Forging new pathways of research and innovation in open and distance learning:
Reaching from the roots
Proceedings of the 9th European Distance and E-Learning Network Research Workshop, 2016
Oldenburg, 4-6 October, 2016
ISBN 978-615-5511-12-7
ISSN: 2707-2819
doi: https://doi.org/10.38069/edenconf-2016-rw-0027

INTEGRATION OF LEARNING ANALYTICS IN BLENDED LEARNING COURSE AT A UNIVERSITY OF TECHNOLOGY

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Abstract

The main purpose of this study is to use Learning Analytics to improve the instructional design in an undergraduate Mathematics Education I course. Students enrolled in the course come from varying backgrounds. The Learning Analytics will improve the flexibility of the course and provide a platform to understand misconceptions experience by the students. The integration of computational aspects is necessary to illuminate teaching learning and assessment in a Blended Learning setting.

A Blended Learning model is used to teach first year undergraduate mathematics education I course at the School of Education, Durban University of Technology. Students were taught a course in mathematics using a Learning Management System.

Data is constructed using items from the discussion forum on Black Board and a post assessment task given to 170 first year Mathematics Education I students. Four levels of Learning Analytics: descriptive, diagnostic, predictive and prescriptive are used to discuss the data set.

Activity theory is used as theoretical framework. Mixed methods were used to analyse the quantitative and qualitative data.

Student errors from the post-test are categorised as cognitive errors with structural errors, arbitrary errors and executive errors to establish links with pre-knowledge frames and concept representation. The structural errors indicate that the representation of concepts is necessary in the content design of the course.

Results show that there are more structural errors than executive and arbitrary errors.

Introduction

Using Blended Learning in an undergraduate mathematics course provides opportunities to improve the instructional design to help students minimise errors. This study focuses on errors in basic trigonometry using a Blended Learning format. The essential elements of the learning involve a didactic contract referred to by (Gür, 2009) in a study at Turkey on Trigonometric Learning.

The study applies learning analytics to examine the students understanding of the concepts.

Learning Analytics

Analytics is the process of discovering, analyzing, and interpreting meaningful patterns from large amounts of data (Jindal, 2015). Analytics is usually defined, in practice as any fact-based deliberation which leads to insights (diagnostics) and possible implications for planning future action in an organizational set up (Banerjee et al., 2013)

Descriptive analytics provide a rich data source to measure, compare and improve individual performance. A Learning Management System (LMS) affords functionality to follow or trace student activities and capture data sets to help improve the learning experience. (Norris et al., 2009) is of the view that analytics that besides using quantitative analysis, the qualitative view will provide additional insight to aid the design of the course offering.

Diagnostic analytics provide relevant data to on why students experience these types of errors and misconceptions. In a Mathematics education course such data will allow the designer of a course to alert students of certain obstacles in their learning path early enough to motivate to correct them and improve their effort.

Prescriptive analytics refers to what should be done about such errors and misconceptions. Blended Learning strategies offer other opportunities to assist students in their effort to minimise errors.

Predictive analytics are used forward planning. (Raj, 2014) suggests that analytics can be used for favourable planning using a combination of data about who, what, where, and when and analyzing why and how. Predictive analytics give a glimpse into the future. It can be used to make changes to course content based on data from the descriptive and diagnostic analytics

Figure 1 is adapted from a business model (Banerjee, 2013)

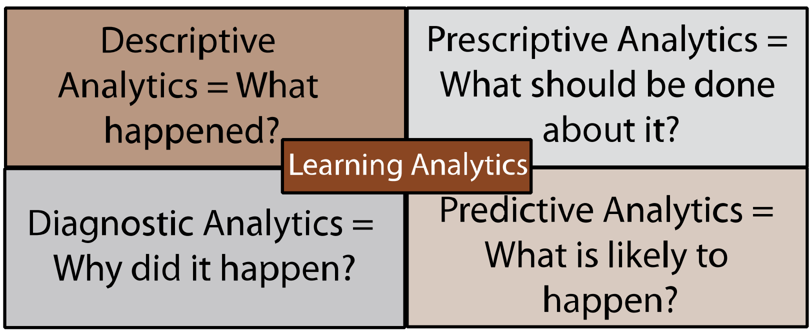

Figure 1. Types of Learning Analytics

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Activity Theory Framework

The Blended Learning model is conceptualised using the Activity Theory (AT) (Vygotski, 1962). This is an artefact-mediated and object-oriented model. Research shows (Barab et al., 2004) and (Karasavvidis, 2009), that AT can be used as theoretical and an analytical framework for examining design and development of technology-supported human-computer interaction, and online and blended learning communities.

The six component of an Activity System, (Engestrom, 1993) are subject, object and related outcomes, mediating tools and artefacts, community or communities, division of labour and rules.

In our project the subject is the student or class group from the MTMC 101 undergraduate course. The object and the related outcomes are the actual online material the student examines in this course and what the material intends to achieve, how these activities transform the student or class group. The online tools, learning resources and conceptual theory used to facilitate the mediation between subject and object. The community is the individual student or the class group. Division of labour: All members of the community do all aspects of the work. The rules are all the implicit regulations, norms and standards that regulate the activity within the system.

(Russel, 1997) describes an activity system as "any ongoing, object-directed, historically-conditioned, dialectically-structured, tool-mediated human interaction". A schematic representation of the Activity System used in this project is given below:

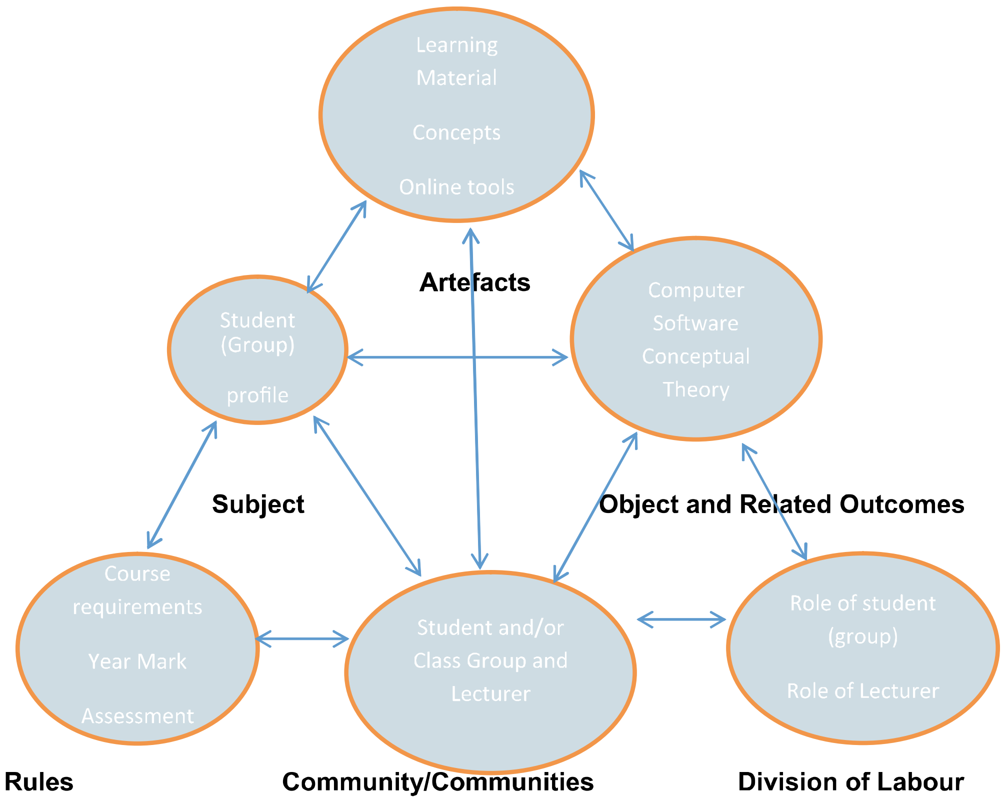

Figure 2. Model of activity system (Adapted from Engeström, 1987; p.187)

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This triangular structure suggests that at any given point any two elements are mediated by another element in the system. For example to get to the object, the subject and community are mediated by the artefacts and rules.

Cognitive Frame Theory

A frame is an abstract formal structure that is stored in memory and somehow encodes and represents a sizeable amount of knowledge. This collection of knowledge representation structures or *frames* grows as more complex frames are built on the existing ones.

We focus on the sequential processes which guide mathematical problem solving activity, the critique which is an information processing operator that is capable of detecting certain of frames, information in one's mind must be typically organized into quite large chunks (Davis & Mc Knight, 1979; Minsky, 1975). Minsky (1975) states "when one encounters a new situation one selects from memory a substantial structure called a frame. This is a remembered framework to be adapted to fit reality by changing details as necessary".

Davis (1984; pp.276-7) lists six possible frame selection procedures:

- Bootstrapping – deals with what one sees in the given. It leads to certain associations, frames that involve such things;
- Not knowing too much – deals with the limited knowledge on a topic or concept;
- Focus on some key cue – deals with the presence of a small number of cues that lead to the retrieval of some specific frame;
- Using context – deals with how the context influences student's choice;
- Using systematic search – deals with the student learning things in a systematic way and develops systematic procedures for searching his/her memory;
- Parameter-adjusting or spreading activation – deals with how certain frames or assimilation patterns acquire high expectation values.

Categorisation of Errors

Errors in trigonometry can be categorized as structural errors, executive errors and arbitrary errors as described by Donaldson (1963). Structural errors arise from a failure to appreciate the relationships involved in a problem or group of principles essential to the solution of the problem. Failure to tackle relationships in a problem arises from a false expectation of the problem. Structural errors may arise in connection with variable interaction. These errors occur in the deductive mode when the subject reasons deductively but fallaciously. One may expect that failure to perceive inconsistency or consistency would be a common source of structural error (Donaldson, 1963). An incorrect frame may be retrieved or the frame maybe not developed adequately. Structural errors are caused by incorrect frame retrieval, sketchy or incomplete frames, deep-level procedures and sub-procedures.

The second type of error is the executive error. Executive errors occur when there is a failure to carry out manipulations, although the principles may have been understood. Some defect of concentration, attention or immediate memory lie at their origin. The most prevalent of

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this class of errors is loss of hold on reasoning (Donaldson, 1963). A correct frame maybe retrieved but a sub-frame responsible for calculations maybe underdeveloped.

The third type of error is the arbitrary error. Arbitrary errors are those in which the subject behaves arbitrarily and fails to take account of the constraints laid down in what was given. These are errors which have as their outstanding common feature a lack of loyalty to the given. Sometimes the subject appears to be constrained by knowledge of what is "true" by some considerations drawn from "real-life" experience. Sometimes there is no constraint of any kind. The subject simply decided "it is so" (Donaldson, 1963). Incorrect inputs maybe assigned to the retrieved frame. "Arbitrary" errors are caused by mapping incorrect inputs to the retrieved frame (surface structures).

Methodology

Qualitative and quantitative methods were used.

The Questions and the Scoring Procedure

Scrutiny of the students' protocols suggested was based on the official marking memorandum.

A score of 0 was given for no response or for an incorrect attempt.

The grading procedure for the items also took into consideration the following:

- equivalent answers or methods were accepted;
- correct answers were give full credit;
- understanding of a method was the main criterion used rather than penalizing for carelessness.

Question (a) was based on this item testing reciprocal functions and quotients. Students had to simplify the LHS to prove the identity.

Prove the identity $\frac{\cos x \sin x \sec x}{\tan x \cot x \cos ec\ x} = \sin 2x$

Coding scheme: 1 mark for writing $\sec x$ as $\frac{1}{\cos x}$ and $\tan x$ as $\frac{1}{\cot x}$ and $\cos ec\, x$ as $\frac{1}{\sin x}$

Question (b) was also based on the proof of a basic trigonometric identity. It also required quotients and reciprocal functions.

Use a sketch to prove $1 + \tan^2 x = \sec^2 x$

Coding scheme: 1 mark for drawing the correct sketch. 1 mark for simplifying the LHS and 1 mark for showing equivalence.

ISBN 978-615-5511-12-7

Question (c) was also based on proving an identity. It also required quotients and reciprocal functions. This question required simplification of both sides of the equation to prove equivalence.

Prove $\tan x + \cot x = \sec x + \operatorname{cosec} x$

Coding scheme: 1 mark for writing $\tan x = \dfrac{\sin x}{\cos x}$ and $\cot x = \dfrac{\cos x}{\sin x}$, 1 mark for simplifying the LHS and 1 mark for showing equivalence.

Question (d) required application of reduction formula, special angles and co-ratios.

Prove $\dfrac{\sin(90° - x)\sec(x - 360°)\tan(180° + x)}{\operatorname{cosec}(180° - x)\cot(90° - x)\cos 0°} = \sin x$

Coding scheme: 1 mark for correct simplification of each expression on the LHS and 1 mark for showing equivalence.

Question (e) required application of special angles and negative angles.

Prove $\dfrac{\cot 240° + \sin^2(-225°) - \cos^2(30°) + \sec(-330°)}{\sin(-210°)\cos 0° + \sin^2(-60°) - \sin^2 210°} = \sqrt{3} - \dfrac{1}{4}$

Coding scheme: 1 mark for correct simplification of each expression on the LHS and 1 mark for showing equivalence.

Results

Table 1 shows the error classification for each item from the assessments that were concerned with basic trigonometry. Students encountered more structural errors than, executive errors and arbitrary errors.

Table 1: Classification of errors

Classification of Items	Structural Error	Executive Error	Arbitrary Error
Item (a)	55	43	22
Item (b)	73	37	24
Item (c)	57	28	21
Item (d)	86	36	18
Item (e)	68	38	19

Discussion

In question (a) the majority of the students were able to make the correct substitution but still failed to prove the identity. The descriptive analytics indicate that frames from the algebra domain were underdeveloped. 55 structural errors (37 percent) and 43 executive errors (29 percent) and 22 arbitrary errors (15 percent) were recorded. These are indicative of incorrect

ISBN 978-615-5511-12-7

frame retrieval. (Davis 1984) refers to this as the ability to do a systematic search for the correct frame. Here multiple frames were needed to correctly solve the problem and this was lacking. Student's also displayed inadequacies in manipulations of fractions.

In question (b) almost 50% of the cohort were unable to draw a correct sketch to present the proof. This is indicative of "not knowing too much". These concepts are met at grade 10 at secondary school. It shows that conceptual understanding is lacking.

In question (c) there were 38 percent structural errors. Errors were similar to those in question (a). Students were making errors in connection with variable interaction and frames from algebra were inadequately used.

In question (d) the expression $\sec(x - 360°)$ seemed "unfamiliar" to the majority of students. A relatively high percentage of structural errors were recorded (51 percent). In question (d) there were 58 percent structural errors. This question recorded the most of the errors

In question (e) the terms $\sin^2(-225°), -\cos^2(30°)$ *and* $\sin^2(-60°)$ were confusing to students. Students failed to see that the expression had to be simplified first and then squared.

These would represent descriptive analytics and provides valuable information both for curriculum planners and facilitators for future design of instructional material.

Items from discussion forum forms part of both the diagnostic and prescriptive analytics. It provides real time information on errors and misconceptions that students experience.

Some exemplars from the discussion forum on Blackboard were selected for discussion.

Item 1 is the initial post to a problem:

> "$\cos^2(180 - x) = -\cos^2 x$
> *I just want to ask how we reduce* $\sin(720° - x)$ *?*"

Item 2 is a response to item 1 given by another student:

> "$\cos^2(180° - x)$ *is not equal to* $-\cos^2 x$
> *You need to work out* $\cos(180 - x)$ *and then square it. You should write it like this:*
> $\cos^2(180° - x) = \left[\cos(180° - x)\right]^2 = (-\cos x)^2 = +\cos x$
> *I hope this helps.*"

Then for the other one reduce $\sin(720° - x)$ to $\sin(360° - x)$ and them solve it.

In the fourth quadrant sine is negative so $\sin(360° - x) = -\sin x$

ISBN 978-615-5511-12-7

Item 1 shows that the student mixes up the signs in the reduction formula. The student is not clear about what $\cos^2(180° - x)$ means. It is clear that the student knows that the cosine function is negative in the second quadrant so giving a negative answer "seems" appropriate.

Item 2 posted by another student gives clarity. It may occur that the first student was not able to write $\cos^2(180° - x)$ correctly in terms of using the correct notation to assist the solution, hence an incorrect sign resulted.

Item 3: is another problem experienced by a majority of students:

> *"Good people I am having a problem with* $\tan(x - 180°)$. *Is the answer* $-\tan x$ *?*
> *tan is negative in the second quadrant so it must be correct."*

Item4: is a response to the problem in Item 3:

> *"You are incorrect. First write* $\tan(x - 180°) = \tan[-(180° - x)]$ *Now you can work it out"*

Again this is a case of mixing the signs in the reduction formula. These examples forms part of parameter-adjusting (Davis 1984) which deals with how certain frames or assimilation patterns acquire high expectation values.

The Descriptive analytics provided by the student post on Blackboard can be used both by the students in the class group and the facilitator. The correct response is the Prescriptive Analytics offers a solution to the problem. Most important of all is that a diagnosis can be made as to why the student struggled to follow the correct algorithm to get the solution.

What is likely to happen (Predictive analytics) is that more students will benefit from the discussions unlike when it is done on a one on one basis or in a class tutorial face to face.

Linking this to the Activity System suggested by the theoretical framework it makes sense to create an environment that encourage student collaboration in a student-centred environment to capture errors and misconceptions early enough to be able to assist and motivate discussion.

Conclusion

Learner analytics from posts on the discussion forum provide teaching assistants and course facilitators with valuable information on student's experience. The errors and misconceptions identified can be dealt with by peer collaboration or input from teaching assistants or the course instructor. In an online environment these can be done effectively and quickly as compared to traditional tutorials that have a scheduled time slot.

ISBN 978-615-5511-12-7

Lots of practice is necessary to undo the incorrect frames that have been cemented in the student's mind as their "correct frames". The online forum using the discussion forum is recommended as a means to assist the reinforcement of the correct frames.

References

1. Davis, R. B. (1984). *Learning Mathematics: The Cognitive Science Approach to Learning Mathematics.* Croom Helm Ltd.
2. Davis, R. B., & Mc Knight, C. (1979). Modelling the process of mathematica thinking. *Journal of Children's Mathematical Behaviour, 2*, 91-113.
3. Donaldson, M. (1963). *A study of children's thinking.* London: Tavistock Publications.
4. Engerstrom, Y. (1993). Developmental studies of work as a testbench of activity theory: The case of primary medical practice. In Chaiklin & Lave (Eds.), *Understanding practice: Perspectives on activity and content.* New York: Cambridge University Press.
5. Engeström, Y. (1999). Activity theory and individual and social transformation. In Y. Engeström, R. Miettinin, & R. Punamaki (Eds.), *Perspectives on activity theory* (pp. 19–38). New York: Cambridge University Press.
6. Gür, H. 2009. Trigonometry Learning. *New Horizons in Education, 57*(1), 67-80.
7. Jindal, R. a. D. B. M. (2015). Predictive Analytics in a Higher Education Context. *IT Professional, 17*(4), 24-33.
8. Minsky, M. (1975). A framework for representing knowledge. In P.H. Winston (Ed.), *The Psychology of computer vision.* New York: Mc Graw-Hill.
9. Norris, D., Baer, L., & Offerman, M. (2009). A National Agenda for Action analytics. *Proceedings of National Symposium on Action Analytics.*
10. Raj, P. a. D., G.C. (2014). Big Data Predictive and Prescriptive Analytics. *A Handbook of Research on Cloud Infrastructure for Big Data Analytics.* IGI Global
11. Vygotsky, L. (1962). *Thought and language.* Cambridge, MA: MIT Press.
12. Vygotsky,L (1978). *Mind in society: the development of higher psychological processes.* Cambridge: Havard University Press.

ISBN 978-615-5511-12-7