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Science-writing in the blogosphere as a tool to promote autonomous motivation in education

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ABSTRACT

We sought to establish a collaborative learning environment for our first-year university cell biology course that would be sufficiently challenging to warrant team effort and turn students into autonomous learners. We chose team-based science-writing blogs, a choice grounded in the Self Determination Theory. This theory posits that a sense of autonomy, competence and relatedness are essential requirements to perform a task in an autonomous-motivated fashion. Through surveys over a period of four years, we assessed how students perceived the blog project. Qualitative analyses revealed that students recognized and appreciated their autonomy. They also consistently considered as positive a sense of competence, expressed as being useful, and relatedness, i.e. relating with others and working together. A quantitative analysis based on an intrinsic-motivation inventory revealed that students experienced science-writing on the web as an intrinsically motivating learning task. We conclude that web-based learning triggers motivation to learn autonomously and discuss how task authenticity may play an important role in this process.

> "We had dreamed for years of an institution of independent scientists, working together in one of these backwoods ("blank spaces on the map of science"), not as subordinates of some great executive officer, but joined by the desire, indeed by the spiritual necessity, to understand the region as a whole, and to lend one another the strength of that understanding". Citation from: Wiener N. (1965) Cybernetics: or the control and communication in the animal and in the machine. MIT press, paperback edition.

1. Introduction

1.1. In search of an engaging learning environment

The original cell biology course, which is the subject of this study, was a conventional course with 26 teacher-centered lectures and 6 practical classes. Lecture content was and continues to be fully covered in 11 multimedia resources, comprising texts, images, animations and references to key articles. The resources also contain auto-evaluation questions so that students can master the subject independently of the lectures (for more information http://www.cellbiol.net/cbe/multimedia.php). Lecture attendance is not compulsory but students must attend practical classes. Course questionnaires repeatedly revealed that they find the subject of cell biology interesting, important and that they appreciated the course. Indeed, student retention rates are well above average for 1st year university courses in France, in the range of 75%. Despite their alleged interest in and satisfaction with the course, we observed over the years a gradual disengagement in class as witnessed by an increase in the incidence of disruptive behavior. Students would frequently form "discussion groups" on unrelated subjects, incessantly consult messages on their smartphones, and would watch and share unrelated videos on their laptops. We concluded that the traditional lecture format seemingly lacked purpose. The students were unable to pinpoint the predominant underlying cause of their behavior. Some accused the disruptive students of being unsuitable for higher education, others expressed the need to release pressure from a heavy curriculum, a number of students mentioned that they could not follow the lectures since the cognitive load was too high, and certain students did not see the point of being focused in class because the course content was fully covered anyway by multimedia resources. The situation was better in practical classes mainly dealing with microscopic analysis of body tissues, but even there students manifested a minimal-effort attitude. Frequent questions about what exactly they needed to be able to do, or to know, in order to pass the test, were the order of the day.

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We wished to counter this type of behavior by creating a more engaging, motivating and learning-centered environment. We also thought that we should not try to oppose the students' desire to talk with each other nor counter their interest in social media and information technology, but rather find ways in which it engaged them to learn. In other words, we had to think of a suitable pedagogical setting that would allow the affordances of team-based and web-based tools to be exploited for the learning of cell biology (discussed in Dabbagh & Reo, 2011; Jaffee, 2003). Questions that are key in this respect are: what is it about a particular technology that makes students want to interact with it in a particular way or what perceived abilities does the technology provide or enable (Dabbagh & Reo, 2011)? In order to find this suitable setting, we sought inspiration in theories and findings about the facilitation of engagement and chose the Self-Determination Theory (SDT) of motivation. This theory qualifies different types of motivation and connects them with goal-orientation (Pintrich, 2000; Ryan & Deci, 2000a, 2000b). Goal orientation matters because we wanted our students to be able to function in a self-regulated fashion with a minimum of external control.

The outcome of our reflection led in 2012 to a complete overhaul of the cell biology course by offering students more say; more choice (autonomy) and a stronger sense of perceived competence and relatedness. Firstly, lectures became "structured" (Freeman, Haak, & Wenderoth, 2011), meaning that they comprised a blend of activities including teacher-centered teaching, quizzes with the use of student response systems ("clickers") (Caldwell, 2007) and short exercises in which students had to explore the web to find the answers. Secondly, we replaced practical classes with an open-ended collaborative project in which the students created a science-writing blog. Instead, a separate course was developed in which they studied microscopy and molecular biology techniques.

This article concerns the science-writing blog project of the cell biology course and deals with the question of how exactly students perceived the project. Over a period of four years we asked them to describe the positive and negative features and analyzed their comments in light of the motivation criteria set forth in the Self-Determination Theory. Moreover, they completed a quantitative survey, known as the "Intrinsic Motivation Inventory", which measured to what extent they felt they had functioned in an autonomous motivated fashion.

Before presenting the research questions and the results of this study, we discuss theories to date about motivation and dedicate a section to the Self-Determination Theory. We define what blogging is and how it is currently used in higher education. A brief account is provided of the pilot projects that have been decisive in developing our science-writing blog project. Finally we describe the affordances of blogging in the perspective of the Self-Determination Theory.

1.2. Motivation

Motivation is a fundamental concept in any behavior, including learning. In the context of learning, motivation gets students to: 1) establish a personal learning agenda (what to do and when): 2) take at least some of the initiatives (mobilizing executive functions) that shape the learning process (employing cognitive skills) and: 3) develop an ability to assess the extent and success of their learning (employing metacognitive skills) (Ryan & Deci, 2000a, 2000b). Motivation became a subject of research in order to understand what drives behavior. The earlier studies in humans described motivation as a means to satisfy one's need to achieve. Motivation leads to employing means to overcome obstacles, to exercise power, to face challenges and render activities efficient (theory of Murray, cited by Franken, 1988). Then followed a series of theories that distinguished between different needs: basic needs (being safe, nourished and recognized by a community) and the need for self-actualization, also known as fulfilling one's potential or exploiting one's talents. Motivation to achieve was supplemented with another drive, namely motivation to avoid failure. Which achievements people seek depend on their innate abilities but also on task difficulty (cognitive load) and a perceived sense of luck (Attribution Theory) (Weiner, 1974). The duality in motivation, seeking and avoiding, may have an important gender component where women may seek to avoid achievement and choose to underperform, because it could tarnish their femininity, which is held by some to be culturally determined. Tarnishing femininity could lead to social exclusion resulting in a lack of fulfillment of one's basic needs. According to the Social Cognitive Theory, the choice of achievement is largely determined by the social context because we learn by observing behavior around us and by imitating those actions that are socially rewarded or not punished. Through observation and imitation we develop a sense of self-efficacy, which in turn determines which activities we undertake or choose to persist at. With a given sense of self-efficacy and a concomitant level of motivation for achievement, we may approach the learning task with different goals: one where we are eager to prove our ability relative to others, i.e. *performance* goal-orientation, or another where we wish to explore the matter to the fullest, obtain a real understanding, i.e. *mastery* goal-orientation (Ames & Archer, 1988; Astin, 1993; Dweck, 1986; Pintrich, 2000). The Self-Determination Theory adds another layer of complexity by postulating that motivation comes in different qualities and that these, in turn, determine goal orientation (Ryan & Deci, 2000a, 2000b). The quality of motivation interests us particularly because it is instrumental not only in the way people learn (deep, *mastery*-, versus surface, *performance*-oriented) but also in the sense of well-being and satisfaction with an educational trajectory. In the context of life sciences education, the quality of motivation is thus expected to contribute toward students becoming more capable biologists, who might then contribute more effectively to research, business, education or administration. For a detailed review about motivation theories, see Kusurkar, Croiset, Mann, Custers, and ten Cate (2012). Although higher education institutions realize the importance of *mastery* goal-orientation, and often complain about students' lack of it, few take the effort to investigate the underlying reasons (Kusurkar et al., 2012). Despite its importance (Meyer & Turner, 2002), affective and motivational components of learning are generally undervalued in universities. Below we outline how we used the Self-Determination Theory as a framework for developing a learning environment in which students could function in an autonomous motivated fashion and adopt *mastery* goal-orientation.

1.3. Self-Determination Theory

Self-Determination Theory posits a taxonomy of motivation comprising *amotivation, extrinsic motivation and intrinsic motivation*. *Amotivation* is a lack of motivation, characterized by being devoid of regulation, impersonal, and associated with a sense of incompetence, a lack of value and perceived contingency. Boredom could possibly qualify as a state of *amotivation* (Pekrun, Goetz, Daniels, Stupnisky, & Perry, 2010). *Extrinsic motivation* can be subdivided according to the quality of regulation. Four subtypes are recognized: external, introjection, identification and integration. External and introjection regulation are characterized by processes such as compliance and reactance, avoiding punishment or reaping reward, seeking approval from others or performing because of ego-involvement (being considered "clever" and wanting to live up to that reputation). The two other subtypes, identification and integration, refer to different levels of agreement with objectives, of finding the activity important for understanding the learning material, of finding it interesting and congruent with personal ideas about, for instance, a future job. The best quality of motivation is referred to as *intrinsic motivation* which occurs when activities offer genuine enjoyment and satisfaction. When behavior is externally regulated, which is the case for the first two subtypes of *extrinsic motivation*, one speaks of non-self-determined behavior and controlled motivation. When behavior is internally regulated as in the

last two subtypes of *extrinsic motivation* and in *intrinsic motivation*, one speaks of self-determined behavior and autonomous motivation (summarized in Fig. A1, Supplementary material) (Kusurkar, Ten Cate, et al., 2013b; Kusurkar, Croiset, Galindo-Garré, & Ten Cate, 2013a; Ryan & Deci, 2000a, 2000b; Vansteenkiste, Sierens, Soenens, Luyckx, & Lens, 2009). Controlled motivation means that an activity is carried out because of internal or external pressure or for external reward. The activity will cease when the pressure drops and it is associated with surface learning and short-term memory. In an educational setting, controlled motivation is exemplified by questions such as "what do you need to know to pass the test". Autonomous motivation, on the contrary, means that an activity is carried out because of an inherent interest or because a person finds it personally important. In this, students set their own learning agenda and operate in a self-regulated fashion. Educational institutions should seek to function in a culture of autonomous motivation because this is associated with deep learning and a long-term memory.

According to the Self-Determination Theory, autonomous motivation requires the fulfillment of three basic psychological needs which are: a perceived sense of autonomy, competence and relatedness. Autonomy refers to the need for choice and the need to feel ownership for one's behavior (De Charms, 1968). The need for competence refers to feeling capable of completing a given task (Harter, 1978). The need for relatedness pertains to the feeling of belonging to a group of friends or peers. Learning environments where teachers incorporate practices that satisfy these needs enhance students' autonomous motivation for learning (Kusurkar, Croiset, & Ten Cate, 2011; Ryan & Deci, 2000a, 2000b).

The bulk of studies concerning the quality of motivation have been performed in secondary schools (Niemiec & Ryan, 2009). With respect to higher education, medical education has received much attention recently (Kusurkar et al., 2012; van Berkel & Schmidt, 2000; Vansteenkiste et al., 2009; Wouters, Bakker, van Wijk, Croiset, & Kusurkar, 2014). Moreover, most of the research on motivation has been driven by a predominant focus on cognitive and individual psychological aspects and tends to discount the importance of additional contextual factors such as team effort and the importance of task quality (Fulmer & Frijters, 2009).

1.4. Blogging and higher education

Blogging is a form of social media and can be considered as a social software learning environment (Dabbagh & Kitsantas, 2012). The term 'blog' is an abbreviation of 'web log', a mode of communication with posting of news items, hyperlinks to third-party sites and the opportunity for readers to enter personal responses. Among many other social media, blogging is considered the most versatile with many dimensions that are suited to students' unique voices, empowering them and encouraging them to become more critically analytical in their thinking (Oravec, 2002; Williams & Jacobs, 2004). The use of blogs in educational settings can be globally divided into three genres: 1) filters where authors comment on the content of other sites; 2) personal journals where authors write about their lives, thoughts and feelings; 3) knowledge blogs where authors make observations and record relevant references about a particular knowledge domain. In a survey of blogs used in education, it was found that over 70% were personal journals through which learners created a personal learning environment (Sim & Hew, 2010). It should be noted that blogs are not necessarily personal journals; they can be team-based or institution-based (Oravec, 2002; Williams & Jacobs, 2004). Studies have shown that personal journals (genre 2) enhance learning engagement by promoting education in an informal setting because students comment on each other's work outside class or beyond campus (Dabbagh & Kitsantas, 2012; Harrison, Dunbar, Ratmansky, Boyd, & Lopatto, 2011). Moreover, personal journals may help in fostering a learning community, where participants feel they are an important part of the classroom in which their opinions matter (Churchill, 2009). In a broader context, the use of social media may enhance a sense of personal agency in the learning process (Dabbagh & Kitsantas, 2012), a sentiment that students often express as "feeling empowered" (Oravec, 2002). Schmidt (2007) suggests that social media facilitate three social cognitive processes: information management, identity management and relationship management. These processes result in a change of self-representation and generally lead to an enhanced sense of competence, relatedness (sense of being a part of the activity) and acceptance (social approval) (Turker & Zingel, 2008). As a consequence, higher education courses that employ a multitude of social media (ranging from Delicious, blogs, wikis, Second Life and Facebook) give rise to more self-regulated communities (Hemmi, Bayne, & Land, 2009). Finally, in the opinion of Brown and Adler (2008), who consider that understanding is socially constructed, the use of social media impacts education by expanding the various aspects of social learning. It should be noted that students' willingness to participate in publically exposed personal journals is still a matter of debate and the question of whether or not students contribute merely because of external pressure has not been properly addressed (Sim & Hew, 2010; Williams & Jacobs, 2004). Moreover, no studies have analyzed how students experience the creation of team-based blogs.

The finding that the use of social media leads to an enhanced sense of competence, relatedness and social approval (Schmidt, 2007; Turker & Zingel, 2008) played an important role in our decision to choose blogging as a tool for our collaborative course project, because it concurs with the requirements of autonomous motivation. Two of our pilot experiences also helped in this regard. The first experiment concerned the use of an internal (accessible only to course students and teachers) collaborative Wiki platform where students were asked to write a personal journal about a specific course subject and were encouraged to use the platform to comment on each other's writing. After one semester, the students largely refrained from making written comments about other people's work and the platform effectively became an on-line correction tool for teachers. In a second experiment we asked students to prepare a Wiki document collectively in teams and to provide us with associated illustrations, which we then published on the Cell Biology Promotion website (http://www.cellbiol.net/ste/alp.php). Now students reported a great interest in collaborating with each other, felt responsible for each other's contributions and felt excited by the public exposure of their work (unpublished observations). We took this to mean that it would be difficult to entice students into social interaction and collaboration on the basis of personal journals but that, on the contrary, collaborative effort within teams would work out well, in particular when the product eventually became accessible via internet.

We chose to focus on blogging rather than on other social media for four reasons. First, blogs are an effective collaborative platform for the production of team-based scientific documents. Second, they allow the creation of a compilation of blog posts where teams can expand their documents with time and experience and thus cover substantial material. Third, blogging platforms offer a rather versatile graphical approach, allowing teams to personalize the layout. The fourth reason is the possibility to publish the scientific document on the web. We consider this type of blog as a knowledge blog or, more specifically, as a "science-writing" blog. A successful science-writing blog requires the input of multiple skills: finding an interesting subject, making the subject visually pleasing, properly pitching the laymen's level of understanding and revealing the state-of-the-art of the subject in question. Collectively, these affordances offer a rather complex learning environment, a challenge that provides real meaning to teamwork. They also help students to think critically about their subject, stimulate them to synthesize and communicate scientific information, and importantly, support self-regulated learning (Dennen, 2014; National Research Council, 2011; Sim & Hew, 2010; Williams & Jacobs, 2004). Lastly, we chose blogging as the tool for the open-ended learning project because

this is the least amenable to a *performance*-goal orientation. Students do not know what will be appraised and by whom (the teacher, the blog visitors or their social network). We are aware that such an approach conflicts with objective grading.

The blogs were not considered for public debate in the sense that students were not asked to make comments or express opinions that would lead to counter-arguments or counter-opinions. Students were asked to display consensual knowledge that was verified and approved by the scientific community. In this respect, beyond the collaborative team effort, the level of interactivity is limited because of the nature of the product. Instead, we envisioned that students could use more specific network tools to enhance social interaction since virtually all students have a Facebook account. Finally, we felt that blogging was most suited to establishing group identity, building social contexts of knowledge, enabling personalization of the learning path and contributing to folk knowledge as semi-experts. Combined with the possibility to integrate the blog into web-based social networks, blogging by itself would largely support the principle of "learning as a social process" (Brown & Adler, 2008). This in turn should lead students to take on a *mastery-oriented* learning approach. In self-determination terminology, team-based blogging could possibly qualify as an intrinsically interesting task because it bears the characteristics that satisfy three essential needs, a sense of autonomy, competence and relatedness, for the natural expression of the curiosity of man (Ryan & Deci, 2000a, 2000b).

1.5. The creation of science-writing blogs in the perspective of the Self-Determination Theory

Below we outline in more detail how the affordances of team-based blogging fit with the motivation criteria set forth by the Self-Determination Theory.

A sense of autonomy is generally described as giving learners the opportunity for self-regulation, allowing them to master their own future, and letting them work at their own pace and seek challenges that are optimal for their level of development (Harter, 1978), whilst being devoid of an excess of repression or instructions. In this context, autonomy is not about individuality or self-regulated behavior; it is about giving choice to the learners. We anticipated that the freedom of choice of subject, freedom to design the blog to the team's liking, as well as an assignment period of roughly four months, would largely satisfy this need. Moreover, by letting students work in teams, the authority of the instructor is naturally reduced, which also is conducive to enhancing perceived autonomy. The matter of autonomy is delicate because groups need both freedom and guidance (Kusurkar & Croiset, 2015). Instructors must feed the collaborative effort with input such as facts, symbols, concepts and paradigms, thus eliciting worthwhile conversation that enhances the sense of competence, but they must also support group-functioning and facilitate productive interaction among the team members, as the latter is a key factor in students' appreciation of collaborative projects (Deci, Eghari, Patrick, & Leone, 1994; van Berkel & Schmidt, 2000)

The need for competence is generally understood as being the consequence of an inner necessity to produce desired outcomes. The need for competence refers to having the tools and the cognitive skills to succeed at a task. It has a direct impact on one's confidence and the perception of efficacy. Engaging in an individual learning task is largely dependent on perceived competence and on some level of control (Harter, 1978; Vallerand & Reid, 1984). Competence is not static because it is constantly subsumed by task evaluation, progressive instruction and by constructive feedback throughout the learning process. The team-based blog project offers two types of support with respect to perceived competence. First and most importantly, students can support each other by sharing different cognitive skills and insights, thereby reducing the individual cognitive load (Kirschner, Paas, & Kirschner, 2008). Bandura refers to this as "*perceived collective efficacy*" that is considered to foster *"motivational commitment to the task, resilience to adversity and performance accomplishments*" (abstract, p75) (Bandura, 2000; Prussia & Kinicki, 1996). In terms of the Self-Determination Theory, we refer to this as collective competence. Secondly, science-writing blogs may offer students an additional "empowering" dimension, namely the utility of their work for people actually visiting or commenting on their articles. Internet traffic might serve as a formidable source of positive feedback, thus boosting perceived competence.

The need for relatedness with significant others originates from studies dealing with interpersonal attachments, also known as identification with peers (Baumeister & Leary, 1995; Reis, 1994). Team-based projects offer rich interactions that allow identification with the group (Ryan & Deci, 2000a, 2000b). However, relatedness goes much further because it also applies to identification with goal achievement, such as learning biology or career objectives. Furthermore, it applies to identification with instructors and with the specific learning task, all elements that help to create motivation (Ryan & Deci, 2000a, 2000b). Studies have shown that identification with learning tasks is facilitated by task authenticity (Barab, Squire, & Dueber, 2000; Blumenfeld et al., 1991; Larmer & Mergendoller, 2010; Visser, Ket, Croiset, & Kusurkar, 2017). The science-writing blog format is particularly useful in this respect because it constitutes an authentic task in an authentic environment (Oblinger, 2012). It is authentic because the semester-long project contains features of a scientific project comprising elements such as negotiation of the subject, sustained involvement and project ownership, all characteristics of a typical research project in science (Rahm, Miller, Hartley, & Moore, 2003. In addition, science increasingly involves communication via the internet, i.e. authentic communication between stakeholders. Besides the web editions of hard-copy science journals, many publishers have created additional features on their websites such as protocol exchange, job opportunities, science blogs and science podcasts through channels such as nature.com, science.com and elifesciences.org. In other words, the web is becoming increasingly important for the social negotiation of knowledge. From a students' perspective, it constitutes an authentic environment (Clark, Logan, Luckin, Mee, & Oliver, 2009; Fox & Rainie, 2014; Greenhow, Robelia, & Hughes, 2009). Students use it and contribute to it by using Web 2.0 tools (Fox & Rainie, 2014). The term Web 2.0 describes the second stage of the evolution of the World Wide Web in which content delivery has been facilitated by user-friendly editing software, i.e. web-based tools devoid of any requirement for markup language. The term Web 2.0 encompasses social media, or social software, and the more ancient computer-mediated communication technologies. Collectively, Web 2.0 refers to the web as a channel for communication, collaboration and creative expression that is accessible to anyone with an internet connection (Dabbagh & Reo, 2011). Facebook, LinkedIn, Wikipedia, YouTube, WordPress, Blogger, Twitter and others offer means, via tools and applications, to participate in the web-based "conversation of mankind" (phrase from Michael Oakeshott, discussed in Bruffee, 1984).

1.6. Purpose of the study and research questions

The purpose of this study was to analyze the underlying motivational factors that led students to undertake the blog project and to evaluate these factors in light of the criteria postulated by the Self-Determination Theory (Slater, Slater, Heyer, & Bailey, 2015).

1) How do students experience the collaborative blog project; are their motivational arguments in line with criteria for autonomous motivation as postulated by the Self-Determination Theory?
2) How has the collaborative effort contributed to the success of the blog project?
3) Does the blog project stimulate learning and enhance interest in cell biology?

Table 1
Demography of course and survey participants.

1st year University, Life Sciences & Technology Introductory Cell Biology course, runs once a year from February to May					
Year	2013	2014	2015	2016	Sum/average
Female	31	28	19	22	100
Male	11	12	10	10	43
Average age	19.1	18.8	19.1	18.9	19.0
Participation in course surveys (%)	95.3	97.6	100	100	98.2

The student numbers, female and male, their age and the percentage of participants in the surveys are shown. Note that the results were obtained from almost all the students so they were not biased by the selection of a subpopulation.

4) Do students function in an autonomous motivated fashion and adopt a mastery-oriented learning approach?

2. Methods

2.1. Research context

The current study concerns an introductory cell biology course which is offered once a year to university students in preparation for the "grandes écoles" in France. These students, on average 19 years of age, prepare for advanced studies in agricultural and food sciences, biotechnology, molecular biology, cognitive sciences or the environmental sciences (see Table 1 for demographic information). The students are selected largely on their secondary-school exam results (baccalaureate) and are considered "high achievement learners" embedded in a presumed culture of *performance-oriented* behavior (Brown, 2009; Hofstede, 2011). As mentioned previously, the course is divided in two equal parts; structured (interactive) lectures (Freeman et al., 2011; Freeman et al., 2014) and a collaborative science-writing project in the format of a blog. We also refer to this project as "science-writing in the blogosphere". The term blogosphere describes the universe of connected blogs or the ensemble of the community of bloggers (Wikipedia, eponymous article). The lectures make the students acquainted with cell biology concepts, facts, symbols and terminology, essential knowledge that allows them to connect the discipline with the subject they will explore in the blog project.

The course annually enrolls on average 35 students and comprises 50 h of face-to-face instruction and an estimated 70 h of self-study. This amounts to 6 ECTS in the European Credit Transfer and Accumulation System. The course program (outlined in Fig. 1a), the multi-media documents, the student library and the message forum are available on Moodle, the learning management system used by the university.

2.2. Team formation

The students in the class had known each other for 5 months and we had opted for student-selected team formation. This mode of team formation carries the risk that teams behave as social entities rather than learning entities and as a consequence may engage less in the collaborative aspects of the project, i.e. toward each other, the supervisor and other class mates (Brickell, Porter, Reynolds, & Cosgrove, 1994). However, because students are denied any choice in the first two years of the curriculum and because they had to agree on a common topic, we gave room for personal affinity. Moreover, we anticipated that the nature of the project and the exposure on the web would encourage the teams to take on a genuine collaborative and productive attitude and would reduce the risk of "social club behavior" (Nieminen, Sauri, & Lonka, 2006; van Berkel & Schmidt, 2000).

2.3. Instructions for and scaffolding of the blog project

At the start of the course, students were asked to form teams of 3 to 5 members. The teams assigned a coordinator for on-line communication with the instructors and for note-taking during the tutorial sessions. The teams were asked to create a science-writing blog, comprising as many articles as team members and dealing with a subject of their choice. Two restrictions applied: the subject had to be connected with the course material and the instructors had to be convinced that they could conveniently deal with the subject. The connection with cell biology course material had to be emphasized in a so-called "molecular page", where students provide molecular detail about relevant cellular components such as how membrane pumps work, receptors, signaling pathways, the process of protein maturation, muscle contraction, cell death through apoptosis, etc. The students were free to choose the blog-provider (WordPress and Blogger were the most popular choice), and only one team had contacted an informatics student with whom they had developed the necessary "php" scripting. Students were also asked to develop strategies to communicate their project with the outer world in order to attract traffic to their blog.

Students received support from the instructors in five formal tutorials (see Fig. 1a and b for time-line and tutorial content). Briefly, in the first tutorial, students were given instructions about team functioning (Asgari & Dall'Alba, 2011), they were asked to set their own team functioning rules, referred to as basic rules, and explain the choice of their subject. In the second tutorial, they had to provide an outline of how they were going to develop the subject and discussed task delegation. The third tutorial comprised a team auto-evaluation test (see below, section dealing with individual accountability) and a progress report. In the fourth tutorial, individual members reported on the documents they had explored and what they had learned from them. The fifth session dealt with the molecular page, how annotated databases could help in providing information or how they could reveal protein structures with the use of computer-based graphical programs. Additional support came through discussions after class, email exchange and through help with finding appropriate literature (PubMed or Google Scholar searches).

2.4. Communication between teams and instructors

Communication took place through the course forum on Moodle and team-specific email messages which were relayed through the team-assigned coordinator. Document libraries were created on Moodle comprising on-line documents, especially scientific articles, that students themselves had no access to via the internet.

2.5. Blog assessment

Students received written feedback (formative assessment) about their blogs prior to their oral presentation and the blogs were reread for a final grade (summative assessment). They were informed that if the blog contained unacceptable errors, in particular when dealing with human pathologies, they would not get a mark unless they had made the required corrections. Students complied with this rule and were generally anxious about the "scientific" correctness of their information. The teaching, scaffolding and evaluation procedures represented up to 134 h for a total of 8 teams (Fig. 1c), i.e. roughly 24 h more than we would spend on the conventional course. Students presented their blog to peers in a symposium lasting one morning. In a time slot of 15 min, preferably with visual aids, they had to deal with the following aspects of their blog: a) choice of subject, b) development of subject, c) description of the molecular page and d) description of the strategies used to attract traffic to their blog. The teams were free to decide how they organized the oral presentation, but all team members participated, each covering a specific topic of the project.

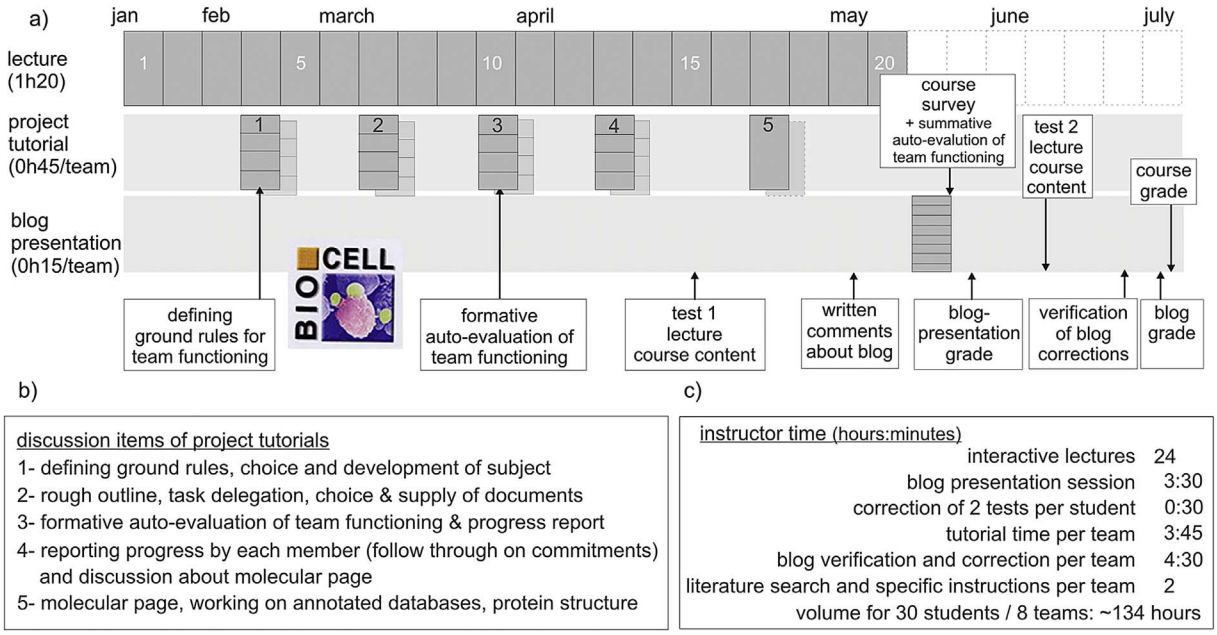

Fig. 1. Outline of cell-biology course activities. a) Course roster, comprising lectures, tutorials and an oral presentation session. b) Description of typical discussion items of tutorial sessions that accompany the blog project. c) Estimated instructor time of entire course, based on 30 students with 8 blogs.

2.6. Course grades

The course had four grades: one for the lecture activities (questions and exercises, weighting 0.15), one for an in-course test (0.15), an end-of-course test (0.3), and one for the blog (0.4, divided between the oral presentation (0.1) and the blog itself (0.3)). The blog presentation and the blog content were graded by two or three instructors, depending on the year. The blog was graded in a concerted manner, was guided by a project-assessment rubric (Table A1, Supplementary material) and comprised two successive procedures; first a ranking and then the attribution of a grade. In the blogs, we looked for coherence between the different articles, the citation of sources, the relevance and quality of illustrations, and the effectiveness of the content. We also verified whether the students had used networking and communication strategies such as making blogs interactive (quizzes, polls) or connecting their blog with institutions, societies or their Facebook network. The presentation was graded for flow of information (buildup of subject), quality of slides (clarity, visibility) and coherence between the spoken work and the accompanying illustrations.

2.7. Individual accountability for blog project

At the end of the blog presentation, students were asked to assess themselves and their team members in light of their own set of basic rules, in a manner similar to that used in the 3rd team tutorial. This exercise differed in that each evaluation item contained weighting coefficients: 0.8 (below expectation), 1.0 according to expectation (satisfactory) or 1.2 above expectation. The procedure is described in Table 2. The sum of all items constituted the student's functioning index (Asgari & Dall'Alba, 2011; Brown, 1995; Kaufman, Felder, & Fuller, 2000). This procedure led to variations in individual grades that never exceeded 5% of the team grade, meaning that the teams generally functioned satisfactorily. Team self-evaluation is important because none of the criteria set forward by the Self-Determination Theory would be fulfilled if students did not adopt a collaborative attitude. Instructors should not impose rules, nor should they wish to spy on how students operate, which is up to the team. However, team members must have formal means to draw attention to dysfunctioning, so that instructors can offer help in getting them back on the track.

2.8. Finding blogs on web

A portal page was created for the blogs on the Cell Biology Promotion website where it can be accessed through the following URL: http://www.cellbiol.net/cbe/bloggingproject.php. The blogs are in French but some have the “Google translate” option. A typical example in case is “l'asthme de A à E” (“asthma from A to E”), a blog accessible directly at URL: http://tout-sur-l-asthme.blogspot.fr/

2.9. Survey instruments and data analysis

This was a mixed methods study with collection of both qualitative and quantitative data. This is a typical approach where, because of the novelty of the procedure, open questions are asked first to establish which aspects should be highlighted in a subsequent quantitative survey. Course questionnaires were distributed at the end of the blog-presentation session (see Fig. 1a). From 2013 to 2015 the survey contained predominantly qualitative questions. In 2016, we added the quantitative Intrinsic Motivation Inventory (discussed below). Students filled out the survey individually and anonymously and were informed that their participation in the study, or not, did not impact their grade and that the information could be used at a group level for a scientific publication. Over a period of 4 years, 140 out of 143 students participated in the surveys, thus excluding the possibility of a selection bias (see Table 1).

2.9.1. The qualitative open-ended survey

Because of the novelty of the science writing project for the students and ourselves, we initially sought to gather students' perceptions of the project in a qualitative manner. We were curious to find out whether students used terms that refer to a sense of autonomy, competence and relatedness, without any suggestions on our part (Fulmer & Frijters, 2009; Slater et al., 2015). We repeated this questionnaire over a number of years to learn how consistent these feelings were. From 2013 to 2016 we asked the following three questions: 1) What did you find most valuable in the blog project? 2) What features were not satisfactory? 3) Do you have suggestions for improvement?

Once we had learned that students appreciated the team effort, we sought to know what they appreciated. We asked the following two questions (from 2014 to 2016): 1) Has team work contributed to the

Table 2
Procedure for calculating individual grades (individual accountability).

Team A, 4 members	Member 1 about herself			Other 1 about member 1			Other 2 about member 1			Other 3 about member 1			Functioning
Report of member 1	Below	Satisf	Above	Below	Satisf	Above	Below	Satisf	Above	Below	Satisf	Above	
	0.8	1.0	1.2	0.8	1.0	1.2	0.8	1.0	1.2	0.8	1.0	1.2	Weighting factor
Is on time in meetings		X		X			X			X			
Respects deadlines for assignments		X		X				X			X		
Participates in discussions		X			X			X			X		
Does not impose personal opinion		X			X			X			X		
Stays on task throughout meetings		X		X				X			X		
	0	5	0	2.4	2	0	0.8	4	0	0.8	4	0	
	5/5 = 1.0			4.4/5 = 0.88			4.8/5 = 0.96			4.8/5 = 0.96			Points/ basic rule

Member functioning index (1 + 0.88 + 0.96 + 0 0.96)/4 = 0.95
Individual grade coefficient = member functioning index (0.95)/average of team functioning
Individual grade = team grade X individual grade coefficient
Example for team member 1: team grade for blog is 14/20, average team performance is 0.98, so individual grade is calculated as: 0.96/0.98 × 14 = 13.7/20

Teams set their own basic rules (in the range of 5 to 7). At the end of the course they assessed their own contribution and that of team members on the basis of these rules. When students achieved a result below expectation, they were given 0.8 points for that rule. If their performance was satisfactory, the coefficient was 1.0 and when they functioned above expectation they could get 1.2. Collectively this led to an average contribution, number of points divided by number of basic rules. The average evaluation of all the team members provided a member functioning coefficient. This procedure was performed for all team members, leading to an overall team performance which served as the 100% benchmark. Students below that mark got a grade lower than that of the team, while students above the mark got a grade higher than the team grade. Calculations were performed on an Excel spreadsheet.

quality of the blog: YES/NO. 2) If so, explain how. This would provide us extra information about the importance of relatedness and collective competence, as well as the nature of the task. Because the blog project is part of the cell biology course, we asked whether the blog project had raised their interest in the discipline and helped them to explore the different subjects. We also asked the students to grade the work load. A table of the survey instruments used in this study is available in Supplementary material (Table A2, Supplementary material).

2.9.2. Data collection and analysis of qualitative survey

The data from the qualitative questionnaire and a description of the valuable and less satisfactory features in the students' own words were analyzed in a two-step process:

1. Thematic analysis in which the students' remarks were translated into higher level themes deductively using the framework of Self-Determination Theory. Codes that did not fit into autonomy, perceived competence or relatedness were added as separate themes, interest & enjoyment and value & usefulness, according to the other subscales of the Intrinsic Motivation Inventory. Coding was done independently by the two authors (coder 1 and 2). Any differences of opinion were resolved through consensus (Braun & Clarke, 2006). Out of 409 student remarks, there were 34 mismatches.
2. Quantitative assessment of the qualitative remarks, generating fractions for each theme in the positive and negative comments (Wouters et al., 2014) (see Table 3).

2.9.3. The quantitative survey – the intrinsic-motivation inventory

We next sought to know whether the sense of autonomy, relatedness and competence led the students to adopt an autonomous learning

Table 3
Data collection and analysis of qualitative survey.

2015: What did you find most valuable in the blog project?	Coder 1	Coder 2	Consensus
The pleasure of discovering, of understanding	A	A	
The study of things beyond the lecture program	A	A	
Learning by myself	B	B	
Working in a group	C	C	
Personal involvement	B	B	
Autonomous search for knowledge	B	B	
Good communication between group members	C	C	
Involvement and help from the teacher	C	C	
Team work	C	C	
Learning new things, new concepts	A	A	
Coming together, being together & working on project	C	C	
Freedom to create everything	B	B	
Learning to create a blog	D	E	E
Team work	C	C	
etc			
Occurrence of subscales (example of 2015)	Number	Fraction	
A. Interest & enjoyment	21	0.239	
B. Autonomy & choice	10	0.114	
C. Relatedness	18	0.205	
D. Perceived competence, valorization	25	0.284	
E. Value & usefulness	14	0.159	
Sum of student comments for 2015	88	1.0	

This table illustrates how we coded student replies independently to the question of what were the positive features of the project. We coded each reply according to a restricted set of 5 criteria thought to enhance autonomous motivation. Thus we coded “the pleasure of discovering, of understanding” as A, interest & enjoyment, etc. This was repeated for the 409 comments. Of these we had 34 disparate scores (8%) between coder 1 and coder 2 and these were further discussed until consensus was obtained. For each year, we calculated the fraction of A's, B′s, C′s, and so forth, and plotted them in a histogram as presented in Fig. 2. This method quantifies the qualitative results by showing the prevalence of student remarks over the years. The same procedure was applied for the remarks about the negative features of the project, but here we were not limited to the themes of autonomous motivation.

approach. In 2016 we asked them to complete a full-scale standardized reliable and validated Intrinsic Motivation Inventory (originally developed by Ryan and Deci) (Deci et al., 1994; McAuley, Duncan, & Tammen, 1989). The original questionnaire can be retrieved from the Self Determination Theory website (http://selfdeterminationtheory.org/intrinsic-motivation-inventory/). Although referred to as the IMI, the survey measures more than just intrinsic motivation; it covers a range of criteria that indicate whether or not students adopted an autonomous learning approach. These criteria are classified into 7 subscales; a) interest/enjoyment (a self-report measure of intrinsic motivation), b) perceived competence (measure of competence), c) effort/importance (a predictor of competence, predictor of autonomous motivation), d) pressure/tension (negative predictor of intrinsic motivation), e) perceived choice (predictor of autonomy), f) value/usefulness (measure of relatedness to subject, predictor of autonomous motivation) and g) relatedness (measure of social relatedness) (see Figs. 2 & 4).

The questions were translated into French with the help of a French biology teacher. In order to verify whether the questions of the French version resembled the original meaning, one of the members of the Language Department at the University translated them back into English. Three questions had to be rephrased until agreement was obtained (see Table A3, Supplementary material). This is a best practice procedure prescribed for cross-cultural use of self-report questionnaires (Beaton, Bombardier, Guillemin, & Ferraz, 2000).

2.9.4. Data collection and analysis of quantitative survey

The data from the full Intrinsic Motivation Inventory questionnaire were collected and analyzed as shown in Table 4. The average value of each subscale (repeated for 33 students) was fed into a statistical program that calculated the mean values and presented the data in the form of a boxplot (Kirkman, 1996). The boxplot indicates the lowest mark (lower vertical bar), the lower-, median- (double horizontal bar) and upper quartile ("the box") and the highest mark (upper vertical bar). The numbers in the boxes represent mean values of the student replies. Values greater than 4 (for interest/enjoyment, perceived competence, effort/importance, perceived choice, value/usefulness and relatedness) are considered as positive predictors of autonomous motivation. Pressure/tension is a negative predictor of autonomous motivation and the average value should be below 4. Interest/enjoyment is a specific measure of intrinsic motivation. The individual values of each subscale (repeated for 33 students) were fed into the SPSS program (IBM) for measurement of internal consistency (see below).

2.9.5. Reliability of sub-scales of Intrinsic Motivation Inventory

The validity of the Intrinsic Motivation Inventory had been established previously (McAuley et al., 1989). With respect to internal consistency, a reliability Cronbach-alpha analysis was applied for each of the subscales. This measure indicates whether students interpreted the questions in a consistent manner, meaning that they understood the question and replied consciously rather than in a random fashion. All subscales, except interest/enjoyment and perceived choice, had acceptable or good reliability. The overall questionnaire may be considered reliable (for Cronbach alpha values, see Fig. 4, bottom row).

3. Results

3.1. Brief description of blogs

Most of the blogs dealt with human immunological, physiological or pathological issues, while only a few concerned subjects such as the use of cannabis, coffee consumption and hydrostatic equilibrium in plants (see Table 5). All the blogs were organized as a learning document: starting with generalities and ending with a detailed molecular description of cellular components involved in the phenomenon described. One team examined the subject of sweating and designed and performed an experiment to test the efficacy of deodorants. They tested different products, took armpit samples of the subjects, used Petri dishes and counted bacterial colonies. Among the comments on this blog were two questions from secondary school students, who asked for more detail so that they could repeat this experiment in their biology class. Three teams had inserted a Google poll to learn about cannabis use, sleep disorders and the impact of coffee, and human organ regeneration. These teams had managed to involve hundreds of participants. Finally, another team studied Bruton's syndrome, an immune disorder, and obtained help from a pediatrician. Together they attended a few consultations to learn more about patients' symptoms and their treatment. They translated this experience into a question-answer dialogue at the start of their blog. Many groups added quizzes to liven up their blog, added polls to ask visitors to assess their work, and one or

Table 4
Data collection and analysis of quantitative Intrinsic Motivation Inventory.

Replies of student 1	1	2	3	4	5	6	7	Points	
Subscale A: Interest, enjoyment									
I really liked this blog project very much							X	7	The outcome of each item was fed into SPSS to calculate internal
Completing the blog was fun							X	7	consistency of replies on subscale
I found this blog project boring (reversed question)		X						6 (8–2)	
The blog project did not hold my attention at all (reversed question)		X						6 (8–2)	
I would say that the blog project was really interesting							X	7	
I enjoyed writing the blog							X	7	
	Average score on subscale							6.7	Data for box plot
Subscale B: perceived competence									
I think I am quite good at this type of task						X		6	The outcome of each item is fed into SPSS for calculation of internal
Compared to other students I think I did quite well in this project						X		6	consistency for the replies to the subscale
After working on the blog for a while I began to feel quite competent					X			5	
I am satisfied with my performance on this task						X		6	
This was an activity that I could not do well (reversed question)	X							7 (8–1)	
	Average score on subscale							6.0	Data for box plot

The Likert grades that students gave to each statement of the inventory were scored as points between 1 and 7. In the event of negative statements, the count was reversed, 8 minus Likert grade. The average of all statements was calculated for each subscale (33 students). These data were fed into a web-based program that created box plots as shown in Fig. 4. The grades of each separate item (45 in total) were fed into the SPSS program (IBM) to obtain the Cronbach-alpha value.

Table 5
Global overview of blog subjects, number of visits, comments, Facebook likes received, and types of activities offered to visitors.

Subject	Visits	Comments, Facebook likes	Activity for visitor	Subject	Visits	Comments, Facebook likes	Activity for visitor
year	2013			year	2014		
sweating	11,482	3	experiment	anesthesia	20,240	0	–
human hydrostasis	12,061	3	quiz	cannabis & appetite	12,540	5	quiz
plant hydrostasis	17,350	0	quiz	taste for pleasure	16,078	13	recipes
asthma	39,514	5 comments 234 likes	–	influenza	10,131	1	puzzle
caffeine	7253	0	–	insulin	?	0	–
teeth	9529	1	quiz	Bruton's syndrome	?	2	–
breast milk	22,377	63 likes	quiz	serotonin & depression	4317	145 likes	quiz
cystic fibrosis	12,826	8	quiz	hair	?	128 likes	–
panic and adrenaline	11,963	1	–				
animal toxins	43,343	15	–				
year	2015			year	2016		
multiple sclerosis	6208	0	–	sleep	6263	15	Google poll, 1800 participants
stem cells	8940	0	–	coronary heart disease	10,011	15	–
celiac disease	19,628	20	quiz	food addiction	9644	10	recipes
auto-immune disease	8505	2	–	cannabis	5100	5	Google poll, 290 participants
vaccination	4746	17	quiz	multiple sclerosis	7257	9	–
immunity of transplants	27,430	2	–	diabetes type 2	9645	4	–
				organ regeneration	8293	9	Google poll,?

Note that most subjects dealt with human immunology, physiology and pathology and that they obtained about 5000–10,000 visits per year. The blogs receive comments and when students have created a dedicated Facebook page, they get likes. Note that three teams had organized Google polls, which involved 1800 participants in the case of the subject of coffee and sleep.

two blogs contained short animations. The most visited blogs dealt with animal toxins, asthma and organ transplants. Each of them had an average of 11,000 visits per year. These blogs were characterized by a very systematic approach to the subject. The asthma group ("Asthma A to E") excelled in being able to pinpoint a number of important issues in an otherwise complex immune disorder. This team also created a lively Facebook page. The least visited blog dealt with serotonin and depression and received only 1816 visits per year.

3.2. Students' expressions of positive features correspond with criteria for autonomous learning whereas negative comments mainly concern learning obstacles, cognitive load and work load

3.2.1. Positive features of blog project

There were more positive comments (409 in total) on the project than negative ones (237 in total). Students made on average 2.92 positive remarks with remarkably little variability over the four years (ranging from 2.6 to 3.1). With respect to the positive features, students said that they learned a lot, liked literature searches and appreciated the teamwork which allowed them to learn through debate and exchange of information. They felt empowered by making their knowledge and skills accessible to peers and laymen. They appreciated the freedom of choice and having responsibility for their own learning. They expressed their pleasure at having had the opportunity to explore cell biology in a self-regulated fashion. Finally, they mentioned that they appreciated the information and communication technology (see also Fig. 2, right hand column). The appreciation of team was reflected by the fact that only 2 teams out of 34 reported failure by one of its members to respect the basic rules. The tutorials gave the same impression; the teams operated in a coherent fashion, delegated tasks effectively and sought to be productive.

We codified the student replies to the five themes as indicated in the results section (2.9.3) and counted their occurrence over a period of four years (2013–2016). We plotted individual years to reveal how the occurrence of the remarks varied from year to year. Cohort cultures were shown to play an important role in collective class feelings. For instance, the relative importance of the value/usefulness of the project was very high (45.5% of all remarks) in 2013, whereas it represented only 14.1% of all remarks in 2016. Students found the project particularly "interesting and enjoyable" in 2015, accounting for 23.9% of the remarks, whereas this criterion received only 5.8% in 2013. However, two sets of criteria stood out as being both consistent and prominent, with a steady occurrence of 45.8% of all remarks, namely those dealing with a sense of competence and social relatedness. Typical remarks of relatedness were: "working in a group", "team work", "coming together, being together and working together", "sharing knowledge with each other", "discussing things that I learned with my class mates", "I found the interaction with the group very enriching", "team work is motivating", "setting up a project, as a team". Typical remarks of competence were: "being useful", "making the images and designing the website", "being able to write for laymen", "getting positive feedback from visitors", "creating a blog that is visible on the web is new to me and very good", "I loved to create a blog from scratch", "providing a complete product, detailed and unique, on the web", "being able to communicate our knowledge", "handling IT tools", "learning with computers", "carrying out a project successfully is very rewarding", "the creativity of the project" and "doing something original".

3.2.2. Negative features of blog project

There were consistently two negative features, scoring each year more than 10% of all comments, and they mainly concerned the difficulty of finding relevant literature and selecting the most valuable articles (sifting information) and understanding molecular mechanisms (cognitive load) (Fig. 3). Other negative features varied considerably over the years and, as mentioned above, may partly be explained by cohort cultures. In 2015 and 2016 students commented on the considerable effort required to find the relevant literature and translate their knowledge into a blog (i.e. excessive work load). The steep increase in perceived workload in 2015 is likely due to the fact that one other course had started a problem-based learning project. The ensuing conflict between the tasks was repeatedly reported in the tutorials so the other course and the project have now been moved to the 3rd semester. In 2014 and 2016 students reported trouble in getting to grips with the content management systems (repeated bugs in Blogger) and found it difficult to make a visibly attractive layout with their own

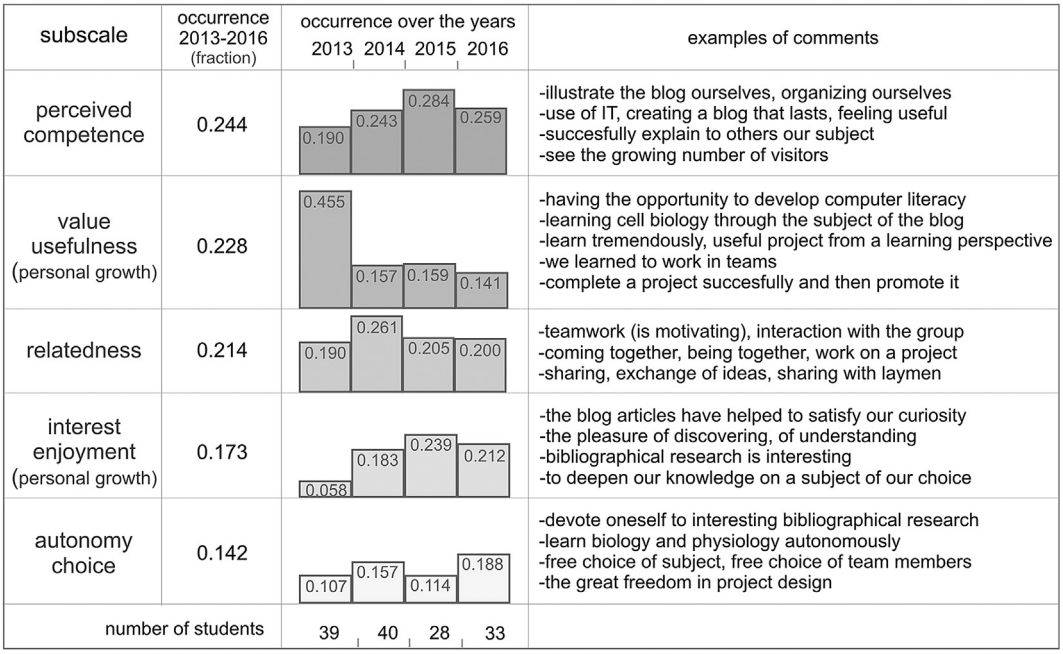

Fig. 2. Student comments about positive features of science-writing blog project. At the end of the course, students were asked to express what they found positive in the blog project. The comments of 140 students were coded according to five themes, each of which corresponds to criteria that play a role in autonomous regulation (shown in the left panels). Besides autonomy, competence and relatedness, they cited value/usefulness and interest/enjoyment. The method of coding of the replies and subsequent calculation of their occurrences are shown in Table 3. To read the figure, take the example of perceived competence. In 2013, of the 121 comments, 23 related to this theme which gives a ratio of 0.19. In 2014, of the 115 comments, 28 related to this theme and the ratio is 0.243. Of the 88 comments in 2015, 25 concerned competence, giving a ratio of 0.284, and in 2015 of the 85 comments, 22 related to perceived competence which gives a ratio of 0.259. Over a period of 4 years, the occurrence of comments about perceived competence had a ratio of 0.24, meaning 24% of the 409 replies. Typical examples of comments that we qualified as perceived competence are shown in the right-hand column. Note that the fraction of remarks concerning autonomy/choice, value/usefulness and interest/enjoyment varied greatly from year to year. In contrast, the remarks about perceived competence and relatedness were rather stable. The average occurrence illustrates that over a period of 4 years (and 409 replies), students made the most comments about perceived competence and the least about autonomy/choice.

images (IT & graphical skills). Two groups mentioned their difficulty in finding appropriate strategies to attract traffic to their blog. It should be mentioned that starting from scratch necessarily means that traffic is limited in the first weeks so students have to boost the interest for their blog in order to get a significant number of hits by the end of term. Most students used their Facebook groups to spread the news and success depended in part on how connected they were in the virtual social networks. In 2015 the students were particular anxious about the molecular page, in which they had to write about the cell biology of their subject, and felt the instructions were not sufficient or were given too late ("insufficient instructions"). Getting a consensus about the content of the blog articles within the team was another (but minor) obstacle in 2013 and 2014 (team functioning). In 2014 many students reported difficulty in writing complicated science in simple laymen's terms (ability to write popularized discourse). In the first two years, students noted that the predominantly English-language literature posed problems for them (language). Some students mentioned that they found it difficult to organize their time (autonomy) or they expressed their dislike of having to give their oral presentation in public (oral presentation).

Over the four years, the students hardly ever complained about "hitchhikers", i.e. those who got a free ride (Kaufman et al., 2000).

3.2.3. Suggestions for improvement

Students expressed the need for better instructions about the molecular page and more help with it. They suggested including illustration classes (learning to use graphical programs), they would appreciate receiving more information about blog providers, some training in dealing with content-management systems and more tutorials.

3.3. Collaborative effort contributes to success of project

Because of the overwhelmingly positive remarks about the importance of collaborative work, we explicitly asked whether team work had contributed to the success of the project and if so how? All students found teamwork important for the outcome of the blog (100% of the student replied "Yes", Table 6). Sharing ideas, information and opinions (the process of collaborative thinking) and feedback stood out as the most cited arguments for why teamwork was important. These were followed by task delegation and combining complementary skills and talents. They said that teamwork had led to better quality, broader coverage of the subject and, for some, had even acted as a source of motivation. The student replies (61 in total) could be divided into 6 major themes as shown in Table 6.

3.4. Blog project stimulates learning and enhances interest in cell biology

When asked how they graded the science-writing project as a learning tool, the students gave an average mark of 4.4 on a scale of 5. Similarly, the students found that the project enhanced their interest for cell biology and gave it an average mark of 4.2 on a scale of 5. The students worked hard because they considered that they had a fairly high work load, with an average mark of 3.7 on a scale of 5 (Table 7).

3.5. Students functioned in autonomous motivated manner and adopted mastery-oriented learning approach

Students appreciated the blog project, a feeling observed during the tutorial sessions and quantified in the Intrinsic Motivation Inventory in 2016 (Fig. 4, top panel). They found the project highly interesting and enjoyable and felt competent in creating the blog. They also found it important so they made a great effort. They did not feel tense or pressurized, valued the project and thought it useful. Team functioning obtained the highest average mark. Thus, it can be concluded that the students functioned in an autonomous manner and that science-writing in the blogosphere can be considered as an intrinsically motivating

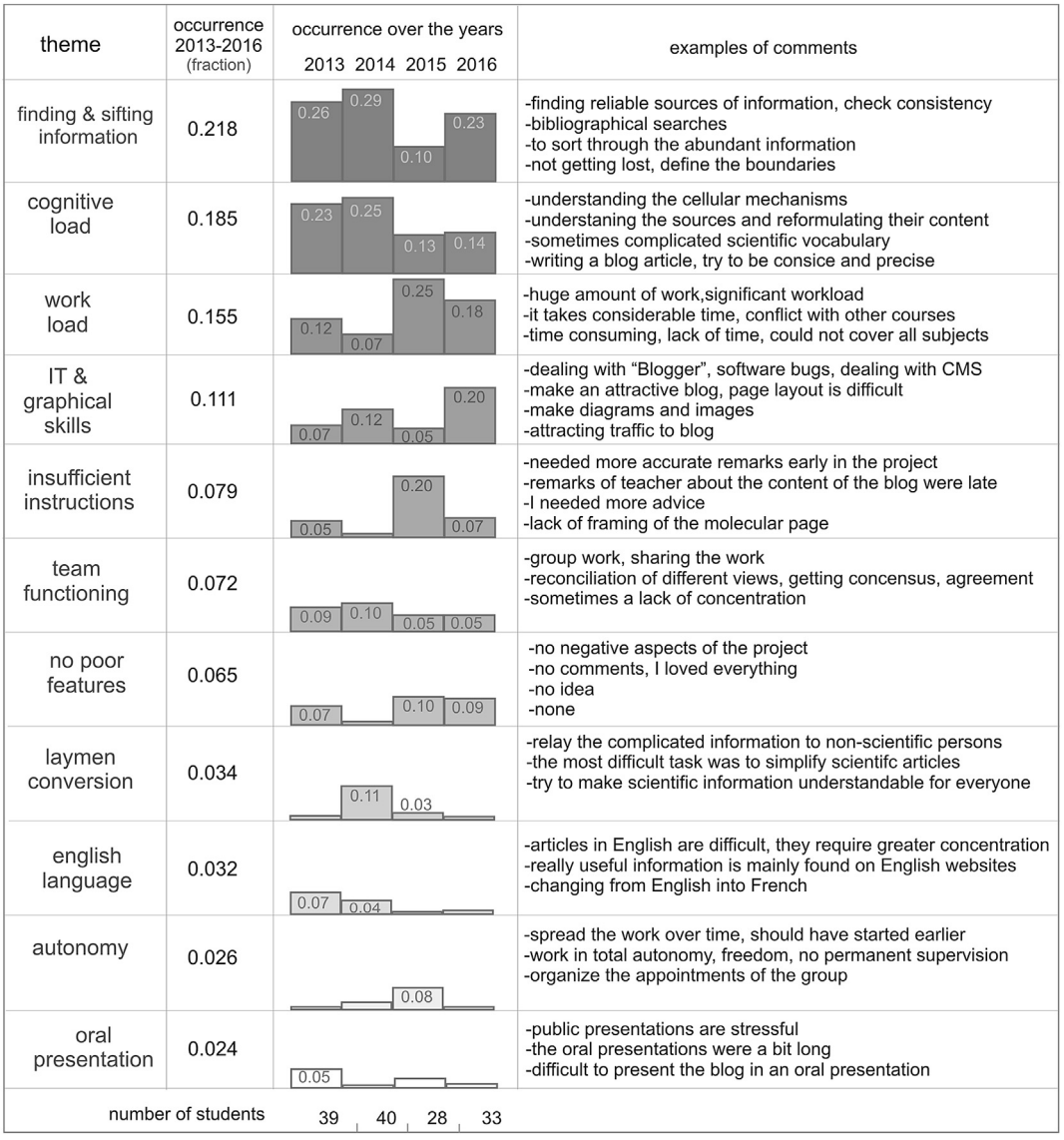

Fig. 3. Student remarks about negative features of science-writing blog project. At the end of the course, students were asked to express what they found negative in the blog project. The comments of 140 students were arranged in multiple themes, not predefined, as shown in the left panel. The average occurrence indicates that over a period of 4 years (and 237 replies), students made most remarks about the problems of finding and sifting through pertinent information while only very few remarks were made about the problem of too much autonomy or anxiety for the oral presentation.

Table 6
Student remarks about contribution of teamwork to outcome of blog.

Has teamwork contributed to the success of your project?	100% YES
Arguments how teamwork has helped	Fraction of all arguments
Sharing, collaborative thinking, multiple opinions and points of view and ideas, feedback	0.42
Task delegation, going faster	0.25
Combining complementary skills and talents, efficient	0.17
Better quality of blog	0.13
Better coverage of subject, more comprehensive blog	0.02
Motivation	0.01

In 2015 and 2016 we asked students to comment on the importance of teamwork. The 61 participants all replied in the affirmative. We again grouped the replies in themes and scored their relative prevalence (fraction of all arguments put forward). The highest occurrence of "sharing, collaborative thinking, multiple opinions and points of view and ideas, feedback" reveals the importance of both relatedness and collective competence.

Table 7
Science-writing blog project as a learning tool.

On a scale of 5 (low – fair - high)	Grade (out of 5)
As a learning tool, how would you grade the science-writing blog project?	4.4
Did the project enhance your interest for cell biology (course material)?	4.2
How did you find the amount of work?	3.7

Throughout the four years we asked students how they graded the blog project as a learning tool. The students graded statements on a scale of 1 to 5. Note that students found the work load fairly high which corresponds with the high effort/importance that they reported in the Intrinsic Motivation Inventory (subscale c in Fig. 4).

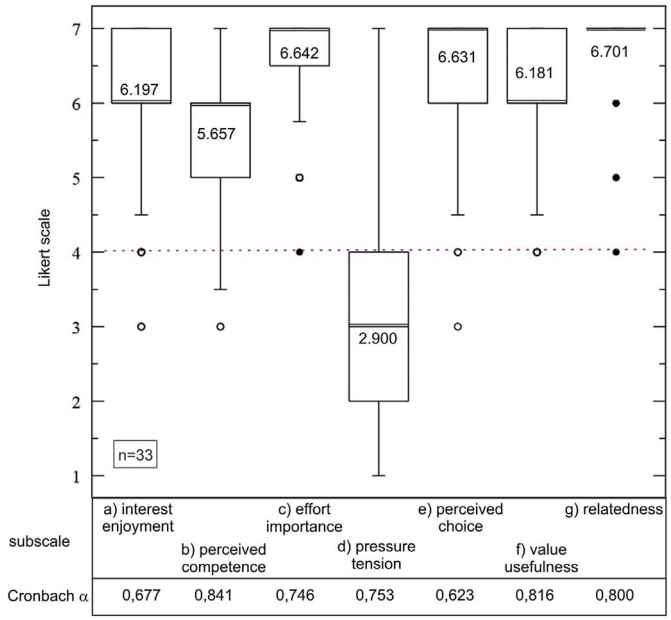

Fig. 4. Box plot representation of outcome of Intrinsic Motivation Inventory. In 2015 at the end of the course, students were administered the Intrinsic Motivation Inventory. This is a quantitative survey instrument where students answer statements by indicating, on a Likert scale from 1 to 7, to what extent they disagree or agree. The survey contained 45 statements, separated over 5 subscales (themes, a, b, c, d, e, f and g), each of which is an important criterion in establishing autonomous motivation. Data collection and calculations are illustrated in Table 4. The box plot indicates the lowest mark (lower bar), the lower-, median- (double bar) and upper quartile ("the box") and the highest mark (upper bar). The numbers represent mean values of the student replies. Filled circles are outliers and open circles are suspected outliers. Note that the feeling of pressure/tension (subscale d) varied most but lies well below the cut-off point of 4. Relatedness, subscale g, had hardly any variation and a median at 7.0, stressing once again how much students appreciated the team effort. The Cronbach alpha value shown underneath each box plot indicates the consistency of the students' rating of the statements. Note that most of the Cronbach alpha values are above 7, acceptable or good, whereas two values are in between 6 and 7, questionable, but none are poor or unacceptable. The inventory can therefore be considered reliable.

project. The very high score for "relatedness", with hardly any variation, fits with the information obtained from the open-ended questionnaires about the importance of teamwork and both results show that students unanimously appreciated the collaborative work.

4. Discussion

4.1. Blog project gives rise to autonomous motivation

For this team-based project in our cell biology course, we sought to establish a learning environment that would turn students into autonomous learners. We decided to use science-writing blogs, a choice that was grounded in the Self-Determination Theory. We evaluated the blog project in the same framework by asking whether or not students related their appreciation to the criteria of autonomous motivation, as posited by the Self-Determination Theory. The answer was in the affirmative. The qualitative evaluation surveys revealed that the positive features of the science-writing project corresponded predominantly with descriptions of conditions that are thought to enhance autonomous motivation. Students mentioned the pleasure of choice, of learning autonomously (autonomy), of working in a team (relatedness) and of feeling useful (competence). These findings are also reflected in the quantitative Intrinsic Motivation Inventory where students gave high scores for all subscales, interest/enjoyment, perceived competence, effort/importance, perceived choice, value/usefulness and relatedness, and a low score for perceived stress/tension. We conclude that science-writing in the blogosphere qualifies as an intrinsically motivating learning environment and that students consequently adopt a *mastery*-goal orientation (Dabbagh & Kitsantas, 2012; Ryan & Deci, 2000a, 2000b). Furthermore, the surveys showed that the blog-project had stimulated students' interest in the course material and that they experienced blogging as a highly rewarding learning tool.

4.2. The social dimension: when relatedness and competence merge to foster collective competence

An unexpected finding is that students consistently expressed the importance of relatedness over the study period. They expressed this positive feature in terms of working in a team, communication with the group, sharing different viewpoints, sharing knowledge with the team, sharing skills and discussing work progress with instructors but also in sharing with everybody connected to the internet. From a more detailed analysis about the importance of the teamwork, we learned that it was perceived as both a feeling of comfort and empowerment. Students perceived teamwork as comforting because they could share their workload, skills and responsibilities. They also perceived it as empowering because they could successfully manage the heavy cognitive load, cover more ground and create a higher quality product. It was also felt to be comforting and empowering in the sense that, through the multiple tutorials, the instructors also shared their knowledge and skills and took part in the construction of the blog as true collaborators (Johnson, Johnson, & Smith, 1998; Slavin, 1980). In support of this, the quantitative Intrinsic Motivation Inventory of 2016 showed that "relatedness" attained the highest scores on all subscales, with a mean of 6.7 on a scale of 7. Students clearly appreciated teamwork, one student describing the positive feature of the project as follows: "coming together, being together and working on a project".

Much of the recent research on motivation has been driven by a focus on cognitive and individual psychological aspects and has tended to discount the importance of additional contextual factors in the relationship between motivation and academic achievement (Fulmer & Frijters, 2009). What the qualitative surveys of this study reveal is that contextual factors matter considerably, in particularly the social learning environment: students need each other and need visitors to their blog. The way students appreciated team work and how it contributed to the success of their undertaking indicate that relatedness and perceived competence seem to be inseparable entities. The social dimension by itself creates a sense of relatedness and competence; in the words of the students, "being together and working on a project". We hypothesize that when students work together in productive teams, relatedness and competence merge to foster a sentiment of collective competence (empowerment), which could explain the high quality of motivation (intrinsic motivation) revealed by the Intrinsic Motivation Inventory. These findings add a new perspective to the motivation theory, namely the importance of the quality of team functioning. We postulate that autonomous motivation does not follow on automatically by putting people together in a team; it requires the creation and maintenance of cooperative and productive teams. This aspect of motivation merits further analysis and we are currently assessing how team scaffolding activities intended to support team functioning impact the quality of motivation in collaborative projects. For instance, with team support do the members experience more autonomy, more interest and enjoyment, less pressure and perceive a higher level of relatedness?

4.3. Quality of task determines quality of team functioning and impacts autonomous motivation

The above-mentioned interrelatedness between team functioning and motivation has already been mentioned in two independent studies about motivational processes in problem-based medical education (Nieminen et al., 2006; van Berkel & Schmidt, 2000). Analysis of motivational processes in problem-based medical education revealed that

team-functioning depended on the quality of the learning task (in medical terms the quality of the "case"). In the introduction we mentioned that identification with a learning task contributes to motivation in the sense that students can relate to that task. Identification in turn is facilitated by task authenticity, in other words a high quality task is an authentic task (Barab et al., 2000; Blumenfeld et al., 1991; Larmer & Mergendoller, 2010). For this reason we chose the blog format because it constitutes an authentic task in an authentic environment (Oblinger, 2012). Our students' remarks and activities confirmed this hypothesis. We highlight three aspects of authenticity that we believe positively influence team functioning and contributed to the feeling of autonomy and "collective competence". One relates to Bruffee's "conversation of mankind", the other to preparing students for future professional life and the last to the role of public exposure in perceived autonomy and competence.

4.3.1. Task authenticity: Web 2.0 and initiating students into the conversation of mankind

The social context of learning is important because of the aforementioned sense of collective competence. It is also important because knowledge or belief is established in a process of social justification. To understand knowledge, students must understand how knowledge is established in the normal discourse of communities of knowledgeable peers (Bruffee, 1984; Rorty, 1979). In essence, education is an initiation into the skills and partnership of these conversations. Students must therefore acquire the intellectual (e.g. vocabulary, concepts and scientific arguments) and moral habits (social skills) appropriate to conversation. In the introduction we argued that the web is becoming increasingly important in the process of social negotiation of knowledge. Today students, who we may consider tomorrow's experts, are likely to play a role in feeding the web-based negotiation process. They should be prepared for this task as we prepare them for writing scientific reports, seminars and other tasks (Rorty, 1991; Savery & Duffy, 1995). To use the terms of Bruffee and Rorty, through science-writing in the blogosphere, students are introduced to the community of knowledgeable peers and contribute to the generation and maintenance of the conversation within that community; they contribute to the conversation of mankind (Bruffee, 1984; Rorty, 1979). This is exactly what students reported when they commented that "the most useful aspect in this project is that the blog serves as a working platform that offers a large number of people the benefits of our thoughts". Moreover, the collaborative nature of the project engages students in conversation among themselves, and provides the necessary social context in which students can experience and practice the kinds of conversation valued by scientists. They also have the opportunity to discuss with their teachers and experts in the field. The following student comment is a perfect illustration of this: "[this project offered] a different type of dialogue with scientists and students".

The project constitutes an authentic environment because virtually all students own smartphones and Web 2.0 has become an integral part of their social life (Clark et al., 2009; Fox & Rainie, 2014; Greenhow et al., 2009). The learning task therefore is situated in an authentic real-life environment. This particular aspect provides an additional sense of social relatedness. Far beyond campus life, students are offered the possibility to share their knowledge and skills with their virtual social networks. The very act of sharing may enhance their sense of ownership (Nail, 2007). Indeed, from the oral presentation of the blog, we learned that nearly all teams sought to bring the blog to the attention of the public by making every effort in alerting their social networks about their work, mainly through the use of their own Facebook account and through Facebook groups. Students contacted all kinds of medical charities and even went out into the street to distribute flyers with QR codes that directed the recipients to their blog. In such an environment, learning can be considered to be most effective because students no longer behave as students but as practitioners who develop their conceptual understanding through social interaction and collaboration in the culture of the domain (scientific literature, Wikipedia, hospital websites, charity organizations, etc), not of the educational institution (Brown, Collins, & Duguid, 1989). Moreover, in this environment, according to Astin, students become more *mastery*-oriented rather than *performance*-oriented (Astin, 1993). To cite a relevant student comment: "the blog project allowed us to understand that a project can have a broader scope and is not just made for a teacher".

4.3.2. Task authenticity: the blog project and preparing students for future professional life

The authenticity of the blog project was also visible in how the students related their effort to their future profession. Apart from thinking that teamwork is an essential aspect of their future jobs, a number of teams even used their project to create online surveys in order to undertake a real study. These authentic experiences were expressed in the following manner: "this project has led to the foundation of a long, scientific and collective effort, [it served as] an opening to the conditions of our future profession" or "[a positive feature of the blog project is] the fact of having done a real scientific project comprising research, assimilation and restitution of knowledge".

4.3.3. Task authenticity, Web 2.0, perceived autonomy and competence

The work on cooperative (or collaborative) learning by Johnson et al. (1998) and Slavin (1980) (see also Barkley, Major, & Cross, 2014) demonstrate how multifaceted education really is and how inapt higher education instructors generally are in the implementation of constructive learning methods. There is still plenty of scope for improving our project but one of its strong features is that it makes up for some of the instructor's shortcomings. Herein resides the power of what students repeatedly refer to as sharing their knowledge: the blog is scrutinized and appreciated by a wider public – albeit virtual – and this exposure provides immense purpose to the team effort. In other words, the wide public exposure sets the condition for appropriate collaborative behavior (Slavin, 1980). This may be one of the reasons why we hardly ever received complaints about "hitchhikers". The rich social context of the web acts as a positive feedback and thus enhances perceived competence, providing empowerment to the students. They relate this as "feeling useful" or "getting the pleasure and motivation from people who comment positively about the blog". In addition, rendering their work available to the public necessarily contributes to the students' perception of autonomy because it extends the range and scope of the social interactions on which all learning depends (Little, 1996). A few blogs attained more than 10,000 visits within a year, which is insignificant compared with the millions of visits on popular sites, but it is immense compared to the attention normally obtained in scholarly group projects, which are restricted to a few classmates and one or two instructors. Here is where one aspect of authenticity truly emerges in the project, when students perceive the relationship between the practice they are carrying out (learning cell biology and rendering their knowledge accessible in a blog) and the use value of that practice (people actually consult their blog) (Barab et al., 2000). In this regard, Web 2.0 can make an essential contribution to higher education (Brown & Adler, 2008; Churchill, 2009; Hemmi et al., 2009).

4.4. Limitations of the project

From a student perspective, the negative aspects mainly concerned the difficulty in finding and sifting through essential information. In the early years (2013–2014), students mentioned the additional problem of the English language. They also repeatedly mentioned a high cognitive load and work load, each of which could be overcome by group effort and supervision.

From an instructor perspective, two points require consideration; the first concerns the assessment of the quality of the students' work and the other concerns time. Both are inherent to open-ended projects, be it blogging or any other type of task. An assessment rubric was used so

that students knew what instructors were looking for and instructors knew how to grade, but this is the easy part. Getting to a state where two or more instructors independently attributed a similar global mark proved impossible. We therefore adopted an iterative process in which we first selected the worst and the best efforts, set a bottom and top grade, then ranked the intermediates and finally provided their grades according to their rank. All of this was done in a face-to-face discussion. Major unresolved issues are: how do you deal with teams who have covered a lot of ground but unconvincingly and without a great deal of coherence versus teams who have covered little ground but in a very convincing and coherent fashion? Also, it is difficult to dissociate graphical aspects from content; how do you compare a beautifully presented blog that is full of incoherence with a boring layout but excellent content. In short, assessment is not fully objective and some students may feel they are treated unfairly in view of the enormous effort they have made. However, in this respect, the blog environment offers a bonus; just as it allows students to learn in an out-of-class environment, it also allows them to seek valorization beyond the academic setting. For instance, students can incorporate their blog into their portfolio which offers a unique way to render their communication skills visible to a potential employer. Moreover, where the instructors may have failed because of grading constraints, students may feel appreciation by the number of visits to their blog.

Concerning time, Fig. 1c shows the cost of up to 134 h instructor time for 30 students with a total of 8 teams. A large number of hours are taken up by the formative assessment of the blog with comments and corrections that allow students to improve their work. These hours are mandatory, not only because of their educational importance but because the content is exposed on the World Wide Web so the information must be correct.

4.5. Implications of this study and future directions

Given the apparent sensitivity of students for relatedness and competence, the social learning environment of students deserves more attention from higher education teachers. Rather than exclusively focusing on what students have to know, staff should invest more in how students appropriate that knowledge. Task complexity and authenticity, team effort and, importantly, exposure on the web are among the ingredients that facilitate the motivation to learn. Besides creating a suitable learning environment, teachers should also take part in the learning process by monitoring team functioning and, if necessary, providing teams with clues such as information, articles and counseling whenever they dysfunction or fail to find interesting approaches to their subject. Two future directions could follow on from this study. Given the importance of team functioning in how students perceive and invest in the learning task, we are currently testing whether team auto-evaluation procedures facilitate autonomous motivation as measured by the Intrinsic Motivation Inventory. The second is the question of project assessment: how to reconcile freedom of choice with reliable objective grading. Do students feel that their grade is fair or not? Finally, should students take part in project assessment?

5. Conclusion

In light of the Self-Determination Theory of motivation, we developed a program for an Introductory Cell Biology course that better meets the needs of autonomy, relatedness and perceived competence. As a result we have introduced structured lectures, a blend of passive and active learning methods, and have replaced the practical class with a team-based project where students create a science-writing blog on a subject of their choice but which is still related to cell biology. We have learned from both qualitative and quantitative surveys that students highly appreciate the blog task. They appreciate the freedom of choosing a subject and constructing a blog in their own fashion, i.e. working in autonomy. They express a sense of usefulness (perceived competence) because their efforts are embedded in a broad social context, the web. They express their appreciation in terms of the pleasure of sharing understanding and constructing a blog together (sense of relatedness). Moreover, the quantitative Intrinsic Motivation Inventory revealed that students worked in an intrinsically motivated fashion, i.e. they were fully "self-determined". As a consequence, staff-student contact time, both in lectures and in tutorials, has gained in quality. Besides the aforementioned broad social embedding, the success of the blog project also lies in the specific affordances of this social medium. We postulate that both the public exposure and the complexity of the task provide an immense purpose for team effort. The ensuing quality of team functioning creates a feeling of collective competence and this becomes an argument for motivation in its own right. If one considers higher education as "lighting the fire" rather than "filling the bucket" (Kusurkar & Ten Cate, 2013), then group-based science-writing in the blogosphere is an excellent learning tool.

Declaration of interest

The authors declare no actual or potential conflict of interest (financial, personal or otherwise)

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Appendix A. Supplementary data

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