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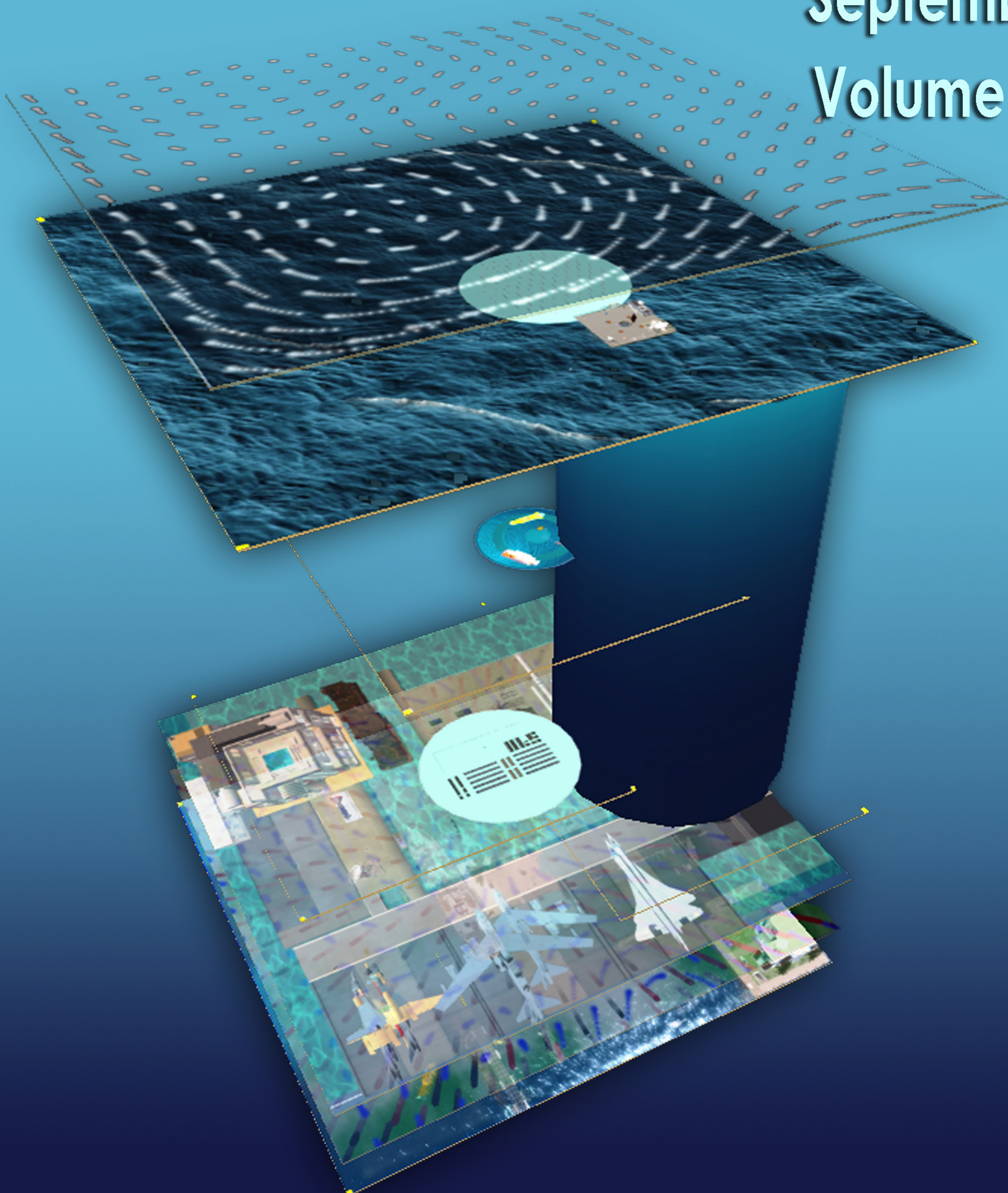

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Assessment and Learning in the Virtual World: Tasks, Taxonomies and Teaching For Real

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Abstract

Many educational institutions make use of assessment schemes based on an ordered hierarchy of cognitive activity, where the judgments of educators on the learning progress of students are expressed using marks or grades. These have high face-validity because they appear to represent intuitively sound descriptions of learning development. The language found in many such assessment structures and their protocols reflects the hierarchy within a revised Bloom's Taxonomy where, in the cognitive domain, evaluation and synthesis is regarded as superior to analysis or application, which are themselves rewarded above memory or understanding. Virtual worlds provide an opportunity to explore new educational contexts for analyzing and measuring cognitive processes that support learning. The present research used the *Second Life* virtual world as a medium for remotely located students to communicate in the collaborative construction and programming of robots. Iterative tasks were used to explore several neo-Bloomian cognitive processes and knowledge dimensions. Analysis of 60 hours of video from classroom activity, transcribed data and in-world interaction suggests that the hierarchy of descriptors and associated ratings that are used within assessment schemes based on neo-Bloomian taxonomies may not accurately correspond to the 'higher order' cognitive ability development of students.

1. Introduction

The informed use of technology within education tends to occur in distinct phases (Baker, Gearhart and Herman, 1993) and the uptake in the use of virtual worlds appears to mirror this. In the early phase of adoption practitioners often seek to create engaging experiences in new learning environments by replicating familiar real world buildings and institutions such as lecture classrooms, libraries and universities (Jennings and Collins, 2008) together with their established approaches to the learning experience. The transposition of existing practice into these virtual world environments may not be successful and does not always exploit their unique features, or the opportunities they present for communication and collaborative learning in meaningful ways (Martin, Vallance, Wiz and van Schaik, 2010).

However, with a more considered approach purpose-built, virtual educational environments can provide opportunities which lead to learning. Neo-Vygotskian social-constructivism argues that learning is a ‘‘process whereby knowledge is created through the transformation of experience” (Kolb, 1984, p. 41) and that this creation of knowledge requires learners to be actively engaged as participants in the process of learning. Within the context of virtual world opportunities, Mayes and de Freitas (2007) propose that this engagement is characterized by a cycle of *situative learning* (where learners form communities of practice), *cognitive learning* (where they build upon their experience, reflection, experimentation and abstraction), and *associative learning* (encouraging feedback and transfer). de Freitas and Neumann (2009) refer to Dewey’s concept of inquiry (pre-reflection, reflection, and post-reflection) to propose that learners’ virtual experiences, their use of multiple media, the transactions and activities between peers, and the facilitation of learner control will between them lead to ‘transactional learning’. Their Explanatory Learning Model “aims to support deeper reflection upon the practices of learning and teaching” which, they argue, leads to “wider opportunities for experiential learning” (*ibid* p.346).

Recent studies suggest that this approach has merit. Hobbs, Brown, and Gordon (2006) studied students’ interactions within the *Second Life* (SL) virtual world while completing a series of complex, open-ended tasks and found that, ‘‘with careful planning the intrinsic properties of the virtual world can inform transferable skills and provide a rich case study for learning” (p. 9). These conclusions are supported by Jarmon, Traphagan, Mayrath and Trivedi’s (2009) study, which used a mixed methods approach to demonstrate the effectiveness of *Second Life* in a project-based experiential learning setting where students learned by doing and then applied ‘virtually’ learned concepts to the physical world. Reliable and accurate metrics are needed for evaluating learning experiences in virtual worlds and for assessing the associated cognitive development of learners if these technologies are to become an effective resource for educators: “In order to achieve this next step two related aspects are required: the first is developing better metrics for evaluating virtual world learning experiences, and the second is developing better techniques for creating virtual learning experiences (e.g. frameworks, approaches and models)” (de Freitas, 2008, p.11).

As virtual spaces seem likely to become more commonly used for learning and teaching in mainstream Higher Education, either through growth in the use of immersive virtual environments or simply as a result of the development and spread of the 3D-internet, educators will need to be more informed of the benefits and limitations for learning, teaching and assessment within these spaces. This is important as educators across educational sectors seek to develop learning and teaching resources that more effectively enable the achievement of the learning outcomes specified within the assessment schemes that are applied to evaluating students' work.

Our design is intended to promote this by studying how students managed the transfer of their learning, reflection and conceptualizing from virtual to physical world and how their communication mediated the development of their knowledge and understanding. This research is designed to inform the design of tasks in virtual worlds to successfully achieve desired objectives. The long-term aim of this experimental research is to provide educators with a framework of metrics that can be used when designing tasks and subsequently assessing learning outcomes of students when engaged in virtual worlds.

2. Background

For over sixty years Bloom's ideas provided a widely accepted taxonomy that allowed educators to visualize teaching objectives and perceived learning together with an associated notation, categorization and assessment of aims (Bloom, 1956; Anderson, Krathwohl, Airasian, Cruicshank, Mayer, Pintrich, Raths and Wittrock, 2001). In Bloom's taxonomy, a range of learning objectives were represented as cognitive functions (Anderson et al., 2001) that enabled learning to be understood as the "… recall or recognition of knowledge and the development of intellectual abilities and skills" (Bloom, 1956, p.7). The six categories associated with cognitive processes identified in the revised taxonomy are: remember, understand, apply, analyze, evaluate and create (Anderson et al, 2001). Verb subsets that can be associated with these cognitive processes are: (1) remember—recognize, recall; (2) understand—interpret, exemplify, classify, summarize, infer, compare, explain; (3) apply—execute, implement; (4) analyze—differentiate, organize, attribute; (5) evaluate—check, critique; and (6) create—generate, plan, produce. Underpinning the cognitive processes described by Bloom are four general types of knowledge that include: factual knowledge, conceptual knowledge, procedural knowledge and metacognitive knowledge (*ibid*). The strength of Bloom's revised taxonomy is that it provides a visualization of the relationship between cognitive processes and knowledge (see Table 1).

	Knowledge Domain			
Cognitive Process	Factual - knowledge of discrete, isolated, content elements	Conceptual - knowledge of more complex, organised forms such as classifications, categories, principles, generalizations, theories, models and structures	Procedural - knowledge of how to do something	Meta-cognitive - knowledge about cognition in general as well as awareness of and knowledge about one's own cognition
Remember - retrieve relevant information form long-term memory				

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Understand - construct meaning from instructional messages, including oral, written, and graphic communication				
Apply - carry out or use a procedure in a given situation				
Analyze - break material into constituent parts and determine how parts relate to one another and to an overall structure or purpose				
Evaluate - make judgments based on criteria and standards				
Create - put elements together to form a coherent or functional whole, reorganize elements into a new pattern or structure				

Table 1: Bloom's revised taxonomy grid

The language found in many commonly used assessment structures and marking schemes in Higher Education institutions reflects the implicit hierarchy within Bloom's revised Taxonomy where, in the cognitive domain, evaluation and synthesis are privileged and rewarded above analysis or application, which are themselves more esteemed than memory or understanding. Visible within such schemes is a tacit acceptance that the attainment of 'lower order' cognitive elements within the hierarchy, such as 'remembering' or 'understanding' is an essential precondition for intellectual progress towards the mastery of 'higher order' elements such as analysis, evaluation and creation. Student work which is mostly comprised of the remembering and understanding of knowledge (recalling facts, theories, procedures, etc.) is often labeled within such marking schemes as 'weak' or 'flawed and inaccurate' when demonstrated at a low level, when the percentage mark allocated is typically no more than about 39. As greater memory and understanding is demonstrated, such marking schemes tend to refer to the learning outcomes as being 'limited or insufficient' (marks are usually given between about 40-49), 'acceptable' (50-59), 'clear and analytical' (60-69), to 'excellent and critical' (70+). The award of marks in the higher ranges is often also differentiated by the degree to which excellent and critical understanding of areas of knowledge are seen to be characterized by being 'organized', 'systematic' or, at the highest level, 'complete'. Whilst the terminology varies somewhat from one institution or programme to another, the marking schemes and guidelines we have found exhibit a significant congruence with the revised Bloom's hierarchy of 'remember', 'understand', 'apply', 'analyze', 'evaluate' and 'create' (Anderson et al, 2001).

A similar structure of judgments is applied to the knowledge dimensions assessed in student work, where the ways in which knowledge and understanding may be displayed is classified by whether these are simply 'used' (factual), or are 'theorized' (conceptual or, depending on context, 'procedural') or, at the highest levels, whether they are presented in ways indicating that they are 'synthesized' (meta-cognitive). For example, we have found that assessment frameworks characterize a weak demonstration of understanding concepts as 'insufficient' (>39 %), whereas above this their 'integration and analysis' into the work is rewarded more highly (40-49% and often 50-59%). Beyond this students gain still higher marks for the integration and analysis of 'different' or 'diverse' concepts (60-69%) and the work for which the highest marks are given must 'synthesize and interpret' complex concepts (70+%).

Similarly, the use of argument and discussion is increasingly rewarded from its weakest expression, when it is found to be 'unclear' or 'unsourced' (>39%) or 'invalid' (40-49%), to when it is 'reasoned' and 'valid' (50-59%), 'rational' or 'logical' (60-69%), or evidenced by being 'sound', 'compelling' or at best 'original' (70+%). In the same way the use of analytical and research methods in student work may be judged to be 'narrow' or 'inappropriate (>39%), 'limited' or 'ineffective' (40-49%), 'adequate' (50-59%), 'effective' (60-69%), or 'very effective' or 'excellent' (70+%). The use of such language underscores an acceptance of Bloom's approach to the assessment of learning where cognitive forms and levels are conceived as organized into strata, where successful attainment in each is a prerequisite for progression to the one above it.

3. Methodology

It was decided to explore the degree to which activities in virtual worlds are likely to provoke behaviors which can be located within the neo-Bloomian taxonomy. The research project was conceived to facilitate an exploration of this by studying the communicative exchanges between, and within, teams during problem solving tasks. Closed and highly defined tasks seemed most likely to provide the necessary comparability and empirical data to determine the success of task completion. To satisfy these criteria, the programming of a robot to navigate mazes of varying complexity was adopted (Barker and

Ansorge, 2007). Our research was designed to observe students communicating in-world the programming of a robot to follow distinct maze which, in turn, results in tangible and quantifiably measured outcomes. The robot selected for the programming tasks was LEGO robot 8527 supported by the LEGO *Mindstorms* NXT software version 1.1. LEGO robot 8527 was adopted due to its simplicity and potential for sensors to be added as the research tasks developed. The instructions for the design of LEGO robot 8527 are available at http://preview.tinyurl.com/yfw75s2.

In order to establish objectives and a focus for measuring task success and learning, students were asked to prepare solutions to a number of pre-defined tasks of varying complexity set by the researchers. The tasks were to design two-dimensional mazes for their robot to successfully navigate from the start to completion in the physical and virtual (*Second Life*) environments. In order to quantify each task complexity the programming the LEGO robot required a determination of an action and a vector. Adopting Barker and Ansorge's (2007) approach, task complexity was calculated according to the number of sections that made up a given maze, where a section was defined as an element that was different in orientation (direction) to the preceding section. When a maze contained a larger number of elements than another maze, its complexity was deemed to be greater. Mazes with an equal number of sections were deemed to be of equal complexity. For example, a maze requiring five distinct maneuvers such as a forward move, a left turn, a forward move, a right turn and then a final forward move, was defined as a maze of complexity level five. Successfully navigating this maze would be no different in level of intrinsic difficulty to navigating a maze requiring a right turn, a forward move, a right turn, a forward move and then a left turn. Mazes with differing levels of complexity could therefore be provided for participants to facilitate true comparisons of like with like and to act as the problem specification dependent variable. The principles used for maze construction are set out in an earlier paper (Martin et al., 2010).

Once this virtual learning space had been built, sixteen (16) tasks were implemented: the initial seven (7) were utilized for practice; data was collected from the remaining nine (9). Each task in the sequence was designed to be more complex than its predecessor so as to challenge students to communicate a more demanding construction process in order to reach a successful outcome; that is, program a LEGO robot to follow a specified circuit of movements and turns. Communication between participants (in this case, N=8) was supported by the virtual world chat facility and the behaviour of participants' avatars in the environment. One team had to design a maze on the floor of their laboratory using adhesive tape. Next, the second team's task was to act as 'learners' and create a robot program (using the *MindStorms* software) to follow a maze that the other (teaching) team had designed. The learning team used the information provided in an attempt to solve the robot programming problem. The learning team's attempts to do this were then communicated back to the teaching team who, in turn, used their robot to run the program on the taped maze to establish its success. The teaching team was encouraged to offer feedback via the *Second Life* environment to the learning team when the robot executed an incorrect maneuver and in answer to questions from the learning team.

4. Results

Over sixty (60) hours of video of participants communicating in the real world was recorded. This data was transcribed and analyzed using *Transana* (http://www.transana.org/) and *TAMS Analyzer* (http://tamsys.sourceforge.net/) software. Screen captures of all actions in the virtual world were also recorded and aligned to the real world video data recordings. The coding for the analysis was based on the cognitive processes and knowledge dimensions featured in Bloom's revised taxonomy. Five independent coders pre-tested an initial subset of data using a randomly selected subsample of 10% of the transcripts as training material. Interpretations were revised where needed and pretesting continued until intra-team coding was consistent. A second randomly selected subsample was coded and the reliability of coding established by calculating the percentage of coding agreement. The process of selecting subsamples and coding was repeated until a 90% coding agreement was attained. Initial indications from our data suggest that the nature and defined difficulty of learning tasks can be used to create metrics for designing and evaluating learning scenarios in immersive virtual environments that can be articulated within Bloom's revised taxonomy and this is discussed below.

During the coding process associative verbs were used for each of the Cognitive Process and Knowledge Dimension taxonomic elements. For instance, the verbs of 'implementing', 'carrying out', 'using', 'executing', 'running', 'loading', 'playing', and 'operating' were associated with the cognitive dimension of *Apply*. 'Comparing', 'organizing', 'deconstructing', and 'attributing' were associated with cognitive dimension of *Analyze* and so on. Analysis of the transcripts determined which descriptor to assign, although the Knowledge Dimension proved challenging. To assign one of the taxonomic elements of Factual, Conceptual, Procedural or Meta-cognitive, the researchers used the *Transana* software to link to the specific portion of communication so that both the transcribed text and synchronized video could be compared. This method of combined data observation allowed for the analysis of the transcripts in context and produced more informed and accurate coding.

This process is illustrated below by way of an extract from Task 9. The 'student' participants are following instructions from the 'teacher' participants as they attempt to program the LEGO robot to move over an obstacle. In lines 274 to 279 the participants talk about the movement of the robot as a result of their programming. The participants are applying their programming knowledge to make the robot follow a particular route (procedural knowledge). In lines 280 to 284 the participants evaluate what happened. They notice that the robot did not move up an incline and over the obstacle but turned in another direction when it hit a ramp. In lines 285 to 290 the participants are taking about what happened and use analysis and reason (line 288: Well, the friction is smaller on the floor…) One participant accepts the analysis and offers a reasoned outcome (lines 289 and 290). At this point in coding, the transcript was hyperlinked to the video capture using the Transana software to confirm what was actually occurring in the lab. The video showed participants physically moving the robot and discussing the implications of their actions but indicated that they were doing more than just undertaking a procedure and were evaluating and analyzing what was happening and what may happen. The participants were demonstrating knowledge of the concepts involved in programming the robot in order to overcome an obstacle placed in its path.

273. THE ROBOT GOES.

274. {PROCEDURAL}{APPLY}

275. C: Oh, it's coming for me, now it's coming for you.

276. Y: Turn. Okay, go, all the way, all the way, all the way, all the way, go go go.

277. C: Fight.

278. Y: Then, after that reverse. And then.

279. G: More? {/APPLY}{/PROCEDURAL}

280. {CONCEPTUAL}{EVALUATE}

C: More for this, one direction.
G: It was just forward but it turns because it's pushing it,
it's okay, because once we get to about here, ask them to modify the image.
C: Yes. {/EVALUATE}{/CONCEPTUAL}
{CONCEPTUAL}{ANALYZE}
G: Sit in a line with where we are now.
C: Yes, but will it have enough power to do it more?
G: Well the friction is smaller on their floor, so I think this is a good first draft.
C: Okay, because if it is even a slight more,
then, then it will not move it. {/ANALYZE}{/CONCEPTUAL}

The video analysis and coding undertaken by the researchers was a Japan – UK transnational collaborative effort using Google Documents to share coded data files that were periodically viewed in a dynamic Motion Chart (Al-Aziz, Christou and Dinov, 2010). This representation of Cognitive Dimension metrics and Knowledge metrics over task time enabled a study of the effect of one cognitive process on a particular knowledge dimension, and attempts to draw conclusions from the task 'processes' rather than just the 'outcomes'.

As expected, the procedural knowledge employed by participants appeared unrelated to instances of 'remembering' and 'understanding' and was instead more frequently associated with 'applying' or 'evaluating' (Figure 1). Procedural knowledge was most commonly found when subjects were 'applying' or 'evaluating'. No consistent trend was found in the frequency with which instances of the cognitive descriptors appeared over time in the tasks (Figure 2). The relative frequency with which particular kinds of cognition appeared in the data (e.g. 'applying procedural knowledge') was not patterned as tasks progressed and difficulty increased. When reading in session order from bottom to top for 'applying procedural knowledge', for example, we find that it occurs as a percentage of the overall total for this across tasks (referred to as series in the Excel chart) - series 1 + series 2 + series 3, etc. - as 19.1%, 8%, 16.6%, 5%, 23.6%, 4%, 7%, 5.5% and 11.1% of the total (Figure 2*)*. Within the framework of our neo-Bloomian taxonomy, contrary to our expectations, no developmental trend appeared in the data as participants worked with tasks and applied procedural knowledge more effectively.

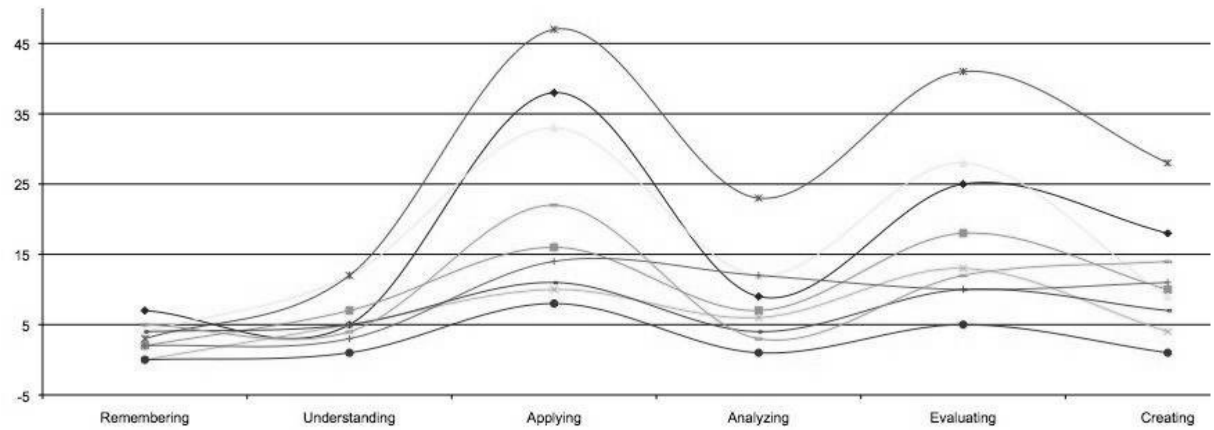

Figure 1: Cognitive descriptor occurrences in procedural knowledge domain

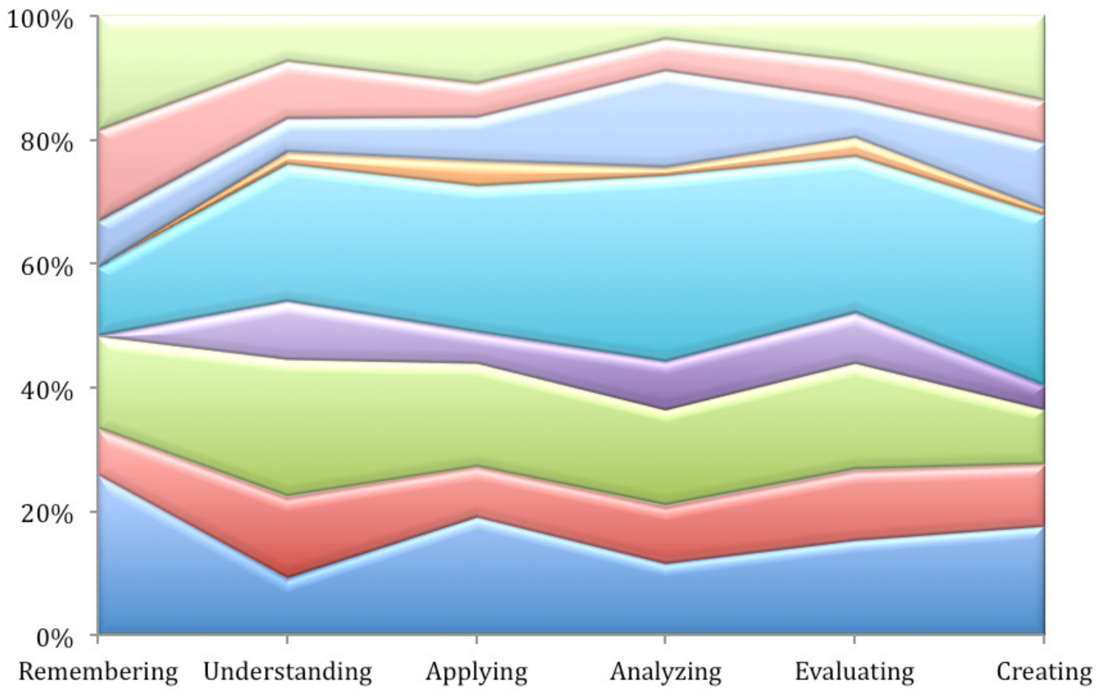

Figure 2: Cognitive descriptor occurrences in procedural knowledge domain, as a percentage per task (sequenced vertically)

As tasks followed each other over the experimental period, the observed cumulative frequency of 'conceptual' knowledge tended to increase for the dimensions of 'understanding', 'analyzing', and 'evaluating', although most intellectual activity appeared to have been directed towards originating, comprehending, understanding and developing knowledge, rather than to applying it. However, as with 'procedural' knowledge, the relative frequency with which the different elements of cognition appeared in the data (e.g. 'applying conceptual knowledge') did not present itself in a linear or rising trend or developmental sequence, but more often was discontinuous (Figure 3).

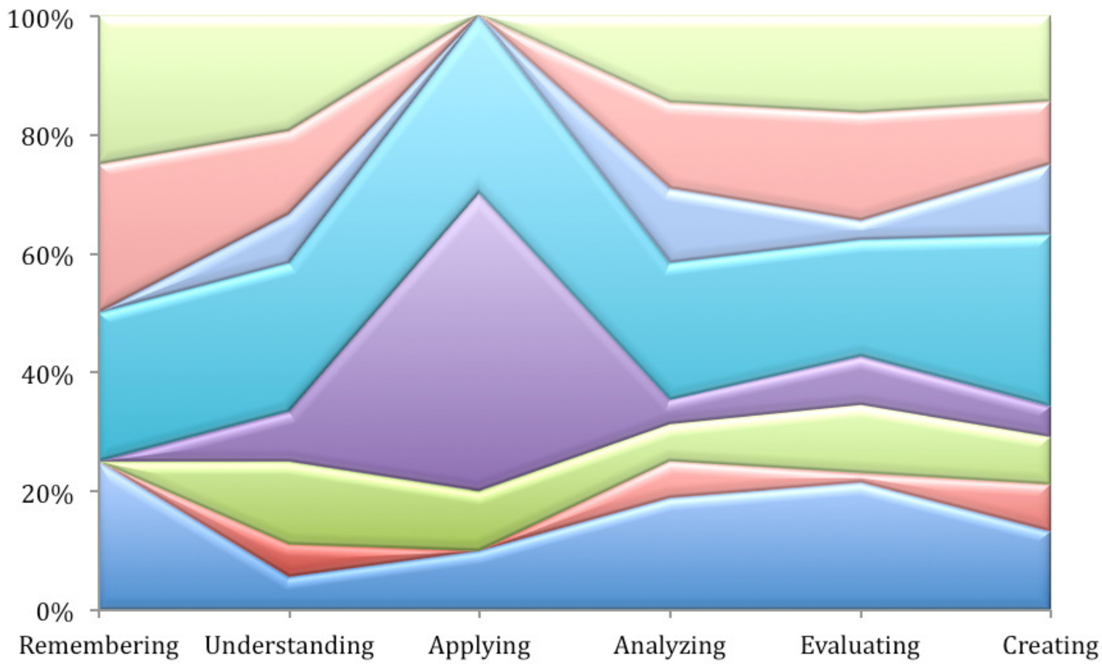

Figure 3: Cognitive descriptor occurrences in conceptual knowledge domain, as a percentage per task (sequenced vertically)

Although these outcomes are derived from tasks conducted within a virtual environment, the associated learning and communicative interaction between participants was conducted synchronously in the physical world, from which data were extracted and the coding and analysis conducted. It is the communicative interactions in the physical world that have been used as signifiers of the learning process and its associated outcomes are the focus of our analysis, in the same way as is applied by educators to more traditional encoded expressions of learning (written work, discussions, presentations, portfolios, etc.). Interactions within and outcomes from the learning tasks in the virtual world can be applied to (and have implications for) real world interactions and learning contexts. These outcomes appear to challenge the often held assumption within educational practice that a consistent and reliable proxy for increasing student mastery of cognitive skills is to be found in the outputs from assessment regimes derived from neo-Bloomian hierarchies. Such assumptions are particularly questionable where assessment schemes presume an ordered relationship between the indications of increasing intellectual competence that they appear to provide and the actual acquisition of increments in higher-order cognition by individuals. Our data suggests that the 'scores' (marks) derived from such assessment instruments are unlikely to correspond closely with the development of cognitive ability in an individual and that mastery of cognitive skills and processes may develop in a more a complex manner. Our data suggest this to be particularly so in the 'higher order' realms privileged in assessment schemes derived from Bloom's revised taxonomy.

5. Discussion

In the next section we will propose that the revealed dynamics between the neo-Bloomian taxonomic elements and the developed metrics may provide some insights into the nature of effective learning not only in virtual worlds but also educational environments in general.

It was not anticipated that communication between participants, during their learning, would display high frequencies of factual or meta-cognitive knowledge, because the nature of the tasks and participants' relative unfamiliarity with LEGO programming, made this seem unlikely; we anticipated that tasks would instead promote conceptual and procedural knowledge, particularly as challenge was increased over time.

There is widespread use by many educators of assessment schemes based on an ordered hierarchy of cognitive activity, where the judgments about the learning progress of students is commonly expressed in terms of percentage marks or ranked alphanumeric grades. Such schemes possess high face-validity because they appear to present common-sense descriptions of learning progression. Often they are implicitly and sometimes explicitly based on taxonomies of assessment identical or very similar to that developed by Bloom. However, Bloom's Taxonomy was never intended to be a theory 'of' learning but taxonomy 'for' learning, teaching and assessing and as such its primary purpose has always been to be a framework for "categorizing educational objectives" (Anderson et al, 2001, p.xxi). It does not therefore follow that Bloom's Taxonomy should be taken to imply that its structures represent a map of a smooth developmental sequence or process of the learning and mastery of particular cognitive skills and abilities.

However, experience suggests that educators tend to apply such frameworks as proxies for learning theory and assume that the ordered structures of cognitive elements within them accurately map the structure and sequence of cognitive development. This may raise expectations that learning will closely follow the hierarchy and associated educational objectives when these are used for the purposes of assessment.

6. Limitations

Our data shows that learning is not as structured or uniform as Bloom's revised taxonomy might be taken to suggest, and the continued use of these in this manner may act to limit an 'analysis of learning'. However, the rationale for continuing the study of its use is that at some point the outcomes from such work need to be applied in the learning contexts where tasks are frequently designed and assessed according to the taxonomy. It may also be helpful in such cases to broaden the taxonomy to include epistemic knowledge, particularly of those kinds that seem likely to offer wider applicability within taught curricula: such as is needed to create subject knowledge that is new to the individual and the knowledge that is required in order to be able to decide whether a proposition, argument or theory is valid. These kinds of epistemic knowledge would have applicability in communicative contexts beyond the focus of the present research into subjects such as history, geography, mathematics and the sciences. Our research aims to produce a framework of metrics for implementing tasks in virtual worlds that will meet specific learning or assessment criteria across a range of such subject contexts.

The manual coding of transcriptions from participant discussions used *TAMS Analyzer* and *Transana* software to alleviate errors in coding, but researchers nonetheless had to interpret and contextualize from 'chat' and video evidence. Linking transcripts to their associated videos allowed for more accurate interpretation and corroboration against Bloom's taxonomic elements. However, our analysis remains an interpretation, despite our procedures to enhance academic rigor, such as linking video to transcribed text and revisiting this to confirm the presence of specific taxonomic elements; and prior benchmarking to ensure high inter-rater reliability in coding. This process proved especially challenging when it came to distinguishing between Procedural and Conceptual knowledge and this underscored the value of using the augmented data observation approach described.

One approach we are developing to overcome the constraints of this second-hand interpretation allows participants to directly input taxonomic data. A virtual data collection tool (a 'BloomsPad') has been developed to allow specific taxonomic elements to be selected by participants at regular intervals in-world. This data is periodically transferred to an online database that records and time-stamps each instance. Data are automatically graphed after each task is completed in order to analyze the pattern of cognitive processes and knowledge dimensions indicated by participants. Subsequent tasks are matched to these data to offer appropriate opportunities for cognitive development, once participants are trained in and familiar with the lexis associated with each taxonomic element.

7. Conclusion

Many expect that collaboration in virtual spaces will become a more prominent feature of mainstream Higher Education, and this research aims to provide educators with a framework to support curriculum design, create effective tasks, and assess learning outcomes within such environments. By supplementing our existing data with improved technology we aim to further inform the creation of a robust and evidence-based framework for practitioners to implement tasks to achieve specific curriculum learning aims in virtual spaces. In working towards this we have used Bloom's revised taxonomy on the grounds that its conceptual structures and language are found in commonly used assessment schemes and marking guides in Higher Education and where, in the cognitive domain, evaluation and synthesis is privileged more than analysis or application and above memory or understanding. The present paper sets out the implementation of iterative and quantifiable tasks to delineate neo-Bloomian Cognitive Processes and Knowledge Dimensions. The observations from sixty hours of transcribed data and in-world communication suggest that the descriptors and associated scores derived from neo-Bloomian assessment schemes may not closely correspond to the development and mastery of cognitive ability, particularly so in their 'higher order' realms.

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