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Thinking in Possibilities: Unleashing Cognitive Creativity Through Assessment in a Problem-Based Learning Environment

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ABSTRACT

This paper addresses the way in which students' cognitive creativity and the construction of meaning could be fostered by means of assessment in a Problem-based learning programme. We propose that a dual assessment structure within such a programme through examinations and coursework assignments could ensure the acquisition of a foundational knowledge base while allowing the development of the cognitive creative process. Using a Dutch University as a case study, including its assessment philosophy and practice, we describe and tentatively support by means of some preliminary results how assessment can foster construction of meaning. The paper closes on suggestions for practice in fostering cognitive creativity through assessment in Problem-based learning programmes.

Keywords: Problem-based learning, assessment, cognitive creativity

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The need to educate individuals to be "creative" and "innovative" workers has been a pressing issue on the agenda of education policy-makers for some fifteen years, as evidenced by a number of reports and papers on the topic published since the mid-1990s (Bélanger & Federighi, 2000; Centre for Educational Research and Innovation, 2008; National Advisory Committee on Creative and Cultural Education, 1999). In recent years, the idea that creativity should be an integral part of our education systems has been eloquently championed by the likes of Robinson in his TED conference talk of 2006. He refers to a form of creativity that is innate in children, which he calls "divergent thinking", defined as the ability to multiple find novel solutions to given problems. He argues that young children possess this capacity to a greater extent than educated adults, and blames the industrial revolution era standardization of basic education for the decrease in divergent thinking capabilities in young adults. However, in spite of the proliferation of enthusiastic advocacy on the topic, the debate on creativity has been somewhat challenged by scholars' struggle to clearly define the concept.

Despite the vast scope of publications on Problem-based learning (PBL) in all of its aspects (e.g., Albanese & Mitchell, 1993), discussions on PBL and the creative process have been subdued in the literature, particularly from the perspective of cognitive psychology. Equally, little has been said about the role of assessment, particularly in higher education, in fostering creativity. Perhaps this scarcity can be correlated with the challenges in defining the term.

Given the limited literature on the role of assessment in fostering creativity, especially in a PBL environment, building an assessment policy aimed at encouraging creativity requires some creative interpretation of its own, which this paper endeavours to share. The paper, therefore, aims to contribute to the PBL literature by (a) providing arguments for the importance of fostering (cognitive) creativity in higher education as a gateway to the sort of ill-defined professions and the skills needed for the 'knowledge economy', (b) synthesizing theory and exemplifying them through sharing practical experiences on the role of assessment in fostering creativity, and (c) suggesting implications for building an assessment policy in higher education that acknowledges the importance of creativity. Specifically, using Erasmus University College (EUC) in Rotterdam as a case study which combines the pedagogical method of PBL with the content of a Liberal Arts and Science program (Servant, Frens, & Schmidt, 2013), this paper shall describe and analyze the assessment philosophy and practice of EUC in the light of our theoretical discussion to propose implications for further theoretical developments and practice on creativity in assessment.

CREATIVITY, ASSESSMENT AND PROBLEM-BASED LEARNING

Creativity in an Educational Context

Although the word "creativity" has been brandished by education ministers around the world, psychologists still do not understand much about the mechanisms of creativity. It has been determined that the type of mental process that accompanies creative thinking is different to

that which accompanies deductive reasoning (Gray, 2011), but how exactly remains uncertain. In a sense, we are only able to observe the effects of creativity, rather than creativity itself. As Mumford aptly put in 1988: "A review of the extant literature [on creativity] leaves one feeling like Alice, who, upon reading 'Jabberwocky,' commented, 'Somehow it seems to fill my head with ideas – only I don't exactly know what they are' (p.27)". Since Guildford's (1950) pioneering work on creativity, some researchers in psychology and neuroscience have focused their research on uncovering the underlying mechanisms of "creativity", particularly in relation to "insight intelligence" (Jacobs & Dominowski, 1981) and "divergent thinking" (Runco, 1991). Cognitive psychology hypothesizes that the creative process is linked to the activation of a wide range of memories (Gabora, 2002). By a sort of weeding process that discards irrelevant associations and keeps those that serve the purpose of an idea (solving a problem, writing a sonnet, composing a song…); this thought becomes increasingly focused until a new solution is formed. Thus, creativity requires the dual capacity to start with a wide activation function (or area of memory that is activated), and to focus this sufficiently to produce a useable idea in the end.

The role of creativity in learning has been most often connected to problem-solving activities, meaning that creativity is measured by a students' ability to approach problems in a novel way (Fasko, 2001). Runco (2003) defined creativity as follows:

> Creativity can be defined in very literal terms. The basic idea is that any thinking or problem solving that involves the construction of new meaning is creative. (…). Equally significant is the premise that creativity is widely distributed. A wide distribution is implied because virtually every individual has the mental capacity to construct personal interpretations. (pp. 318-19)

We have adopted this definition for the purposes of this paper and refer to it as "cognitive creativity".

Creativity and PBL

The literature has demonstrated a link between PBL and an increase in intrinsic motivation in students (Hmelo-Silver, 2004; Noordzij & Wijnia, 2015; Norman & Schmidt, 1992). Runco and Chand (1995) developed a model of learning, which suggests a positive link between intrinsic motivation for a learning task and creative output in the learning process.

This suggests a potential link between PBL and creative output. And yet, despite this implicit correlation, the link between PBL and creativity has been rather more tacit in the literature. With a few exceptions (e.g., Seng, 2000) the general trend is to refer to problem-solving rather than cognitive creativity in PBL courses, as such creativity is not considered one of the core aims of PBL, and has proven incredibly difficult to measure as an outcome of PBL

programmes. The systematic review of the literature on PBL and creativity offered by Tan, Chye and Teo (2009) serves to further confirm this point – they conclude that:

"Despite the strong interest generated in PBL as a means to cultivate creativity and its sound theoretical rationale, it appears that systematic evidence is scarce and a conclusive answer elusive. There is very little solid empirical evidence supported by a diverse range of high-quality studies that points to the effectiveness of PBL in fostering creativity." (p.30)

One suspects that at the heart of this failure to measure the impact of PBL on creativity lies the above-mentioned challenge of defining creativity. Whilst this paper has chosen to focus on the neuro-scientific and cognitive-psychological definitions of creativity, Tan et al. (2009) chose to include other variants such as the socio-psychological and the psychodynamic models of creativity, which simultaneously broadens the scope of the problem and muddies its waters. These interpretations tie into Freudian and social-constructivist sociological perspectives on the human mind, and while they are certainly interesting, the authors felt that such psychoanalytical and sociological approaches would derail this paper from its primary purpose. In addition, the psychoanalytic and sociological approaches are substantially more difficult to evaluate empirically. Thus, from a cognitive-psychological standpoint, we can state that it is a specific feature of PBL that problems are ill-defined (Moust, Bouhuijs, & Schmidt, 2007), and thus offer a wide range of self-study possibilities. Hence, it is expected that students will come across a much wider range of materials than would be covered in a lecture-based course and thus acquire a much expanded activation function – which we have determined to be essential for creativity from a cognitive perspective.

Assessment and PBL

In contrast to the absence of discussion about the link between PBL and creativity in the literature, much has been written about assessment in PBL, even though the subject has always been something of a bone of contention among scholars and practitioners alike. Indeed, the Founding Fathers of McMaster University's PBL programme believed summative assessment to be detrimental to students' academic progress, relying instead on formative self, peer and tutor evaluation as the *modus operandi* of their self-directed learning programme (Spaulding, 1991). Neufeld and Barrows (1974) clearly attributed the responsibility for academic progress to the students and their tutor, rather than to the so-called unit planners. The criteria against which this progress should be measured remained fairly open. Barrows and Tamblyn (1980) proposed an analysis of all forms of assessment for medical education. In it, they rated multiple-choice questions, short answer questions, essay questions and oral examinations poorly, as they consisted mainly in "pure recall" and did not "correlate well with clinical reasoning skills" (p.116-118). The crux of these PBL pioneers' arguments was that written assessment formatted learning in such a way as to short-circuit students' natural curiosity and destroy their creative endeavor. However, as results of McMasters' students at the Licentiate of the Medical Council of Canada (the final authority of granting a license to

practice medicine) reached record highs (Norman, Neville, Blake, & Mueller, 2010), and as sister PBL school at Maastricht University developed its progress test (Van der Vleuten, Verwijnen, & Wijnen, 1996) the philosophy of assessment in PBL began to change, feeding into a scholarly discussion about the role of assessment in PBL.

There are essentially two questions that need to be answered about the role of assessment in PBL: what to test and how to test it? In answer to the first question, some authors, inspired by the work of Wijnen (1991), are of the school of thought that assessment should be about checking the validity of one's knowledge base as well as one's ability to apply this knowledge in the context of real life (Norman, 1991; Schmidt, Van der Molen, Te Winkel, & Wijnen, 2009). Others, Barrows and Tamblyn (1980) chiefs among them, believe that assessment in PBL should focus on process-oriented tasks (Swanson, Case, & Van der Vleuten, 1991), meaning that assessment should check that students know *how* rather than *what*. For example, in the case of medicine, this amounted to assessing the problem-solving process rather than the content of medicine, under the idea that the two were independent (e.g., Neufeld, Woodward, & McLeod, 1989).

In answer to the second question: *how to test*, the most radical innovation in assessing students in a PBL environment came from Maastricht University. The progress test was brought in to Maastricht's medical school to counter test-oriented learning associated with administering end of course examinations only (Muijtens & Wijnen, 2010). It consists in administering 250 multiple choice questions drawn from a bank which covers the entire medical curriculum, four times a year, throughout a student's undergraduate programme starting in year 1 (Van der Vleuten et al., 1996). Initially, students are expected to score quite low on the test, but as their general knowledge and understanding increases over the years, scores increase proportionally. As such, there is no possibility of "learning for the test" – it serves more as a general indication of progress against which students can measure their chances of obtaining their degree. This innovation was perceived to be so successful that it was expanded to several Dutch medical schools, even to some that do not use PBL, and was introduced at McMaster in 1993 (Norman, Neville, Blake, & Mueller, 2010).

The academic debate in PBL on 'how to test' and 'what to test', provide PBL environments with directions for checking the validity of students' knowledge base as well as students' ability to apply this knowledge in the context of real life, but it does not address the assessment of creativity. Therefore, Erasmus University College has developed an assessment philosophy in which assessment is considered a balance point between academic rigour and increasingly demanding creative endeavour– a philosophy that EUC has coined as *Cogitans in Facultates*, or "Thinking in Possibilities".

THINKING IN POSSIBILITIES – EUC'S ASSESSMENT PHILOSOPHY

Erasmus University College opened its doors in September 2013 in the heart of the Dutch city of Rotterdam. Its programme shares the same basic philosophy as the six other undergraduate bachelor programmes in Liberal Arts and Sciences in the Netherlands (Tak & Oomen, 2012), namely the education of flexible, interdisciplinary workers with the generic skills needed for the 'knowledge economy' (Van der Wende, 2011). Behind this broad description lies a truly challenging interdisciplinary, problem-based three-year programme with a historically strong anchoring in the life sciences, humanities, social and behavioural science and economics, and a genuine connection with the community of Rotterdam (Servant et al., 2013).

With the support of a didactic expert and PBL tutors, the course coordinator composes the problem triggers and provides a list of recommended literature, although students are encouraged to read beyond what is given to them, and tend to do so readily. The learning objectives for each course are deliberately made broad and interdisciplinary to allow students some freedom in defining their learning objectives and handling learning resources. Since the goal of a Liberal Arts and Sciences programme is to get students to engage in the academic debate, assessment methods need to reflect this by offering students the possibility to demonstrate their abilities in applying knowledge and to argue their ideas in a social, scientific and political context.

Students have at least two assessments for each course – firstly, a written examination, which we call the *Foundational Piece* and secondly, a coursework assignment, either written or oral, which we call the *Creative Piece*. A series of smaller assignments, such as essay outlines, on-the-ground research and literature reviews, are given throughout the course and build up to the Creative Piece. These smaller assignments are evaluated by the tutors, under the guidance of the course instructor, and used as constructive feedback by the students. It was decided to leave this role to the tutors as they are in the most convenient position to interact directly with the students throughout the course, and thus to evaluate students' work in the context of the topics covered in the PBL groups. Although we have labelled these forms of assessment *Foundational* and *Creative*, it would be erroneous to deduce that there is no place for creativity in the former and for rigour in the latter. If we could picture a spectrum of assessment philosophy ranging from multiple-choice questions with strictly defined, closed answers on the one end and open-ended questions with no mandatory content at the other end, EUC would place itself in the middle of this spectrum to ensure that students produce creative work while still maintaining high standards of academic rigour.

FOUNDATIONAL PIECE: WRITTEN END OF COURSE ASSESSMENTS AT EUC

Written exams at Erasmus University College represent one side of EUC's *Thinking in Possibilities* philosophy. Written exams aim to ensure that students have acquired the foundational knowledge required for any creative endeavour in the field of study at play. Therefore, the written exams are divided into three parts that reflect a progressive build-up from basic understanding to creative argumentation: foundational knowledge questions, application questions, and constructive argument questions.

Part 1: Foundational Knowledge Questions

Erasmus University College has clearly sided with the view that assessment in a PBL environment should also evaluate knowledge (see Figure 1, question 'a' for an example). Thinking in possibilities means that in order to enable any academic endeavour – creative or other – students must have acquired a base of readily available knowledge. That is, codified concepts that form part of the recognized body of scientific knowledge of one or more disciplines. This foundation acts as the fuel for argumentation, the pigment for the creative canvass of student work. In essence, EUC's approach to education requires students to understand, own, and appropriately and comfortably use the concepts and language of a field of study and the disciplines it contains. This is a *sine qua non* condition of their ability to evolve in that field. These concepts are picked up during the PBL meetings and lectures that accompany the course. We have seen that creativity requires a large activation function, and the breadth and depth of the topics covered in the course and the students' self-study aim to provide just this. Testing a students' grasp of said topics requires the crafting of questions where the understanding of these basic concepts can be demonstrated. Furthermore, knowledge questions serve as a form of priming for the more advanced application and constructive arguments questions. Both questions and answers tend to be standardized, simply because the knowledge assessed here is reproductive rather than creative. However, EUC does not use the progress test (Van der Vleuten et al., 1996) for testing these basic concepts. Firstly, the restrictions of testing a single knowledge-base throughout an entire programme by means of the progress test are ill-suited to a programme which aims to build up knowledge in increasing levels of understanding, and therefore difficulty. Secondly, EUC students are not expected to become experts in a field of study, but like an explorer venturing into a new city, they need to understand its contours, landmarks and most important idioms to get around.

Part 2: Application Questions

Having established a students' ability to navigate around relevant disciplines – or not – the second component of the written examination is constructed around the application of abstract concepts to concrete examples (see Figure 1, question 'c' for an example). This mode of assessment builds onto the foundations evaluated in Part 1. A solid understanding of the foundational knowledge is a necessary condition of a successful undertaking of application

questions. To take up our explorer metaphor once again, now our adventurer has understood the lay of the land and can place the landmarks on a map, it is time to verify that he is actually capable of navigating from A to B, thrown in the hustle and bustle of a real city centre! The written exam will depict situations that closely resemble those seen during PBL meetings, similar enough to trigger the use of appropriate disciplinary tools, yet not identical enough to be a simple case of repetition. In order to score highly, the disciplinary knowledge that the student chooses to apply must flow logically from the case presented in the exam question. It must be convincingly argued and relate to the disciplinary concepts uncovered in the PBL meetings. During PBL meetings, the student-chair, guided by the tutor, will often ask students to conceive of different situations in which the concepts could be applied – thus fostering this sort of thinking process as an on-going part of the curriculum.

Part 3: Constructive Argument Questions

The acquisition of the foundational knowledge of a group of disciplines and the ability to apply this to exemplary, realistic and/or imaginary situations constitute the chief purpose of written examinations at EUC and thus account for the majority of the possible score on these. In addition, there is a third component which, more than any of the others, constitutes the essence of *Cogitans in Facultates*: in the final section of the written exam, students must creatively and logically construct an argument on the basis of a realistic but hypothetical situation (see Figure 1, question 'd' for an example), using the methodological tools of the discipline studied. These situations will usually be of social or political relevance, and require students to imagine themselves in a specific role or to come up with suggestions and arguments relating to the situation depicted in the exam question. To return once more to our explorer, the student now finds himself in unchartered territory, and, using the tools and maps he already possesses, must convincingly map out this new terrain. The metaphor is not that far-fetched, in that these questions are dubbed "exploratory" or "open", and thus genuinely conveys a sense of discovery.

Students first read an article from The Guardian, from the 16 February 2014 about the wake-up call on climate change by Miliband. After that four questions need to be answered:

a. What is hybrid management? (*Foundational Knowledge Question*)

b. What types of hybrid management does Labour leader Miliband refer to in his wake-up call? Give an example of each type, using quotes from the newspaper article. *(Foundational Knowledge and Application Question)*

c. Many governments around the world—especially the USA—have argued that the evidence for climate change and the role of human intervention in this is actually still uncertain. Argue how it can be that such opposing views still exist, paying special attention to the notion of uncertainty and how this affects the relation between science and policy. (*Application Question*)

d. Argue what strategies could be used to come out of the deadlock of scientific controversy and political conflict over the issue of global climate change. Describe two possible strategies. (*Constructive Argument Question*)

e. Use a maximum of 700 words for this questions: 100 for a, and 200 each for b, c and d.

Maximum of 14 points: 2 for a, 4 for b, 4 for c, and 4 for d

Figure 1. Example of an argumentative open-ended question from the first year course 'Science, Technology & Society'

Although students do have some freedom to choose the direction in which they want to explore the topic, to score well, they must do so within the structures of academic argumentation, and appropriately utilizing the tools of the various disciplines they wish to call upon. In this part of the exam, extensive self-study for the PBL problems during the course will prove invaluable to argumentation, providing a plethora of examples and evidence to feed their arguments. Gabora's (2002) exposé on the underlying mechanisms of creativity imply that well-read students should be able to better catch the breadth and depth of a discipline and use their knowledge in new situation.

To sum up, in EUC's PBL programme, written examinations are not monolithic repetition engines as they may be in more classic programmes. Building on the diverse foundations of the disciplines covered by each course, they allow students to demonstrate their understanding of the real-world applicability of abstract concepts – and furthermore, to creatively chisel out their own arguments using the tools of the trade. In the third part of the exam, we aim to give students the opportunity to show us what they are capable of, to challenge them to venture at the edge of their knowledge, to take the next little step into further understanding by experimenting. This is, in the end, what will distinguish between the abilities of students and justify the difference in scoring.

CREATIVE PIECE: OTHER COURSEWORK AT EUC

Coursework, either written or oral, represents the second side of EUC's *Thinking in Possibilities* philosophy. Unlike written exams, coursework pieces are prepared at home throughout the course. These assignments assume that students have acquired the foundational knowledge of the relevant disciplines during the PBL meetings and self-study, and therefore aim for a creative application of the course's methods and concepts to situations of a students' choosing. Here, they can demonstrate that they can play with the materials of the course, following their own interest beyond the point where the discussions in the PBL meetings stop.

FROM PBL PROBLEMS TO CREATIVE ESSAYS

In most cases, students submit a topic of their choice for their paper or presentation, within the range of themes of the course. Since the courses tend to be broad and interdisciplinary, the choice of topics is also extensive. The PBL problems provide leads, which students can follow. When students feel that they resonate with a particular topic and would like to

discover more than PBL self-study will allow, they are encouraged to submit this as an essay or presentation option to their tutor. The debates that go on in the reporting phase provide the student with possible lines of inquiry. In that sense, although the specific assignment topics are self-chosen, they fit with the themes discussed in the PBL meetings.

The composition of an essay or a presentation is done in three stages: 1) Students submit a research question or essay topic; 2) Students submit an outline and a literature review, with one or two difficult arguments developed more fully and 3) Students submit the final paper (between 1500-2500 words, depending on the course) or presentation slides. The tutors guide the students throughout the process. The idea is that giving time and feedback between various instalments of the essay or presentation will provide fertile ground for "insight intelligence" (Jacobs & Dominowski, 1981) to operate. Students are expected to follow the standard rules of academic writing and presentation to structure their work in a coherent and logical fashion, and to provide evidence for all arguments. Once these criteria are met, however, they are free to unleash their creativity on the topic of their choice. All assignments award points for creativity – between 5% and 20% of the entire mark – so as to encourage students to come up with daring arguments and challenging topics. The criteria for what constitutes creativity are decided upon by a combination of the tutors, the course coordinator and EUC's didactic experts prior to the beginning of the course. The tutors then award points according to these criteria when they mark the essays. Points have generally rewarded a student's ability to go further than the material already covered in the PBL meetings, either by proposing a new approach, new insights, new material or connecting the topics of a course in a new way.

CREATIVITY IN ACTION: EUC'S "ORIGINS" COURSE

The following are three examples of student essays, which were handed in for the EUC's first year course entitled "Origins". The objective of the course was to give students a macro-view of history from the beginning of time to the present day, with an understanding of the inter-relatedness of modern occurrences with past, seemingly unrelated events. This approach to the origins of the world has been called "Big History" (Spier, 2010). The instructions were to choose a question of history, and explicitly link it to at least three of six "origins": the origin of the universe, the origin of the stars and the solar system, the origin of the Earth, the origin of Life, the origin of Humans and the origin of Civilization. The aim was to get students to think broadly about historical questions by placing them in the context of at least three different time scales.

Origins of the mayan civilization

One student chose to ask the question: "What are the origins of the Mayan Civilization and what were their concepts of time and space in relation to the origins of the Universe?" The

essay looks at the origins of the Mayan civilization from three perspectives: anthropological, following the migration of early humans to the American continent; historical, looking at the development of the Mayan civilization over time; and literary, describing the myths that the Mayans used to relate to the origin of the universe. As an example of "divergent thinking" (Runco, 1991), this student has decided to leave the "origin of the universe" until last, even though this was the first item covered in the PBL problems and is chronologically antecedent. The idea for this essay came to him during the course of the first problem, in which the PBL group discussed alternative views to the origins of the universe. He was particularly interested in the Aztec and Mayan legends, but there was no scope for expanding on this subject during the PBL meetings. Thus, he developed his interest and creativity in the end-of-course paper .

Origins of DNA

Another student chose to address the question: "is DNA a unique pre-condition for life?" – In her essay, she chose to contrast the biological importance of DNA in the origins and evolution of life and humans with civilization's long road to understanding heredity, from the ancient Greeks to the discovery of the sequencing of the human genome. The essay offered a strong grounding in biology, placed in the context of a historical study. The ideas for this essay developed after the problem on the origins of life. The "aha" moment came when the student discussed the topic in the PBL group and the tutor asked if she had considered the possibility of creating life out of silicone instead of carbon. Since the paper proposed some quite advanced ideas, subject-matter experts were called in to assist the tutor in evaluating the merit of some of the biological arguments. This reflects a general understanding at EUC that we do not restrict students' creativity by our own limitations. If a tutor is not able to adequately assess a students' work because it goes into areas with which he or she is not familiar, there is always somebody within EUC's network who can assist.

Origins of scientific theories

One student chose to ask: "Is the process of entropy also occurring in the forming of new scientific theories?" This was one of the more challenging pieces in its ambition to transpose a difficult concept of theoretical physics into a philosophical context. Indeed, this essay looked at the evolution of theories of the origins of the universe from ancient astronomy to super-string theory, mapping their trajectory. It concluded that indeed, scientific theories are becoming more, not less disordered with time, despite attempts at unification, and therefore one could speak of "entropy" in the process of scientific enquiry. This student was particularly interested in the philosophy of science, and for almost every origin problem, brought to PBL meetings classic scientific and philosophical accounts, from Buffon, to Kant, to Laplace. Her argument was daring, and as such, the essay went through many drafts before reaching its final stage, but it exemplifies the creative possibilities allowed by this form of assignment, especially for freshmen students.

The common feature between these three assignments is that they all have grounding in the PBL problems that were offered during the course. These papers came from students' desires to go further into some aspects of the problems that they found particularly interesting. We have seen in our literature review that by their very nature, problems open-ended up a wide range of self-study possibilities – and this seems to be reflected in the breadth of the disciplines covered by the three papers. We have yet to test this empirically – and the review by Tan et al. (2009) has shown that this may be no mean feat – but our experience indicates that students feel a sense of ownership and pride when they discover aspects of a problem in a PBL meeting that other students did not encounter – these tend to be the topics that they choose for their essays.

Below are some preliminary indications of how our students fared in producing creative work, both through coursework, such as essays and presentations, and the constructive argument questions of the written examinations.

PRELIMINARY INDICATIONS

Although EUC is still a very young institution and this paper is conceptual in nature, rather than empirical, after EUC's first two academic years there are some preliminary indications of the beneficial effects of its assessment policy. Given its creativity-oriented assessment philosophy, EUC has translated this to regulations that state that in general a written exam (the *Foundational Piece*) should consists of 40% foundational knowledge questions, 40% application questions, and 20% constructive argument questions. For the coursework assignments (the *Creative Piece*), a variable part of the grading should be for creativity and/or constructive arguments, depending on the assignment.

As an overview, in EUC's eight first-year courses over two academic years, the exams assessed foundational knowledge, application of knowledge and constructive argumentation by means of open-ended questions or a combination of both open-ended and multiple choice questions. Exam questions were not always developed according to the 40% foundational knowledge – 40% applied knowledge - 20% constructive argumentation guideline, mainly due to the challenges of getting everybody on the same page in a start-up institution, but this tended to normalise as time went on. The content of a course was an important factor in allocating questions to the three categories and the choice of questions within each category. Indeed, it stands to reason that on the one hand, in a statistics exam which is almost exclusively based on foundational knowledge, this would be assessed by means of multiple-choice questions only, and on the other hand, the examination of a humanities course would stress applied knowledge and constructive argument questions evaluated by means of open-ended questions.

Although we have not conducted any formal qualitative studies on the subject, informal feedback sessions with first-year students about their experience with the exams have indicated that the fundamental knowledge questions are easier to them than the applied knowledge and constructive argument questions and this is also represented in their scores on the different questions. For example, in a Social and Behavioural Sciences course, students scored significantly higher on foundational knowledge questions (M = 77.4, SD = 15.4) compared with applied knowledge and constructive argument question (M = 57.3, SD = 13.8), t (100) = 13.6, $p < .01$. However, although more difficult and challenging, most students stated that they really enjoy the questions that enable them to demonstrate their understanding of the real world and crave building up their own arguments based on the knowledge and the skills derived during the different courses. This is indeed something that the tutors, course coordinators, and didactic experts at EUC have observed by looking at student results so far (although as stated, this is presently a mere observation that warrants further empirical research).

For the coursework assignments, in six out of the eight first-year courses students were required to hand in a paper or essay and in two course students were asked to give a presentation. For these coursework assignments, students' constructive argumentation and creativity could make up between eight and twenty per cent of their final grade. In line with the preliminary findings of the written exams, in general, students scored lower on this part of their coursework assignments compared to the other parts, such as structure, content, and presentation skills. For example, for the essay of the "Origins" course the score, in percentages, of students' creativity and constructive argumentation (M = 69.7, SD = 16.8) was significantly lower compared to their scores on the other parts of the essays or presentations, such as structure, content, writing skills or presentation skills (M =78.8, SD = 15.0), t (101) = 3.34, $p < .01$.

Having noticed the differences between the scores of the first-year students on foundational knowledge and skills and content on the one hand, and application and constructive argumentation on the other hand, it might be assumed that these differences should diminish when students develop their cognitive creativity in their second and third year at EUC. Further research should, therefore, address the improvement of cognitive creativity in PBL longitudinally by means of an empirical review of the results. In addition, by systematically interviewing students we would gain more insight into students' experience and evaluation of the dual assessment structure with its different levels of assessment.

IMPLICATIONS AND CONCLUSION

Firstly, one of the most challenging implications of the assessment of cognitive creativity in PBL is the alignment of course content and assessment. This means that topics addressed in

the assessment should allow students to apply the abstract concepts of the course topic to concrete examples and to logically construct arguments derived from the course topic to explain realistic situations. In addition, exam questions should depict situations similar to those experienced during the PBL meetings and in the problem triggers in order to help students to activate the relevant parts of their long-term memory. This has particularly important implications for course coordinators and developers, who should therefore develop the problem triggers of a course concomitantly with the course assessments and think of the two in an interrelated fashion rather than sequentially, or even separately. This does not mean that once designed, exam questions should be immovable: PBL always allows for the adjustment of exam questions based on students' reactions to PBL meetings, and their self-study. It does mean, however, that assessment must be considered as a pedagogical tool rather than a mere testing tool, and this idea must be thoroughly embedded in the structure of a PBL programme, including allocating the appropriate amounts of time for examination and coursework development.

Secondly, as we have seen, assessing cognitive creativity allows students to demonstrate what they have learned during their self-study and to take this one step further by making them apply it in new ways during the assessment, fostering their creative development. Another implication is, therefore, that it is important to adjust the assessment of creativity to the level of the student and to build it up in line with the development of students in their successive years.

However, even though this paper concerned itself with the case study of a university programme with entry-selection, constructive argumentation is by no means an elite skill that can only be acquired by students in the context of university education. Instead, it could be argued that all young adults, regardless of their educational background, need to develop this capability given the constantly changing professional and social environment we live in. This implies, therefore, that cognitive creativity should be an integral part of our educational system at all levels. As we have mentioned, developing constructive argumentation should be tailored to students' experience level within an educational programme (whether they be first or final year students), but also to the level of education more broadly across programmes, whether applied or theoretical, university or professional. This also implies that further research on this topic should go beyond university programmes and look at, for instance, polytechnic and applied sciences programmes as well as professional training courses that use PBL.

In conclusion, the authors feel that assessment is an important and often under-rated tool for promoting creativity, viewed from a cognitive-psychological standpoint, in a PBL programme. To do this, assessment must not be conceived as a monolithic knowledge-repetition machine, but as a rich pedagogical tool with three facets – foundational, applied and constructive – that need to be used appropriately to generate creative growth. We are hopeful

that the ideas proposed in this paper can provide some guidelines towards developing assessment policies in present and future PBL programmes, however, given the conceptual nature of our present argument, this leaves the door wide open for empirical studies to support the ideas put forward herewith.

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References:

Albanese, M. A., & Mitchell, S. (1993). Problem-based learning: A review of literature on its outcomes and implementation issues. *Academic Medicine*, *68*, 52-81.

Barrows, H. S., & Tamblyn, R.M (1980) *Problem-based learning, An approach to medical education*, New York: Springer.

Bélanger, P., & Federighi, P. (2000). *Unlocking people's creative forces*. Hamburg: UNESCO Institute for Education.

Centre for Educational Research and Innovation. (2008). *Innovating to learn, learning to innovate*. OECD Publishing. doi:10.1787/9789264047983-en

Fasko, D. (2001). Education and creativity. *Creativity Research Journal*, *13*(3-4), 317–327.

Gabora, L. (2002). *Cognitive mechanisms underlying the creative process*. Paper presented at the 4th conference of Creativity and Cognition, New York, USA: ACM Press. doi:10.1145/581710.581730

Gray, P. (2011). *Psychology*. New York: Worth Publishers.

Guilford, J.P. (1950) Creativity, *American Psychologist*, *5*(9), 444–454.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review*, *16*(3), 235–266.

Jacobs, M. K., & Dominowski, R. L. (1981). Learning to solve insight problems. *Bulletin of the Psychonomic Society*, *17*, 171–174.

Moust, J., Bouhuijs, P. & Schmidt, H. G. (2007). *Introduction to problem-based learning*. Groningen, the Netherlands: Wolters-Noordhoff.

Muijtjens, A., & Wijnen, W. (2010). Progress testing. In: Berkel, H. V., Scherpbier, A., Hillen, H. & Van der Vleuten, C. (Eds.). *Lessons from problem-based learning* (pp. 203-218). New York: Oxford University Press,.

Mumford, M. D., & Gustafson, S. B. (1988). Creativity syndrome: Integration, application, and innovation. *Psychological Bulletin*, *103*(1), 27.

National Advisory Committee on Creative and Cultural Education. (1999). *All Our Futures: Creativity, Culture and Education*. London: DFEE

Neufeld, V. R, & Barrows, H. S. (1974). The "McMaster Philosophy": An Approach to Medical Education. *Journal of Medical Education*, *49*, 1040–1050.

Neufeld, V. R., Woodward, C. A., & MacLeod, S. M. (1989). The McMaster MD program: a case study of renewal in medical education. *Academic Medicine, 64*(8), 423–431.

Noordzij, G, & Wijnia, L. (2015). *Quality of problems in problem-based learning and their role in the association between achievement goal orientation and motivation.* Manuscript submitted for publication.

Norman, G. R. (1991). Assessment in problem-based learning. In: Boud, D. & Felleti, G. (Eds.). *The challenge of problem-based learning* (263-268). New York: St Martin's Press.

Norman, G., & Schmidt, H. G. (1992). The psychological basis of problem-based learning: a review of the evidence. *Academic Medicine*, *67*(9), 557–565.

Norman, G. R., Neville, A., Blake, J. M., & Mueller, B. (2010). Assessment steers learning down the right road: Impact of progress testing on licensing examination performance. *Medical Teacher*, *32*(6), 496–499. doi:10.3109/0142159X.2010.486063

Robinson, K. (2006) *Ken Robinson: How Schools Kill Creativity*. Retrieved from: http://www.ted.com/talks/ken_robinson_says_schools_kill_creativity.html

Runco, M. A. (1991) *Divergent thinking*. Norwood, N.J.: Ablex Publishing Cooperation.

Runco, M. A., & Chand, I. (1995). Cognition and creativity. *Educational Psychology Review*, *7*(3), 243–267. doi:10.1007/BF02213373

Runco, M. A. (2003) Education for Creative Potential. *Scandinavian Journal of Education Research*, *47*(3), 317-324. doi: 10.1080/0031383032000079272

Schmidt, H. G., Van der Molen, H., Te Winkel, W. W., & Wijnen, W. H., (2009). Constructivist, Problem-Based Learning Does Work: A Meta-Analysis of Curricular Comparisons Involving a Single Medical School. *Educational Psychologist*, *44*(4), 227–249. doi:10.1080/00461520903213592

Seng, T. O. (2000). Thinking skills, creativity and problem-based learning. In: Seng, T. O., Little, P., Yin, H. S., & J. Conway (Eds.), *Problem-based learning: educational innovation across disciplines* (pp. 47-56). Singapore: Temasek Centre for Problem-based learning.

Servant, V. F. C., Frens, M. A. & Schmidt, H. G. (2013, August). *Problem Based Learning in the Liberal Arts and Science Context Striking a Balance Between Academic Excellence and Freedom of Inquiry.* Paper presented at *EAIR 35th Annual Forum*. Rotterdam, the Netherlands.

Spaulding, W. B. (1991). *Revitalizing Medical Education, McMaster Medical School the Early Years 1965-1974*. Hamilton, ON: B.C. Decker Inc.

Spier, F. (2010). *Big history and the future of humanity*. Chichester, U.K.: Wiley-Blackwell.

Swanson, D., Case, S., & Van der Vleuten, C. P. M. (1991). Strategies for student assessment. In: D. Boud, & G. Felleti (Eds.), *The challenge of problem-based learning* (pp. 269-282). New York: St Martin's Press.

Tak, H., & Oomen, B. (2012). *De disciplines voorbij: de colleges van Hans Adriaansens* [*Beyond disciplinarity: lectures by Hans Adriaansen*] (pp. 9-20). Middelburg, The Netherlands: Roosevelt Academy.

Tan, O.S., Chye, S. & Teo, C.T. (2009). Problem Based Learning and creativity: A review of the literature. In: O.S. Tan (Ed.), *Problem Based Learning and Creativity* (pp.15-38). Singapore: Engage Learning.

Van der Vleuten, C. P. M., Verwijnen, G. M., & Wijnen, W. H. F. W. (1996). Fifteen years of experience with progress testing in a problem-based learning curriculum. *Medical Teacher, 18*, 103-110.

Van der Wende, M. (2011). The Emergence of Liberal Arts and Sciences Education in Europe: A Comparative Perspective. *Higher Education Policy*, *24*(2), 233–253.

Wijnen, W. H. F. W. (1991) The rationale of a school-based centralized examination system. In A. J. M. Luyten (Ed.), *Issues in Public Examinations* (pp. 149-160). Utrecht, The Netherlands: Lem