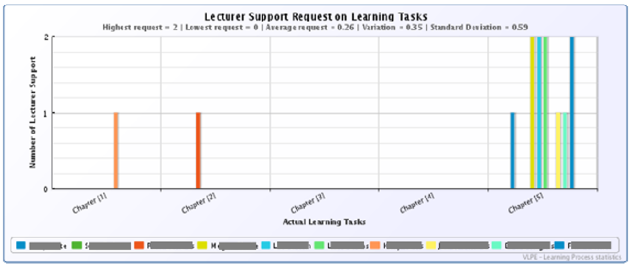

Fig. 18 Number of lecturer supports requested by the cohort

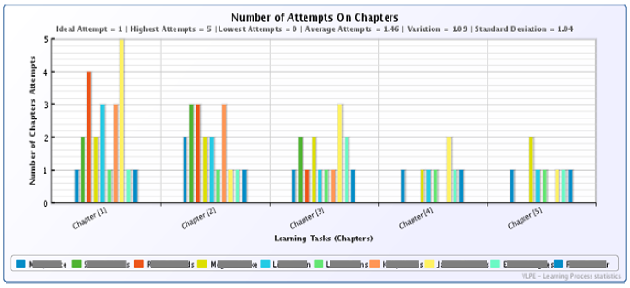

Fig. 19 Number of times cohort attempt reading on chapters

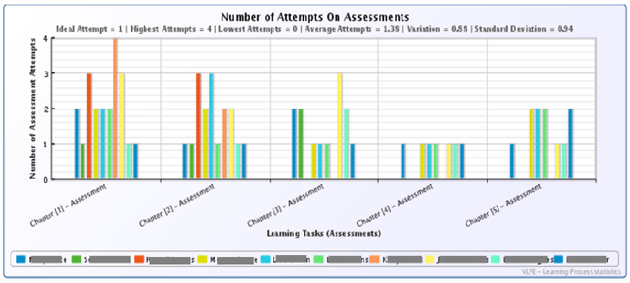

Fig. 20 Number of times cohort attempt the assessments on chapters

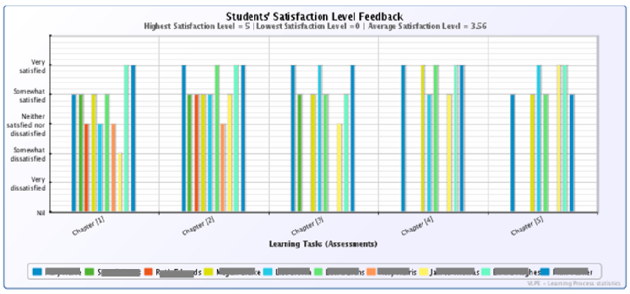

Fig. 21 Cohort feedback on satisfaction level on chapters

Fig. 19 shows that many students were indeed going back and forth on different chapters before they were satisfied. This corroborates one of the categories nature of interaction alluded to by [24] – the challenging category that is discussed in section 3 above. The formative approach employed in the modelled pedagogy is based on providing quick short assessments to gauge students' learning. Fig. 20 show how the students fair through the number of times students have to do the assessments before progression was allowed. Chapter 1 proved more challenging based on performances. Fig. 21 would be even more of interest to the lecturer as this gives a direct feedback on how students view the course materials and their satisfaction levels.

Opinion on each chapter across the board differs; however, there were few "very satisfactions" on chapter 1. This confirms the initial analysis made on Fig. 15 – that chapter 1 would need to be restructured and/or improved.

VI. Conclusion

E-learning is here to stay. If the value of learning in online environments must be gauged or discerned, then, content administration and management are not enough. The administration and management of learning processes would need to part of e-learning formulations as this can be just as important as learning itself.

In this paper, we have presented a system (VLPE) that accounts for the management and analysis of the learning process. What the students do and how they navigate through course materials is determined and quantitative statistical analyses are presented.

Within the VLPE system, monitor-ability, manageability and improvability are enabled using the Cohort Learning Process Dashboard. Typical functions that aid learning and learning process are also enabled. These functions include: assessment delivery; evaluation and analyses of cohort of students' performances; record keeping on the cohort progress and statistical report about performances and live feedback on students' satisfactory levels. The VLPE captures several forms of learning activities conducted by all the e-learning participants i.e. when a student navigates away from a course material and sought a different path within the system as monitored in Fig. 16 (a) and (b). If a pedagogical approach within the modelled learning processes is identified through the KPIs and marked for improvement through the learning process analysis, a new pedagogical approach can be re-modelled around the existing leaning process workflow or as micro sub-processes that can be integrated into the existing workflow. Either way, existing learning process workflow can serve as a template that can subsequently be improved upon with time based on analytical results on its effectiveness. Consequently, a very basic modelled learning process can potentially grow to a very complicated (intelligent and rich in pedagogy) large grid of learning activities, styles, multiple paths and outcomes. The drawback and disadvantage of our BPM approach lies in its complexity. However, as the open source BPM frameworks, on which we rely, are only beginning to gain traction we expect the level of complexity will reduce over time through the addition of more assistive and visual design tools. The VLPE system is a prototype demonstrator of the concepts presented in this paper. It is likely that for commercial or open-source deployment that this approach would be integrated into a current VLE, such as Moodle; however, this would require a significant refactoring of the Moodle system.

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