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The effects of an online learning environment with worked examples and peer feedback on students' argumentative essay writing and domain-specific knowledge acquisition in the field of biotechnology

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ABSTRACT

The present study investigated the effects of an online learning environment supported with worked examples and peer feedback on students' argumentative essay writing and domain-specific knowledge acquisition in the field of biotechnology. As part of a bigger project, a pre- and post-test study design was used with 45 bachelor students who were randomly grouped in pairs. Students were asked to analyse a case and write an argumentative essay taking into account the advantages and disadvantages of genetically modified organisms. The results showed that the combination of worked examples and peer feedback improve the quality of argumentative essay writing and facilitate the acquisition of domain-specific knowledge. Implications, suggestions, and future research are discussed.

KEYWORDS

Essay writing; online learning environment; peer feedback; example-based learning; biotechnology

Introduction

Biotechnology is making a large and rapid impact on society, and new advances typically present socio-scientific issues that divide the public's opinion (van Lieshout and Dawson 2016). Therefore, students should be aware of the practical applications, and the ethical and societal aspects and implications of biotechnology to make well-informed ethical decisions (Dawson and Schibeci 2003). One potential way to facilitate students learning on biotechnology is using online learning environments. In the particular field of biotechnology, online learning environments have been designed to, among others, develop students' laboratory skills (Hsiu-Ping et al. 2014), or acquire domain-specific knowledge (Cheaney and Ingebritsen 2005; Noroozi and Mulder 2017; van Seters et al. 2012). Online learning environments offer multiple advantages such as adapted or personalized instruction to students with varying prior knowledge (van Seters et al. 2012), fostering domain-specific knowledge acquisition (Diederen et al. 2003), or promoting active learning, providing individualized feedback, or reducing cognitive load (Busstra et al. 2008). Online learning environments can include multiple user interface affordances such as texts, diagrams and pictures to guide and orchestrate the student toward productive activities and learning (Fischer et al. 2013; Suthers 2003).

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Supplementary data for this article can be accessed here.

In the context of science, argumentative essay writing is crucial. Students should think critically and reason logically to justify and argue they decisions, point of views and opinions in contrast to the ones of others (Noroozi et al. 2018). However, the argumentative essay writing aptitude of undergraduate and graduate student's is typically below the level necessary to accomplish writing tasks of sufficient quality at school or the workplace (Cooper et al. 1984; Kellogg and Whiteford 2009). This is striking since writing 'is an important tool for thinking, learning and domain-specific knowledge creation' (Dysthe 2007, 237), and is also a good predictor of success during the first year of higher education (Geiser and Studley 2002). Insufficient argumentative essay writing skills can be related to insufficient practice at school/universities (Kellogg and Whiteford 2009), the enormous efforts required from teachers to grade the essays and provide feedback to students (Baker 2016; Cooper et al. 1984), and the fact that argumentation competence is regularly developed indirectly and informally in the classroom (Driver, Newton, and Osborne 2000; Osborne 2010). Scientific literature suggests that the use of online learning environments along with worked examples (also known as example-based learning) (Schwonke et al. 2009; Sweller, van Merrienboer, and Paas 1998; Wittwer and Renkl 2010) and peer feedback (Hattie and Timperley 2007; Kluger and Denisi 1996) can be considered as a promising approach to facilitate argumentative essay writing.

Feedback is characterized as an action where an external agent, e.g. a peer or a computer system, provides information concerning one or more aspect(s) of our performance in a task or our understanding (Hattie and Timperley 2007; Kluger and Denisi 1996). The main ideas behind peer-learning are that peers' social status is the same, and to cut down immediate teacher intervention and allow students to learn with and from each other (Boud, Cohen, and Sampson 1999, 413). Receiving and giving feedback from and to peers, i.e. peer feedback, with comparable motivations is a relevant element of the learning process (Bayerlein 2014; Crisp 2007) because feedback can orchestrate and guide students' learning (Crisp 2007; Orsmond, Merry, and Reiling 2005) and increase learning (Hattie and Gan 2011; Hattie and Timperley 2007; Shute 2008). Similarly, students may learn during and from the discussion itself (Knight and Wood 2005; Smith et al. 2009) since students facing critique may consider the peer's perspective and may construct better arguments to support their own perspective taking the peer's perspective into account (Chan, Burtis, and Bereiter 1997; Weinberger and Fischer 2006). According to Winne and Butler (1994), the information contained in a peer feedback event can contain information that can help the learner to confirm, complement, overwrite, or restructure students' domain-specific knowledge, meta-cognitive knowledge, beliefs or cognitive tactics and schemas.

An instruction method that has been extensively researched is learning from worked examples (Wittwer and Renkl 2010) where students learn by studying from fully worked examples, i.e. examples with solutions steps and the final solution (Ayres 2012). Its effect is known as the *worked example effect*, and is among the best established findings in cognitive load theory (Schwonke et al. 2009; Sweller, van Merrienboer, and Paas 1998). However, worked examples typically include only *product-oriented information*, e.g. the solutions steps and the final solution, thus they are not particularly effective facilitating the process of acquisition of meaningful and flexible knowledge (van Gog, Paas, and van Merriënboer 2004). Therefore, worked examples should also include *process-oriented information*, that is, the rationale of why certain solution steps should be followed (Wittwer and Renkl 2010). Providing the rationale behind the steps or tasks that need to be conducted is supposed to facilitate the internalization of the process. The latter may support students to: (a) provide high-quality feedback which is beneficial to enhance their writing skills (DeNisi and Kluger 2000), and (b) provide on-task feedback rather than off-task feedback on personal evaluations of the learning partner which is less effective (Hattie and Timperley 2007).

As such, the combination of theory or instructional explanations with worked examples facilitates understanding and impedes the creation of misconceptions and inconsistencies (Wittwer and Renkl 2010). Furthermore, including problems to be solved increases the effectiveness of example-based learning (Ayres 2012; Pashler et al. 2007). However, there are situations that may affect the effectiveness of work examples. For instance, work examples effectiveness decreases as students gain experience, such effect is known as the *expertise-reversal effect* (Kalyuga et al. 2003). Similarly, experienced students

may invest cognitive resources in instructional support that may be redundant, i.e. the *redundancy effect* (Sweller 2005; Sweller, van Merrienboer, and Paas 1998). The latter, may inhibit student's self-regulation and learning.

In previous research, the quality of argumentative essays and the acquisition of domain-specific knowledge have been successfully supported by argumentative peer feedback scripts (Noroozi, Biemans, and Mulder 2016). However, it is unclear if combining worked examples and peer feedback can improve the learning outcomes. Hence, this study aimed to investigate the effects of example-based learning and peer feedback on students' domain-specific knowledge acquisition and argumentative essay writing on the field of biotechnology in the form of the following research questions:

- What are the effects of an online learning environment with worked examples and peer feedback on students' domain-specific knowledge acquisition?
- What are the effects of an online learning environment with worked examples and peer feedback on students' argumentative essay writing?

Materials and methods

Context and participants

A study with a pre- and post-test design with participants randomly grouped in pairs was conducted in September 2016 at a university in the Netherlands specialized in life sciences. The participants were 45 Bachelor of Science (BSc.) students registered in a course aimed at introducing students to the domain of biotechnology. The course covers diverse ethical issues relevant to the practice of biotechnology and their significance to society. The mean age of the participants was 18.11 years (SD = .65, MIN = 17, MAX = 20). Students were mostly Dutch (97.8 %). About two-thirds of the students were male and a third female.

Materials, learning tasks and online learning environment

The learning topic was 'insect-cells for cultured meat manufacturing' which falls under the overarching theme of Genetically Modified Organisms (GMOs). Specifically, students were asked to write an argumentative essay on the statement: 'Insect-cell biomass infected with genetically modified baculovirus is a healthy meat alternative'. To compose the essay, students received a case description, a summary of theory about the topic, hyperlinks to scientific publications, and freedom to do further investigation on the Internet. Students were asked to consider various views and opinions on whether or not using 'insect-cells for cultured meat manufacturing' is a necessity or a fad (see Noroozi, Biemans, and Mulder 2016). All the instructions were embedded in an online learning environment that was designed and implemented for the study. The learning environment offered information in different forms such as texts, diagrams, and pictures. Additionally, the learning environment provided students theory and a worked example on how a good argumentative essay should look like. According to Noroozi, Biemans, and Mulder (2016), argumentative essays should include a clear position followed by arguments and evidence in favour of the position, and arguments weakening or against the position. Next, essays should take into account and refute the opponents' opinions, integrate arguments in favour and against the topic, and formulate a conclusion. Finally, essay elements' specifics should be adjusted to the respective discipline because there are variations between disciplines. The learning environment also facilitated the peer feedback process by assigning roles to students, i.e. assessor and assesse, and orchestrating the interaction of the learning partners, e.g. feedback provision, with scripts (Fischer et al. 2013). Finally, the learning environment allowed students to revise their essays considering the peer feedback received. A timer with the expected completion time was available for each of the different parts of the learning environment. Similarly, a word counter for each input box was available.

Procedure

The study consisted of four phases that took place over a period of four consecutive days. Students had the freedom to complete all the phases from their preferred location within the stipulated time frame. On day one, an introduction to the learning environment was given during class time (20 min). Next, students logged in to the learning environment and completed a questionnaire on domain-specific knowledge (15 min). On day two, students, individually, read a theoretical text and scientific publications on the learning topic, with instructions indicating the most relevant parts (30 min), searched on the Internet for more information and sources (e.g. daily papers, periodic journals, and scientific papers) (30 min), and wrote an argumentative essay of ca. 500 words (min. 450, max. 550 words) individually (45 min). On day three, students read a theoretical text on how to write an argumentative essay and received an example of an argumentative essay. Then, each student provided peer feedback to his or her learning partner (90 min). The peer feedback form was a single text field where students had to give feedback (ca.400, min. 350, max. 450 words) to the argumentative essay of their learning partner. The learning environment checked that the answers' word count were within the lower and upper bounds, if the requirements were not met, the learning environment showed textual and visual feedback. Next, students revised their own argumentative essay based on the feedback from their learning partner. Finally, students completed questionnaires on domain-specific knowledge (the same as the pre-test) (15 min), and were debriefed (5 min). The total time for the study was 335 min. approximately.

Measurements

The quality of student's written argumentative essays, i.e. the original and the revised, was measured using the coding scheme developed by Noroozi, Biemans, and Mulder (2016). The scheme considers the features of a complete and sound argumentative essay within the context of biotechnology and was developed in conformity with the literature (Andrews 1995; Qin and Karabacak 2010; Toulmin 1958; Wood 2001). The scheme was validated using a series of consultation meetings and discussions with a panel comprised of experts and teachers.

The coding scheme contains different elements with multiple levels. Every level is comprised of a label, a description, points, and examples to make the coding process easy and unambiguous. A score, between zero and two, was assigned for each of the following elements of the student's argumentative essays: (a) Intuitive opinion, (b) arguments in favour of the topic or pro-arguments, (c) scientific facts in favour of the topic or pro-facts, (d) arguments against the topic or con-arguments, (e) scientific facts against the topic or con-facts, (f) opinion on the topic considering various pros and cons or integration of pros and cons, (g) scientific facts to support opinion on the topic after integration of pros and cons or integration of pro- and con-facts, and (h) conclusion. The assessment scores were given as follows: two points for level 2 or elaborated, one point for level 1 or non-elaborated, and zero points for level 0 or not mentioned. Therefore, the student's quality score of writing argumentative essays is the sum of all points of an essay, with a maximum of 16 points.

The interrater agreement was sufficient (Cohen's Kappa = 0.873) according to Landis and Koch (1977). The interrater agreement with two coders (i.e. the first author and a trained coder) was obtained by randomly selecting 5% of the original and revised assignments. To guarantee reliability, the coder was trained on the coding process and the coding rubrics. Next, the first author and the coder coded 5% of the data independently. The coding discrepancies were resolved through discussion until agreement was reached. Finally, the trained coder coded the rest of the data.

Domain-specific knowledge was measured during pre- and post-test using a questionnaire developed by the course coordinator. This questionnaire was comprised of 17 multiple-choice questions and one open question, e.g. 'What is a continuous animal cell line?', 'Insects that are commercially cultivated include…', 'A baculovirus is…', 'What is a 'master cell bank'?' For each question students received a point, for a total of 18 points. Then, the domain-specific knowledge score was calculated

for each student on a scale from 0 to 1 (#points/18) and then multiplied by 10 to have scores on a scale from 0 to 10. The result was used as the domain-specific knowledge score for the given test.

Results

Following, the results of each research question are presented.

Research question one

A one-way repeated measures ANOVA test indicated that students' domain-specific knowledge improved significantly from pre-test to post-test, *Wilks' Lambda = .465, F(1, 40) = 46.06, p < .001, η2 = .535*. As such, the online learning environment presented a positive effect on student's domain-specific knowledge acquisition. Students' mean quality scores for domain-specific knowledge increased from pre-test to post-test, see Table 1. Student's average gain on domain-specific knowledge was one point on a 10-point scale.

Table 1. Student's pre-test and post-test mean scores for domain-specific knowledge and quality of writing.

	Pre-test	Post-test	
Domain-specific knowledge	*M* = 4.91, SD = .93	*M* = 5.9, SD = 1.28	*p* < .001
Quality of writing	*M* = 10.17, SD = 2.09	*M* = 11.37, SD = 2.63	*p* < .005

Research question two

According to a one-way repeated measures ANOVA test, students' quality of writing argumentative essays improved significantly from the original to the revised essay, *Wilks' Lambda = .80, F(1, 44) = 10.59, p = .002, η2 = .194*. The results suggests that the online learning environment had a positive effect on the student's quality of writing argumentative essays. Students' mean quality scores for writing argumentative essays increased from pre-test to post-test, see Table 1. Student's average gain on essay quality was 1.2 points on a 16-point scale.

Discussion

In this section, the results of the research questions are discussed.

Students were able to improve the quality of their argumentative essays and also gained domain-specific knowledge, from pre-test to post-test, using an online learning environment which combined worked examples and peer feedback. The results sheds light on the positive combined effect of worked examples and peer feedback on the learning outcomes. The aforementioned results are in line with previous research claiming positive effects of worked examples (Ayres 2012; Schwonke et al. 2009; Sweller, van Merrienboer, and Paas 1998), theory or instructional explanations (van Gog, Paas, and van Merriënboer 2004; Wittwer and Renkl 2010) and practice (Ayres 2012; Pashler et al. 2007). Similarly, providing multiple affordances such as texts, diagrams and pictures directed the students toward productive activities and learning (Fischer et al. 2013; Noroozi and Mulder 2017; Suthers 2003). In addition, by facilitating the peer feedback process, students were able to provide valuable feedback to their learning partners related to the understanding of the topic and the writing of argumentative essays (Hattie and Timperley 2007; Kluger and Denisi 1996). The feedback content was facilitated by instructing students to first get themselves informed on the topic under discussion by reading a theoretical text on the topic and scientific articles, and by providing theory and a worked example on how a good argumentative essay should look like. The peer feedback process allowed students to confirm, complement, overwrite, or restructure their knowledge conceptions (Winne and Butler 1994; 5740), and to identify and rectify mistakes and misconceptions (Shute 2008; Van der Kleij, Feskens, and

Eggen 2015), to comprehend the differences between the actual and the desired state, and to receive advice on what to do and how to do it to make better progress (DeNisi and Kluger 2000; Hattie and Timperley 2007; Lizzio and Wilson 2008). Hence, analysing and contrasting the work of the learning partner during the feedback process triggered reflection (Phielix, Prins, and Kirschner 2010), and broadened and deepened students reasoning and understanding (Yang 2010). Finally, the online learning environment facilitated and promoted the development of students' argumentative writing skills, and in consequence fostered student's argumentation competence. Argumentation competence is essential for students in academic settings as they are typically required to work in groups, and to write argumentative essays (Noroozi et al. 2012, 2018). The aforementioned situations require students to think critically and reason logically to argue in favour of their opinion, to reach conclusions, and to take important decisions (Andriessen 2006; Kuhn 1991). Argumentation competence allows students to contrast, acknowledge and take into account or refute the opinions of others (Toulmin 1958; van Bruggen and Kirschner 2003).

Conclusions, implications, limitations, and suggestions for future research

In this study an online learning environment which combined worked examples and peer feedback was used to improve the quality of argumentative essay writing and support domain-specific knowledge acquisition in the field of biotechnology. The use of worked examples and peer feedback improved student's argumentative essays quality and domain-specific knowledge acquisition. Furthermore, the peer feedback process allowed students to provide feedback related to the topic and the writing of argumentative essays. Similarly, the peer feedback process facilitated learning as students received feedback on their current state and suggestions on what they should do and how they should do it to make progress and reach a desired state. The peer feedback process allowed students to contrast each other's work, which in turn, triggered the validation and the restructuring of knowledge conceptions, and the identification and rectification of errors and misconceptions. Meanwhile, the online learning environment facilitated and promoted the development of students' argumentation competence. Students had the convenience and flexibility to work on the assignment during and from their preferred time and location within the stipulated time frame. Similarly, the online learning environment allowed to present information in different forms, e.g. texts, diagrams and pictures, and to structure student's interactions to facilitate productive activities and learning.

This study was conducted in a real educational setting. Such setting offers advantages and disadvantages. An advantage is that the practical relevance and ecological validity of the study are high. The reasoning behind this is that students' engagement in the task in a real educational setting is intrinsically driven by the students' motivation to learn and pass the course rather than by monetary rewards which are typically received upon successful completion of laboratory tasks. Therefore, laboratory settings may produce unrealistic data that produce biased research. A clear limitation of this study was the lack of a control condition to allow us to disregard the effects of variables other than the independent variable. However, we made the deliberate choice of not having a control condition because the revised essay was graded and some students in a control condition might have been in disadvantage. In addition, we were not able to investigate the separate effects of the different instructional scaffolds, i.e. the worked examples and the peer feedback, on the learning outcomes. The latter could be considered as a second limitation of the present study. Thus, further research is needed to investigate whether the scaffolds have a summative effect or lessen the learning outcomes. Moreover, future longitudinal research should be conducted to assess the effectiveness of the instructional scaffolds, but should control for the *expertise-reversal effect* (Kalyuga et al. 2003) and the *redundancy effect* (Sweller 2005; Sweller, van Merrienboer, and Paas 1998) which can inhibit student's self-regulation and learning.

Disclosure statement

No potential conflict of interest was reported by the authors.

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