Puzzle Based Learning in Undergraduate Studies

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ABSTRACT

All undergraduate Radiography students require training in image interpretation and evaluation of x-ray images in their second year of studies as part of work integrated learning.

The method of teaching pedagogy influences the student's learning process and recall ability during examinations. if the teaching process moves to a student-centred approach, students become responsible for their own learning allowing active engagement and construction of their knowledge systems.

Aim/ Objectives

The aim of the study is to implement and evaluate the use of puzzle-based learning in the teaching and learning process of undergraduate studies

Objectives

To determine the efficacy of crossword and jigsaw puzzles as a novel teaching tool for medical imaging education

To increase student's interest and involvement with image interpretation topics

To improve and assess recognition and recall of medical terminology

To improve the understanding of innovative learning

Methods

The study is a cross sectional qualitative research design.

Approval will be obtained from the Research and Ethics Committee of health Sciences.

Online consent will be obtained from students involved, by means of Google Form submission, followed by an information session on Blackboard collaborate on the topic "Image evaluation and interpretation of radiographic imaging".

Conclusion

The research will prove the important collaboration of active teaching methodologies with simple, easy to use didactic material to improve student's understanding of basic concepts in their core module subject

Keywords: Puzzle**,** undergraduate**,** medical education**,** memory recall**,** puzzle-based learning.

INTRODUCTION

All undergraduate Radiography students require training in image interpretation and evaluation of x-ray images in their second year of studies.

The method of teaching pedagogy influences the student's learning process and recall ability during examinations. if the teaching process moves to a student-centred approach, they become responsible for their own learning allowing active engagement and construction of their knowledge systems.[1-3]

LITERATURE REVIEW

Active teaching methodologies refer to educational games such as puzzles, providing challenges and situations to improve overall integration of learning contents.[4-6]The use of interactive crossword and jigsaw puzzles allow an increased interest in a topic of study as well as improvement in problem solving skills.

In a previous research study[4], the use of traditional instruction was compared to puzzle-based learning (PBL), for electrocardiogram interpretation methods for medical students. It was found that the use of puzzles promoted a relaxed learning environment and that the use of puzzles increased their overall scores of traditional teaching outputs by 2,53 %[4]. Another study utilized puzzles for the improved understanding of pathology. A similar methodology was used by comparing to groups scores following two separate teaching methods for each, namely traditional instruction and PBL. The average scores of the puzzle group were significantly higher than the traditional group. It was also confirmed that puzzles aided in improved communication ability, adaptability as well as resourcefulness to adult learners[7].

Previous research has proven a significant improvement of grades in tests applied after use of card games in teaching certain medical terminology.[8] The use of puzzles should include general criteria such as generality, simplicity, a Eureka factor and an entertainment factor.[1-2,9-10]

An empirical evaluation of puzzle based learning was also done which faced a similar issue to the current study, of engaging students with course work in a manner which provoked their critical thinking and problem solving skills. Their study outcome was evaluated by means of an anonymous teaching and learning feedback survey questionnaire[11]. Falkner et al[1,9-10], stated that puzzle based learning (PBL) courses, are not just providing a variety of puzzles, but rather allowing a discussion and understanding of problem solving principles by means of puzzles, which allow an entertainment factor of concepts presented[10]. By means of puzzles, students deeper cognitive minds are enticed to engage and explore topics presented on a much more challenging level.

Educational puzzles should serve certain criteria to be considered as a successful method of teaching and learning, namely generality (includes universal problem solving methods, explained by lecturer), simplicity (should be easy to use and remember), Eureka factor (it should both frustrate the puzzle solver and provide relief upon solving), and ultimately an entertainment factor. Along with this, puzzles should promote positive attributes to teaching and learning such as being engaging, thought-provoking, raising awareness of the myriad of outcomes related to real world problems.

This study will promote the use of formative evaluation which provides both the student with instant feedback as well as the lecturer with key identifiers of what the students understand and what matters require more in-depth teaching. There are limited teaching and learning resources utilizing puzzles and interactive learning to improve learning outputs in the undergraduate studies.[2,9] The research will prove the important collaboration of active teaching methodologies with simple, easy to use didactic material to

improve student's understanding of basic concepts in their core module subjects. The main objectives of the study were:

- To determine the efficacy of crossword and jigsaw puzzles as a novel teaching tool for medical imaging education
- To increase student's interest and involvement with image interpretation topics
- To improve recognition and recall of medical terminology
- To improve the understanding of innovative learning

PHILOSOPHICAL ASSUMPTIONS

The philosophical assumptions embedded within a mixed method design can be summarized as a process of the initial wordly view on the students perceptions and attitudes regarding puzzle based learning. [6,12] Lifelong learning methods allow students the opportunity to pursue activities not previously made available during their teachings. The expansion of cognition, skill and competency will form a vital part of their growth and societal influence.[13]

To promote a pragmatic approach to student advancement in skills, it requires policy makers, teachers, educators and researchers to engage in improvement of skills and intra-personal reflection of students.[12]

Puzzle based learning (PBL) is an experiential pedagogy as it seeks to provide answers to a pedagogical outcome of teaching and learning methods.[1] Epistemological frameworks are useful to develop learning experiences. The organizing frameworks are developed in both positivistic/constructivist setting and as separate/connected judgement.[6,12]

Constructivist learning theory approaches which call for the active assent of a student should be incorporated as part of undergraduate teaching practice. The current research evidence promotes higher learning through the evolution of cognition, more specifically in the frontal cortexes of the brain[14]. Perry and Schommer[5] (1994) noted that students are faced with the predicament of contradicting theories, causing evolution of the nature of knowledge.[5-6,12,15]

To achieve delineation of epistemology during this research study, information gathered would be related to the puzzle based test. This allows systematic assessment of differences which may propose as barriers to education reform efforts. The study also allows the assessment of specific epistemological beliefs propagated through educational practice. The assumption is made that through this systematic approach, a puzzle based learning methodology for undergraduate students can be developed.

METHODS

The study is a cross sectional qualitative research design. The proposed population used during the proposed study will be fifty six (56) Radiographic Sciences students enrolled for Radiographic Sciences (DIR 200) the Faculty of Health Sciences at the University of Pretoria during their 2021 academic year. The students will be informed of free and willing consent to participate in the study with no risk of active participation affecting their module marks or outcomes.

Convenient sampling will occur where the sampling population will be identified as all undergraduates registered for second year of study for Radiography.

Record keeping: This method makes use of the already existing reliable documents and similar sources of information as the data source. The documents included questionnaires, puzzle based assessments. This data can be used in a new research.

Approval to be obtained from the Research and Ethics Committee of health Sciences.

Written, online consent to be obtained from students involved, followed by an information session on the topic" Image evaluation and interpretation of radiographic imaging".

The jigsaw puzzle and crossword puzzle to be tested, will receive peer evaluation from internal departmental evaluators.

The online programme to be used will be Puzzel.org, which has multiple interactive teaching and puzzle options to be used during the course of this study. The platform allows embedding onto the Clickup LMS system of the university of Pretoria which promotes engagement on their current platform of choice. Students who have provided informed consent to participate, will be given weekly 30 minute sessions, during their free time to complete the associated components of the proposed researched. A pre-quiz assessment of conventional x-ray imaging will be provided to the first group followed by the jigsaw and cross word puzzle as an interventional training method for the second group on the topic of basic knee projections.

Following the interactive learning puzzles, a post-quiz assessment of the same conventional x-ray imaging will be provided to assess if the use of puzzles improved the students overall though and understanding of imaging and evaluation of imaging in Radiography.

The two groups used during the study for both theoretical and puzzle methods, will have an informal mark assigned to their image evaluation output. The students are informed that the informal mark is only for the purpose of research output and comparison of methods and will not affect their formal year mark associated with the module, DIR 200. A comparison will be made to the marks if there is a significant difference between the two methods of teaching image evaluation. The topics assigned to this research study is not related to their core curriculum of DIR 200, thus non-participants to the study will not be disadvantaged by means of additional teaching and learning methods used for participants of the study.

The data will be organized in online paper based format, after which the recorded data will be loaded onto the University of Pretoria's Cloud system for research data. The data will be kept for 15 years at the Department of Radiographic Sciences.

Grounded theory analysis will be used derived from data, where the eventual theory are in close relation. The key tool to be used will be coding of components into research outcomes such as concepts and categories. [5-6,12]A narrative/thematic approach to data analysis will be used to assess what is being said by the students in their r reports as opposed to how they are saying it. Thematic analysis and the coding process has a similar action which can be related back to the literature review. The framework for this approach is best used in a matrix to order and synthesize data into central themes and subthemes. When themes are being sourced from the collected data, factors such as repetition, local expressions, similarities, differences and missing data will be assessed.

Ethical considerations

Initial consent was obtained from Teaching and Learning Department of the Faculty of Health Sciences prior to commencement of the study for permission of student participation during the study. The Research and Ethics Committee of the University of Pretoria also provided consent to continue with the study obtained. The information obtained from the students was kept strictly confidential and anonymous in the interactive group sessions. The students will handed in reflection and assessment reports as an anonymous participant identifier number, with no reference to their age, gender or other socio-economical demographics. The Nuremburg code[16] was upheld in the manner of voluntary consent of the human subject being essential. The research is focused on the good of society, unprocurable by other methods or means of study, and not random and unnecessary in nature. During the course of the study, the researcher is willing to end the research study at any stage, if there is probable cause to believe, in the exercise of the good faith, superior skill and careful judgment required of him that a continuation of the research is likely to result in injury[36]. In line with the Belmont report, the three fundamental ethical principles for using any human subjects for research will be upheld namely, respect for persons in the form of protecting their autonomy, beneficence (first do no harm) and justice to ensure non exploitative, well considered methodology.[14]

A comprehensive layout of POPIA compliancy is discussed below:

Participants for the proposed study was recruited directly on campus during online teaching of the proposed module following an information session, discussing their rights to privacy, access to information and what data was obtained during the study.

Participants were provided an online survey link to complete during the course of the study, no reference to their age, name, ID or other personal information will be included in the questionnaire

Voluntary participation is elucidated during the initial information session.

No impediment of University of Pretoria Intellectual Property will be actioned.

The study is part of the development of improved teaching and learning pedagogical tools for undergraduate studies to educated and enhance student's overall performance and assessment outputs in the Faculty of Health Sciences.

RESULTS

Various methods of statistical tracking are used during online teaching and learning on Blackboard Collaborate as well as through the 3rd party links embedded on the platform.

Both activity and performance outcomes were recorded as part of the results in this study. The initial objectives and results outlined for the study are stipulated below in Table 1:

Table 1: Layout of objectives and results

Objectives	Results
To determine the efficacy of crossword and jigsaw puzzles as a novel teaching tool for medical imaging education	Qualitative questions to students
To increase student's interest and involvement with image interpretation topics	Interest rates from 2020-2021
To improve and assess recognition and recall of medical terminology	Marks over 3 year period
To improve the understanding of innovative learning	Summary of marks, interest/engagement and their feedback on use of puzzles.

From the total sample population of the undergraduate group, 36 of the 56 students provided informed consent to participate in the study.

Each lecture session held, included an additional puzzle-based activity for participants to complete as part of their "Prepare, engage, consolidate" learning plans at the University of Pretoria. The activity would be marked as either "pre" or "post" class engagement. The method ensured both assessment of prior knowledge as well as embedding new content following live lecturing sessions.

The statistics for overall participation was assess on both Blackboard Clickup and on the various 3rd party links embedded on their student platform, which also allows statistical overview of participants activity lists of a set period of time.

Along with this, the overall grade average for theory was compared between initial conventional theory based learning to the new proposed puzzle based learning methods over a 3 year period. The subject matter over the 3 year period remained the same, the method of teaching however differed with the included sample population as incorporating puzzles in the teaching and learning pedagogy.

Variations of puzzles were used during the study, as seen in Table 2:

Table 2: Variations in puzzle-based learning methods

Type of puzzle	Description	Content used
Interactive image annotation puzzle	Any image can be uploaded and certain points can be targeted to be annotated during the quiz mode. The image can also be exported as a downloadable worksheet for hardcopy format. The puzzle can be set on tournament mode for students to be awarded badges	Image evaluation of special radiographic projections of the knee and pelvis

Crossword puzzles	To create a crossword puzzle, you need to have at least two words since the words need to be 'crossed'. From that point on you can create more intersections between words and expand your puzzle grid. Tracking (student) puzzle results is a feature for upgraded subscriptions. You can add forced registration to see individual results (per question, in real-time), or add a completion message with a 'collect user info' option that allows you to export the submitted puzzle completions	Terminology and pathology definitions of knee and pelvis related projections
Acrostic puzzles	The acrostic puzzle has a unique setup around a hidden solution 'skeleton' that you need to find through solving individual answers. When creating the acrostic puzzle, you have to make sure you have enough answers to cover your hidden solution. To solve the acrostic puzzle, players need to find the answers to individual questions to gather characters for the end solution. As you go along, the hidden solution will reveal itself and the puzzle within the puzzle is solved!	As part of pre-class engagement and revision of work already covered, the hidden solution would be the password to enter live online class
Sliding puzzles	You can upload your own image to create your own custom sliding puzzle based on that image. The puzzle gets split into as many rows and columns as you like and then gets shuffled! One empty space / missing puzzle piece is left, so you have space to slide the puzzle pieces around.	Basic anatomy images of the pelvis and knee, as the radiographic imaging is underpinned by and understanding of anatomical layout of each bony part.
Jigsaw puzzles	Jigsaw puzzles start from an image that you upload yourself, making it fully personalised from the start! The image then gets sliced up into any number of puzzle pieces, just like your offline jigsaw puzzle.The jigsaw puzzle pieces are randomly spread across the puzzle field and	Specific standard projectiosn of the knee and pelvis were split into 4-9 piece puzzles. This embeds understanding of

	need to be returned to their original spot. You do this by dragging the pieces (touch for mobile, mouse for desktop).	anatomy on a radiographic image
Matching pair puzzles	Matching pairs is all in the name, it is about matching a pair of cards so they are in the same row. You as the puzzle maker create all kinds of logical card pairs with text/image, image/image or text/text combinations. The cards get split into a random order by default and need to be aligned as the correct card pair in the 'solving area' of the puzzle. You can also give the left and right column of the solving area a name, so it is clear which part of the card pair belongs where. The matching pairs puzzle is solved once all of the cards have been dragged and dropped into the right spots. Dragging and dropping is supported on mobile (touch) as well as desktop (mouse).	Terminology and annotation of projections
Escape room puzzle	The scavenger hunt involves connecting multiple challenges/puzzles and unlocking each one step by step. So to make this work, make sure every challenge you add contains some form of completion/question that leads the scavenger hunt player towards the next challenge with a code. Create descriptions with a cryptic message that can lead to a code, add an image as a clue, create a puzzle with a code/hidden solution.	Interactive live class puzzle used, as part of a class team approach to reach the answer at the end of the scavenger hunt/ escape room.

The puzzles which had the best response and active engagement were:
Sliding and jigsaw puzzles were actively engaged by 89,2 % of the sample population
Acrostic puzzles and Matching pairs were actively engaged by 90 % of the sample population, with a time lapse of 44 sec to 2:43 min to complete an activity between the various students.
Interactive image puzzles were engaged by 67 % of the sample population and was used repetitively as part of revision work between 115-134 times over a one-week period by the sample population. Puzzles with a limitation of time to respond to a question had less engagement, at a rate of 59 % only partaking actively

and repetitively on the same puzzle link. Over the 6 month period, the increased use of puzzles for pre and post class engagement increased from 69 % to 91 %

Conventional theory-based learning in the sample population, proved a difficult task to embed certain clinical terms and activities to the students. Their overall recall rate was an average grade of 68 % to 74 % during conventional theory-based learning. The change to puzzle-based learning proved both enjoyable and better at explaining concepts by allowing the students to reach the "eureka" factor during participation. The grade average increased to 86 % during puzzle-based learning, thus an increase of 12 % was noted by using interactive puzzles for pre and post class engagement and assessment activities.

Following the active puzzle learning activities, all participants were encouraged to complete a 10-minute open ended questionnaire on their views and perceptions of methods of teaching used in the online platform setting. The response was very positive towards puzzles, as seen below in Table 3:

Table 3: Student perceptions and views

	Perceptions and views on various teaching methods used over research period	Themes from content analysis
Theory based learning	Dull and very hard to focus on concepts. There's also doubt on how much you know. conventional learning feels normal, but it is very intimidating when you receive a large amount of work and it is only words on a piece of paper. Trying to remember work put in such a bland way is challenging. It is also difficult to stay concentrated when studying such work. I would understand the theory in general however visualization (getting the idea) of the theory would be poor. not fully understandable Uninspiring. Passive. Non-visual. Boring and long. Conventional teaching doesn't really help me formulate a practical understanding of the theory we learn. Learning the work because I have to and not because I enjoy it and have fun	Low self esteem Non engaging Low practical understanding Not enjoyable Passive learning

Puzzle based learning	Very clear and makes studying more interesting, it stimulates curiosity and boosts confidence Using puzzles to study is truly engaging and beneficial. It feels like you are challenged to convert normal information in your brain to a form of solving a problem and engaging "memory reception" in a fun way. The best part is that you stay concentrated and focus the entire time, thus retaining the information in the puzzle was also easier for me. I would master both visualization and theory which results to much greater understanding of the given unit. Better understanding. Retained knowledge. Actively-learnt. Interesting. It made learning more fun and it developed my critical thinking skills. Using puzzles during lessons helped me visualize the theory that we were being taught Vast understanding. I enjoy learning about the work. The information goes in easier Fun, interactive, thinking and learning in a different manner	Active learning Engaging Challenging Fun and interactive Improved memory Improved understanding

Participants were also asked their views regarding future in class assessments and tests being formulated in puzzles. And there responses were recorded below in Table 4:

Student comments	Content analysis
Would be very helpful I would enjoy this as a method of assessment, as long as we get to practice examples in class before being evaluated on them. I think using puzzles for assessments and test purposes is one of the best things that could be used for BRad II students since it is different from the norm and different is good. The puzzles give me the opportunity to not just learn but have	Enjoyable Engaging Improved understanding Non-conventional Easier

fun. Killing two birds with one stone thus I am able to remember theory because I was not using the aid of just boring notes. i enjoy the fun way of learning, and remembering the content better I believe it is a great idea. Puzzles allow for students to actively learn and engage with the work I would definitely like using puzzles for learning activities. Using puzzles for assessments and test purpose would be amazing because it makes learning fun and you actually look forward to doing the assessment/test. Its alot more fun learning through puzzles rather than learn the conventional way. Learning the normal way can get repetive and boring after awhile. They'll be more fun and could make writing assessments and tests easier.	

DISCUSSION OF RESULTS

The results from this study proved a promising role for use of puzzles in the undergraduate module of Radiography students.

In the current health science working environment, graduates require development of problem-solving skills, alongside their clinical and theoretical knowledge. The conventional teaching methods limit student's problem thinking skills by limiting their concentration to questions in a textbook to solve after having discussed the content of a chapter. The issue with this method, is when students enter their professional roles, they soon realize that the problems they face in the working environment are not limited to textbooks or study guides.[1]

Real world

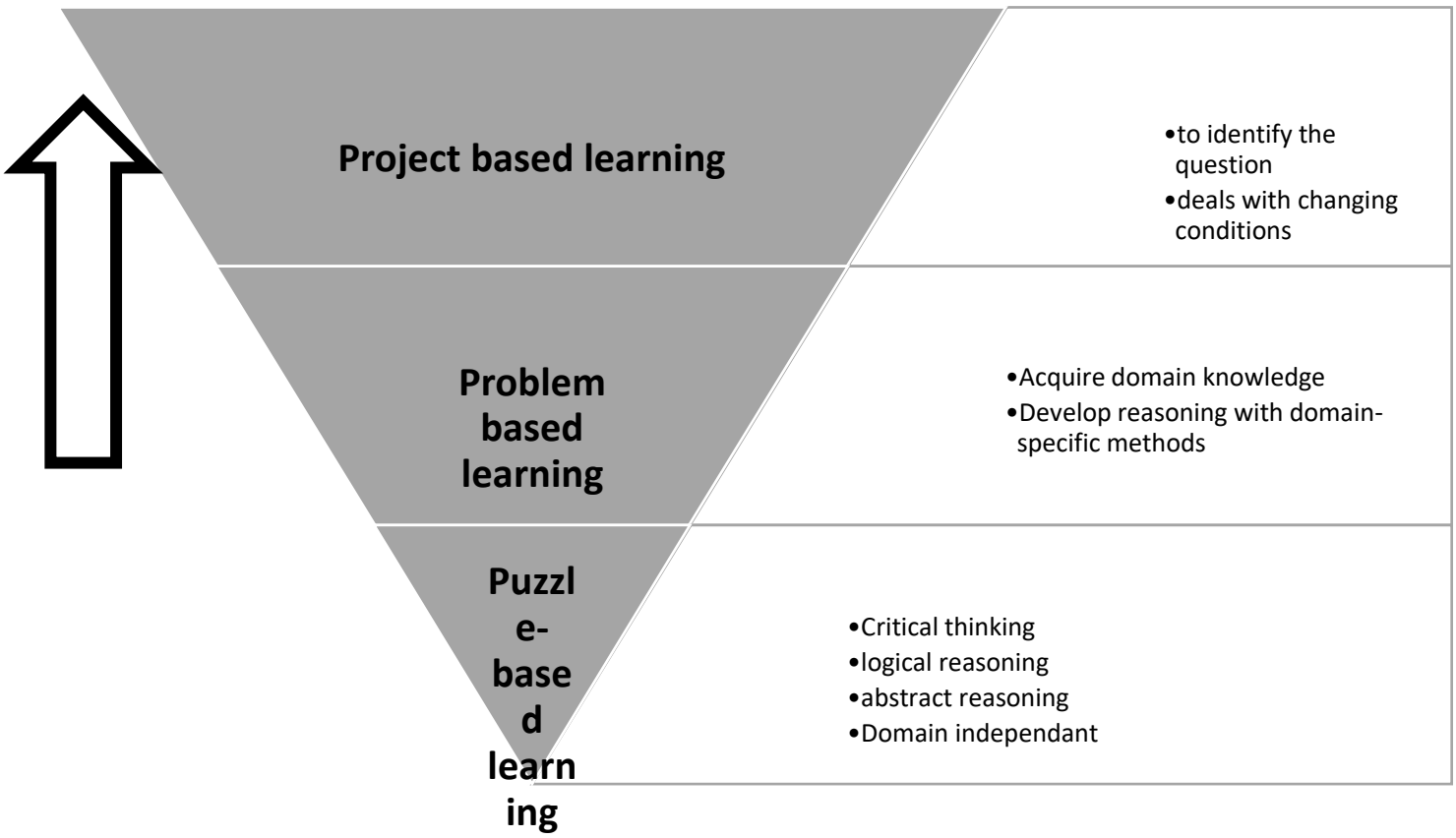

Figure 1. A continuum of learning and skills needed for problem solving in the real world.

In Figure 1, the continuum of learning of various skills are dependent of the layers preceding it. Puzzle based learning allows introspection problem solving skills raising questions such as: "What is the solution?" or "Why did I not see it?"[1,10]

Puzzle-based learning is a pedagogical method in progress. The end game is to develop independent reasoning and critical thinking skills that can lay a foundation for problem-solving in future course work (as depicted in Figure 1). Even though puzzles do allow some interactive fun and engagement, they are ultimately means to a pedagogical end. [10]

One such previous study, the students average mark over a time period of 10 assignments using first conventional teaching, then followed by PBL, increased by 5-8 %. The current study also proved an improvement of 12 % in average grade mark over a period of time.[10]

Another study using puzzles to teach cardiac physiology proved a difference in performance and error output. In the control group of 28 students, the grade output was 8,93 and the number of mistakes made averaged at around 5,62. In the puzzle-based learning group, the grade output was 9,12 with overall mistakes made averaged at 2,72.

The current study output proved a similar response in both the student's perception and response to using PBL as well as their overall grade averages improving following the use of PBL.[8]

The current study showed a 12 % grade average when compared over a three-year time period of the same module contents, with only the ***method*** of teaching changing in the current sample population. The overall interest for post class activities also improved from the previous theory-based assignments, as the puzzles challenged students to apply their knowledge in a problem-solving manner, which allowed improved engagement with the content but also improving their memory recall.

What was interesting to find during the student perceptions content analysis, was that the theoretical conventional method of teaching also prompted low self-esteem and confidence in student's ability to answer questions in class or tests, whereas the puzzle-based method boosted their confidence in answering test questions. For the health science professions, there is a need to develop problem thinking skills as these skills are imperative for their future professional careers.

Along with this active engagement increased with a total amount of 22 % and successful completion of puzzles were between 69 -90 %. This proves that not only does the content improve their understanding, but it also evokes curiosity and active participation, not as a "need" of completion, but due to a "want" of completion; to ultimately reach the so-called "Eureka" factor associated with PBL.

Future studies on the various types of puzzles, and which are most useful in the health science professions would allow further assessment of student performance and skills development over various studies of interest.

DECLARATIONS

ABBREVIATIONS

PBL – Puzzle based learning

LMS: Learning Management system

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

All methods were performed in accordance with the relevant guidelines and regulations for BMC Education

All students have signed informed consent and the research article had Ethics approval from the Institutional committee and Ethics Health Science committee.

Ethics nr: 165/2020

CONSENT FOR PUBLICATION

I, the main author of the research article provide consent for publication

AVAILABILITY OF DATA AND MATERIAL

Data and materials during data collection and application are available upon request

The main author can be contacted as Kathryn Malherbe at: Kathryn.malherbe@up.ac.za or +27716732188

COMPETING INTERESTS

No competing interests

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AUTHORS' CONTRIBUTIONS

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