Improving the Student Experience of Learning and Teaching in Second Year Biochemistry: Assessment to Foster a Creative Application of Biochemical Concepts

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Abstract

Biochemistry is an inherently difficult, content-laden discipline that at times struggles to capture the imagination of students. In an attempt to improve engagement and performance in a second year Metabolism course, the implementation of a creative, multimedia based group project conducted. The project provides a creative outlet for students that supplements the didactic lecture content so commonly used in undergraduate biochemistry education. In completing the assessment task, students gained a deeper understanding of their chosen biochemical pathway and were provided with a range of presentations that neatly summarised the range of content considered fundamental to the understanding of metabolism. On the whole, students found this assessment task to be a useful learning and study tool that added a 'fun' dimension to the course. The current assessment concept, although directly relevant to the education of biochemists, could easily be translated to any subject where an emphasis is placed on the integration of multiple sets of information to achieve coherent understanding.

Introduction

It is well established that as a discipline, biochemistry is epistemologically difficult for students across the tertiary sector (Vella, 1990; Wood, 1990). By nature metabolism contains a significant number of biochemical pathways that are fundamental to a deeper understanding of the discipline, and which hare generally conveyed through didactic teaching methods (Meyer & Land, 2003). As a result, it is not surprising that students struggle to engage in learning metabolism and have difficulty finding an enduring relevance (Wood, 1990). While the traditional lecture may play an important role in biochemical education, a body of literature describes the benefits of alternate approaches that supplement the traditional lecture and improve retention of knowledge and engagement (Reviewed by Taylor & Parsons, 2011). In an attempt to increase engagement and facilitate a shared experience of learning in a second year undergraduate metabolism course, a creative, multimedia based group assignment was developed and implemented.

In the past, students have responded positively to the use of multimedia resources during lectures (Traver et al., 2001). As an extension, this piece of assessment encourages students to develop their own collection of multimedia resources. Positive uses of technology over the

past 30 years in the biochemistry classroom have led to the development of visualisation tools such as molecular models, metabolic maps, symbolic pathways and multimedia/graphical representations of pathways (Leader 1979; Wood, 1992; Torres, 1993; Patel & Shastri, 1996; Lightfoot & Steffen, 1997; Gobert & Clement, 1999; Schnotz & Lowe, 2003; McClean *et.al*., 2005; Machado *et. al*., 2013). However consideration is being given to a student's ability to interpret and synthesise the information presented in these media and the necessity for student to be taught to develop their visual literacy (Christopherson, 1997; Schonborn & Anderson, 2004, 2006; Herraez & Costa, 2013).

Schonborn and Anderson (2006) identified ten fundamental guidelines for the teaching and learning of visual literacy, and the current assessment task makes use of a number of these guidelines to encourage students to interpret multiple sources of content and synthesise the information gained into their own unique creative representation of biochemical theory (Gobert & Clement, 1999). It has been suggested that by constructing their own visual expressions of a biochemical pathway, students become more proficient at processing other abstract visual representations (Christopherson, 1997) that will assist them not only in their studies of biochemistry but to become better metacognitive thinkers (Grayson, 1995; Lowe, 2003).

The rationale for development of the creative task was to formulate an assessment item that encourages students to review complex biochemical theory and develop a multimedia summary that presents theory in a more manageable way. The task provides students with an opportunity to creatively explore fundamental biochemical concepts and encourages engagement, visual literacy, deeper understanding, peer collaboration and entertainment with an overall objective to improve learning outcomes for students. The aim of this study was to evaluate the effectiveness of the creative multimedia task in improving engagement and learning outcomes in second year biochemistry students.

Context

Metabolism (2011MSC) is a second semester second year prerequisite course for students undertaking degrees in Biomedical Science, Health Science, Medical Science, Biomolecular Science and Nutrition and Dietetics at Griffith University Gold Coast Campus. The subject is designed with four typically transmissive-style lectures per week, each of one hour duration and coupled with fortnightly laboratory sessions, each of three hours. The assessment strategy for the course was altered in a staged approach over three years from 2009 in an attempt to improve student learning, performance and engagement in the course with the creative group assignment first introduced in 2011. The described assessment innovation was supported as a Science and Mathematics Educators Network (SaMnet) Action Project in 2011.

The Assignment

This assessment task was designed to be a semester-long group based (5 students in each group) project worth 10% of the final grade for the course. The task involved the production of a 5 minute creative multimedia presentation that could take the form of a song, animation, movie/role play, integrated flow chart/concept map with explanations that was capable of being uploaded onto the course Blackboard site.

The assessment task was introduced to students in Week 1 of the semester, at which time the course convenor assisted with group formation. Each group was required to choose one topic from a list of 7 content areas (Table 1) that covered fundamental concepts/pathways of

biochemistry and which was mapped to clearly defined learning objectives for the course. Each content area was supported by a series of associated resources that briefly summarised the topic and provided links to lecture material, relevant sections of the text book and additional reference material from which students could draw.

Table 1: List of content areas and suggested topics for students undertaking the creative multimedia project as part of 2011MSC Metabolism.

Content area	Suggested topics
Stage one metabolism	• Digestion, absorption and transport of carbohydrates • Digestion, absorption and transport of protein • Digestion, absorption and transport of fats
Carbohydrate Metabolism	• Glycolysis • Gluconeogenesis • Glycogen synthesis • Glycogenolysis
Protein Metabolism	• Transamination • Deamination • Urea cycle • Ammonium relocation from tissues • Protein biosynthesis
Lipid Metabolism	• Beta oxidation • Fatty acid biosynthesis • Regulation of lipid metabolism • Cholesterol synthesis
Citric Acid Cycle	• Reactions of the citric acid cycle, • Glyoxylate pathway • Pentose phosphate pathway • Regulation of the citric acid cycle
Electron Transport Chain Oxidative Phosphorylation	• Reactions of the electron transport chain • ATP synthesis • Chemiosmotic theory • Regulation of electron transport and ATP synthesis • Effects of inhibitors and un-couplers
Integration of Metabolism	• Hormonal regulation of metabolism • Oxygen and metabolic regulation • Exercise Metabolism • Biosignaling

The assessment structure for the task consisted of a two-stage submission process with inter- and intra-group peer evaluation (Table 2). Students were required to submit an outline of their project by Week 7 that included a review of the relevant theory, plan of their presentation and list of contributions for each group member. The outline contributed 40% of their grade for the task and was reviewed by the assessment team, with detailed feedback provided to the groups in relation to the content and structure of their project. The final assessment component was submitted in Week 12 onto the course Blackboard site. Students were given one week to evaluate the projects produced by a minimum of 10 other groups

from the class using the *'Rate Post'* function on the Blackboard site. This component of peer review contributed a further 10% to the overall grade for the project. During this one-week period, the assessment team evaluated each project and assigned a grade for the final 50% of the project. The final component of the project assessment consisted of intergroup peer evaluation, whereby each member of a group assigned a participation percentage of 50%, 75% or 100%, the average of which was used to moderate the final grade assigned to each student for the project.

Table 2: Creative multimedia assessment task components, description and weighting.

	Overview of Assessment Component	**Weighting**
Part 1	Written overview and project plan • Overview of project theory • Plan of presentation • Contributions by each group member	40%
Part 2	5 minute digital media presentation Assessment team grading on the basis of • technical accuracy • entertainment value • usefulness as a learning tool.	50%
Peer Assessment	Whole class evaluation of individual group projects.	10%
Intragroup evaluation	Conducted by individuals in each group based on participation of group member with possible 50%, 75% or 100% contribution.	Average percentage contribution used to moderate final grade for individuals

A two-hour session was held in the final week (13) of teaching that was used to review and discuss the presentations as a class group. This session provided the class with an opportunity the observe examples of the 10 best presentations and for the course convenor to link the student presentations to the learning objectives and revision of the course.

Methods/Evaluation

To evaluate the effectiveness of the assessment task on student satisfaction and performance in the 2011 and 2012 cohorts, a number of evaluation measures were utilized. Both qualitative and quantitative evaluation data was gathered in relation to the creative assessment task and overall for the subject. Student performance data was collected for the creative assessment task for the years 2011 and 2012 and overall student performance in the subject was gathered for the years 2009-2012. All questionnaire data was coded for matching purposes and remained anonymous to all members of the teaching team. All performance data was de-identified prior to analysis.

Student satisfaction
The creative assessment task was evaluated in the final lecture of the 2011 and 2012 semester using a written questionnaire containing both qualitative and quantitative questions. Students rated the quantitative questions on a five-point Likert-type scale, from 1 (*never* or *only rarely* true of me) to 5 (always or almost always true for me). Qualitative questions were included to assess the usefulness of the assessment task in the students' learning process, the likelihood that students would utilize resources developed as part of the creative assignment for their study and overall engagement in and enjoyment of the subject.

Additionally, a formal student evaluation of the course (SEC) was conducted each semester on a University-wide basis and the data gathered in this process for the current course was analysed for the years 2010-2012. These evaluation questionnaires contain a standard array of questions delivered on a 5-point Likert scale; the relevant question used in this project evaluated engagement in the course "this course engaged me in learning". Prior to 2009, the SEC evaluation was conducted in a paper-based format with different questions, and as such was not used in the current analysis.

Student access to project presentations
Student access data for each group presentation was retrieved from the course Blackboard site. The total number of views for each presentation and number of views per student were obtained to track utilization of project presentations.

Student achievement
Performance in the creative task (2011, 2012) and overall achievement in the course (2009-2012) was analysed. To control for variation in cohorts between study years, student performance in the first semester biochemistry subject (Structural Biochemistry) was used as a comparison for the baseline achievement of the cohort. Successful completion of Structural Biochemistry is a prerequisite for progression to the second semester course and as such only results for those students enrolled in Metabolism were utilised.

Perceptions of group work
Student's perception of group work was assessed in both week 1 and week 13 in conjunction with the revised two-factor Study Process Questionnaire (R-SPQ-2F) developed by Biggs, Kembler, and Leung (2001). The question "I enjoy working in groups for assessment tasks" was measured on a 5-point Likert scale. Data collected for the 2011 cohort was unidentifiable, subsequent reevaluation in 2012 coded questionnaire data for matching purposes so changes in individual perception of group work could be measured.

Statistical analysis
All statistical analysis was conducted using *SPSS statistics* for Windows, Version 19, IBM Corp. Armonk, NY. with a P value less than 0.05 considered significant and all data is presented as mean ± standard deviation. Analysis of student performance data for the years 2007-2012 was conducted using unpaired t-tests and One Way ANOVA with Tukeys post-hoc comparisons as relevant. Evaluation of perceptions of group work data was conducted by paired t-test. Reliability analysis was performed on the creative assessment task and overall assessment strategy for the course using Cronbach's Alpha analysis.

Results

Student performance in the creative task was consistently high for both years of delivery, with mean scores of 8.81±1.10 (2011) and 8.85±1.17 (2012) for both iterations and a failure rate for the task of 2%. Cronbach's alpha analysis of the creative task generated reliability scores of 0.72 (2011) and 0.73 (2012) for the task and 0.875 for the entire course assessment strategy.

Quantitative evaluation of the creative project for 2011 and 2012 produced encouraging results (Table 3). An average of 85.5% of students responded positively to the question 'the creative group project helped me understand the theory of our project", with 77% finding the other group presentations useful and 80.9% finding the project useful as a tool for their learning.

Table 3: Results of quantitative evaluation of the creative group task performed in week 13 of semester for the 2011 (n=75) and 2012 (n=80) cohort. Data obtained from a 5-point Likert scale where 5 = strongly agree and 1 = strongly disagree. Data is presented as mean ± standard deviation with percentage positive responses in brackets

	2011	**2012**
The creative assignment helped me understand the theory of our project	3.63 ± 1.18 (84.2%)	3.76 ± 1.11 (86.7%)
The presentations produced by other groups will be useful for my study	3.37 ± 1.16 (76.0%)	3.63 ± 1.28 (78.7%)
I found the creative assignment useful to my learning	3.41 ± 1.19 (79.0%)	3.60 ± 1.22 (82.7%)

Further information regarding student engagement and benefit from the creative task may also be ascertained through consideration of the high level of student access to the individual projects loaded onto the course site (Table 4). A total of 12,349 (2011) and 16,790 (2012) student views were recorded for all projects with mean viewing numbers of 395.7 ± 116.4 (2011) and 442.2 ± 107.1 (2012) recorded for each project. As a requirement of the assessment, students were asked to view a minimum of 10 projects. Interestingly however, the average number of projects students watched far exceeded the minimum requirement with averages of 24.0 ± 6.36 (2011) and 26.5 ± 7.38 (2012) recorded and approximately 20% of each cohort viewing all the available projects. Ten projects were identified by the convenor as the highest quality of those submitted and presented in the final revision lecture. The average viewing rate for these presentations was 531.5 ± 63.86 and 566.8 ± 62.21 with viewing by approximately 95% of students from each cohort. Overall, students spent an average of approximately 7 hours watching the videos produced by their peers. The fact that all presentations were available for download from the course site may mean that these figures are an underestimation of the actual utilization of the projects.

Qualitative feedback obtained by questionnaire in the final lecture session was also largely positive and followed themes of; benefit for examination preparation; fun and engaging

activity; assisting understanding; supporting relevance. Representative comments are as follows:

Table 4: Record of student access to creative group projects from the 2011MSC Metabolism Blackboard site for years 2011 and 2012.

	2011	2012
Total number of projects	31	35
Total number of views	12,349	16,790
Number of views per student	79.6	95.9
Average number of projects viewed by each student	24.0 ± 6.36	26.5 ± 7.38
Average number of views for top 10 projects	531.5 ± 63.86	566.8 ± 62.21

"I think all of the group presentations are amazing! I'm finding them to be so useful in preparation for the end of semester exam. Love them!!"
"It was great to get to do something creative, and engage with the content in a deeper way."
"Helped me understand difficult concepts. I at least know one topic for the final exam inside out."
"It was fun and it reinforced the topic that we chose it also made it relevant to everyday life."
"We chose the electron transport chain and oxidative phosphorylation, It really helped me to learn it, I find it pretty easy to understand now."
"Alternate revision method, fun and easy way to procrastinate and actually learn something when studying for the exams."

Qualitative comments suggested that for the required input of time, this assessment task should have been ascribed a higher weighting for the overall subject and further, that specific time be timetabled for students to come together and work on the project, both of which are considerations for the future.

Although it was not possible to elucidate the exact effect of the creative task on student performance and engagement, both were significantly improved as a result of the diversified assessment strategy for Metabolism implemented in 2011 and 2012 that included the introduction of the creative assessment task. A significant improvement in student performance ($p < 0.0001$) in the course was noted for the 2011 (74.82% ± 15.02; n=155) and 2012 (74.90 ± 14.64; n=175) cohorts when compared with 2010 (62.87% ± 19.16; n=140) and 2009 (62.95% ± 17.66; n=102). This improvement can be attributed to significantly increased performance in the final examination for the 2011 and 2012 cohorts. The format of the final examination and range of learning objectives covered in the test remained consistent over the four years and there was no significant difference in performance scores for the prerequisite course Structural Biochemistry that was used to control against inter-cohort variation. Despite these similarities, the 2011 and 2012 cohorts demonstrated an average 20% improvement in their capacity to answer conceptual, long answer questions. These questions examined a range of content from stage 1 metabolism of macromolecules to the integration and regulation of metabolic pathways, with equal improvement seen across all levels of question all of which are covered as topics for the creative assessment task.

Metabolism is a highly-rated course within Griffith University and since 2010, has consistently rated in the top 5% of courses in the student evaluation of course questionnaire. Course wide evaluation via the Student Evaluation of Course (SEC) measure resulted in a 91.9% (2011) and 98.8% (2012) positive response to the question "this course engaged me in learning" with a 10% improvement in the number of students who selected the strongly agree (top) response when compared to 2010 data (Table 5).

Table 5: Results of Student Evaluation of Course (SEC) data for the question "this course engaged me in learning" for 2010-2012. Data obtained from a 5-point Likert scale where 5 = strongly agree and 1 = strongly disagree. Data presented as mean ± standard deviation.

	Mean ± SD	% Positive	Participation
2010	4.4 ± 0.73	88.6%	48.3%
2011	4.4 ± 0.98	91.9%	48.4%
2012	4.6 ± 0.66	98.8%	45.8%

Prior to the creative group assessment task, students were presented with only one earlier opportunity to engage in group work throughout their degree program. Student Evaluation conducted in the first lecture of week one identified that 63% of students responded negatively to the question "I enjoy working in groups for assessment tasks" with mean evaluation scores of 2.10 ± 1.26 (2011 n=75) and 2.48 ± 1.25 on a 5-point Likert scale. After concluding the group assignment, students were re-evaluated in week 13, with observed increases in group evaluation scores to 3.14±1.92 (2011) and 3.26 ±1.11. Of the data collected for the 2012 cohort, 44 students completed both evaluations and their data was matched and analysed utilizing a paired t-test (Figure 1). There was no significant difference in the mean evaluation scores for the matched responses when compared to those of the remainder of the cohort for either the baseline (week 1) or concluding (week 13) surveys. A significant improvement ($P<0.0001$) in perceptions of group work was established in the matched data of the 2012 cohort that increased from a mean score of 2.33±1.25 in week 1 to 3.35±1.27 in week 13, with an overall increase in the positive response rate by 39% (Figure 1).

Discussion

Metabolism is a complex and often epistemologically difficult discipline for undergraduate students (Vella, 1990; Wood, 1990). The commonly utilized didactic teaching methodology and complex array of visualisation tools associated with courses has been considered to perpetuate the lack of enthusiasm and difficulty in understanding students face (Meyer & Land, 2003; Schonborn & Anderson, 2004; Herraez & Costa, 2013). It is increasingly well recognized within the biochemistry discipline that resources encouraging visualization of biochemical content are important for improving understanding and learning outcomes (Schonborn & Anderson, 2006; Herraez & Costa, 2013). Today more than ever before, tertiary students are searching the internet for animations and visual explanations of theoretical concepts that will assist their learning (Lee, Paik, & Joo, 2012). However, it has been suggested that students require support to develop improved skills in visual literacy if they are to benefit from the array of visualisation tools made available to them (Christopherson, 1997; Schonborn & Anderson, 2006; Herraez & Costa, 2013). Christopherson (1997) makes an argument for structured courses designed to teach skills in visual literacy to undergraduates, however also suggests that inroads may be possible through

assessment that facilitates the development of such skills, a conception supported by recent work in constructive alignment and visual literacy in the education of biochemists (Herraez & Costa, 2013).

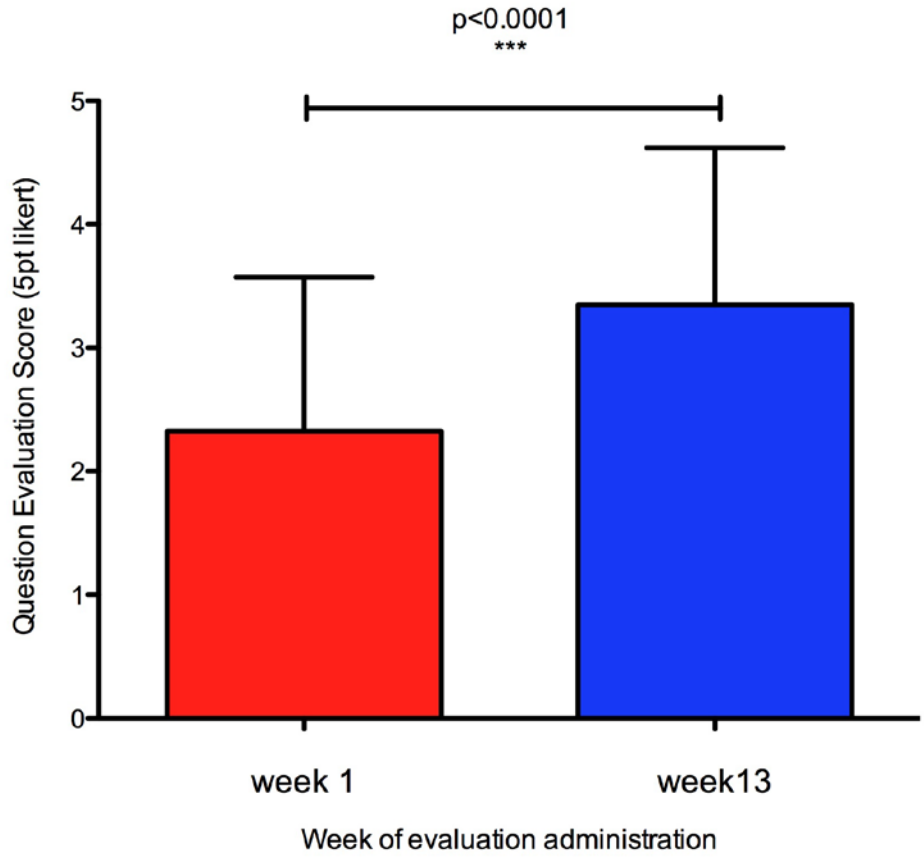

Figure 1. Comparison of matched week 1 and week 13 responses to the question "I enjoy working in groups for assessment tasks" for the 2012 (n =44) cohort. Data obtained from a 5-point Likert scale where 5 = strongly agree and 1 = strongly disagree. All data presented as mean ± standard deviation.

The current thirteen-week Metabolism course exposes students to a wide variety of visualization tools from flow diagrams, images and stylized cellular representations to molecular models and complex animations. The visualization tools are utilised within a curriculum that draws upon the framework for improving visual literacy in biochemistry students proposed by Schonborn and Anderson (2005). Students are presented with visual information and assisted to draw meaning from resources and utilize them to construct meaningful understandings of their own. The creative multimedia task outlined above is an extension of this teaching strategy, in that it requires students to generate their own multimedia representation of a biochemical pathway that has the capacity to be shared with the entire class, a strategy that has been shown to improve scientific visual literacy (Gobert, 1999). The task itself draws upon the inherent media literacy of modern students and requires groups to synthesise the wide range of available theoretical information relevant to their chosen topic and form a coherent representation that is detailed, technically accurate and entertaining.

In completing the assessment task, students gained a deeper understanding of their chosen biochemical pathway with an average of 85.5% of students responding positively that the

task assisted with theoretical understanding over the two years of the project. Overlap in the topics chosen by groups exposed students to multiple representations of similar content and as such fostered a "multiple representation approach to visualization" proposed as one of the 10 guidelines of teaching visual literacy (Piez & Voxman 1997; Schonborn & Anderson, 2006). The strategy of loading student multimedia onto the course Blackboard site combined with the requisite intergroup peer assessment meant that students were encouraged to examine a range of presentations that neatly summarised the content considered fundamental in the learning and teaching of this subject. Students actively engaged with the task and found concrete value in the presentations produced by other groups. This was evidenced through both the quantitative and qualitative evaluations and more strongly by the fact that students viewed an average of 75% of the available presentations and each individual presentation on 3-4 occasions. For those presentations identified as high quality, the rate of viewing increased to 95% of the cohort with an average of 5 views per student. When considering that the videos were only available to students to view from the start of the final week of semester, the average viewing time of 7 hours per student represents a significant proportion of study time students chose to spend revising through this method.

Although the specific effect of the creative assignment on improvements in student performance cannot be elucidated, the combination of this assessment task with the overall diversification of the assessment strategy for the course resulted in significant improvement in overall course performance and capacity to answer long answer questions on the final examination. This improvement in understanding may be attributed in part to the development of skills in visual literacy (McClean et al., 2005; Schonborn & Anderson, 2006; Herraez & Costa, 2013) and the improved learning outcomes associated with positive group work experiences (Gatfield, 1999; Burdett, 2003) however these measures were not quantifiable in the current study.

For this particular group of undergraduate students their exposure to group work prior to undertaking Metabolism is limited to an interview-based assessment task performed in the first semester of first year. Although the evaluation of this particular group based innovation was widely positive (Naug, Colson, & Donner, 2011), baseline analysis of student perceptions of group work carried into second year were consistent with that of others (Burdett, 2003) with only 37% of students responding positively to the statement "I enjoy working in groups for assessment". The introduction of a project that encourages and supports students to maintain contact and produce work over the course of the semester significantly improved student perceptions towards group work (Figure 1). The improvement may be directly linked to the experience of the project where students commonly reported in the qualitative evaluation that the assessment ask was "fun" and "engaging".

On the whole, students found this assessment tasks to be a useful learning and study tool that added a fun dimension to the course. By developing multimedia based representations of complex biochemical pathways students were able improve their understanding of their chosen topic and generate a repository of clips that could be utilized for study purposes.

The importance of developing skills in visual literacy is not limited to students of biochemistry with Christopherson (1997) determining / concluding visual literacy to be important to students in a range of disciplines, including engineering, nursing, business, social and family sciences, the fine arts and communication (, As such, an assessment task that builds skills in visualization utilising a collaborative framework may be of benefit for

any discipline that requires student to synthesise information to develop understanding. As previously stated by Herraez & Costa (2013 p.68) "we lack both a valid list of outcomes supported by empirical research to state categorically what is necessary for a student to develop visual literacy and the assessment to catalyse the process". The nature and structure of this assessment task takes this process one step in the right direction and lays the foundation for further work to quantify the changes in students' visual literacy that may be achieved through such a strategy.

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