Unintentional disengagement is a factor in the failure of a final exam in a moderate-structure cell biology course

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Abstract

This study is situated in the problem of student retention in a first-year science course at a large, open-enrollment university. The study examines student performance in a moderate-structure cell biology course characterized by group classroom activities, frequent knowledge quizzes, a mid-semester exam, and a moderate impact final exam. The design is learning-oriented with a gradual transition from an external, instructor-based arrangement, to an internal, student-based arrangement. Although, consistent with numerous reports, we observe much better overall student performance in this course format, the improvement is largely due to scores on the quizzes and mid-semester exam, with little improvement on the end-of-semester final exam. Using self-reports, scores, and learning analytics from a population of 462 students, we sought to understand what factors contributed to this phenomenon. We found that despite good intentions, an awareness of essential cognitive skills, and an a priori appreciation of the subject matter, about a quarter of the students dramatically reduced their viewing of web-based learning materials in the period leading up to the final exam. This group scored well below average. We conclude that unintentional disengagement is a factor in failing the final exam.
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IJsbrand Kramer designed the course formats and associated learning materials and taught the cell biology courses, Frédérique Pellerin suggested and carried out the statistical analyses and Jean-Luc Bergey participated in the design of the surveys and drafting of the manuscript.

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Running title: moderate-structure course format and situational disengagement
Abstract

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188 words

Key words: university, student retention, transition, situational disengagement, learning-oriented, course design, structure, destructive friction
A Structured Course Format to Facilitate Transition from School to Higher Education

A common problem for universities, in particular when they are non-selective, is low retention of first year students. Research on what plays out indicated that student identity, learning environment antecedents, and how students are guided in the first year of study are important factors (Briggs, et al., 2012; Harvey et al., 2006; Hillman, 2005; Tinto, 1975). With respect to guidance, to ease the transition from school to university, a more learning-oriented course design would allow students the opportunity and time to gradually adapt to the learning style required by universities (Vermunt & Verloop, 1999). A structured course format provides this opportunity. Structured refers to an interactive instructional format with a large number of teacher-controlled activities, in- and out-of-class, combined with frequent in-course assessments (Eddy & Hogan, 2014; Freeman et al., 2014). Structured courses are generally valued by students (Sander et al., 2000) and in most cases lead to better engagement and improved learning outcomes (see Kramer et al., 2022 and references therein). We believe that an important reason for its positive impact on student engagement and achievement, especially in the first year, is that a structured format is more responsive to differences in the level of regulation of learning. In unselected large groups of students, this regulation ranges from “low” to “intermediate” to “high” (Vermunt & Verloop, 1999). It is important for students in university to be guided to a high level of regulation, also called "internal guidance" or "self-regulation" (Zimmerman, 2013). Not only does self-regulation lead to better study results (reviewed in Panadero, 2017), it also takes the teaching pressure off research staff because of looser control (Ferrare, 2019), and, lastly, self-regulation is expected in the graduate job market (Ten Cate et al., 2004). Below we show how a structured course format responds to differences in the regulation of learning.

The in-class activities and quizzes are characteristic of strong teacher control, a degree of control that requires only a low degree of regulation from the learner. The assignments and in-course exams (or tests) require an intermediate degree of regulation, referred to as “shared teacher control”. The final exam, at the end of the semester, is characterized by a high degree of regulation from the student and only loose control from the teacher. Since students enter the university with different levels of regulation, conflicts between teaching style and student regulation should be expected even in a structured course. Strong initial control by the teacher is well suited to students with low levels of regulation (we speak of "congruence"), but will not be appreciated by students with high levels of regulation (it is a possible source of "destructive friction"). On the other hand, the final exam at the end of the semester represents a destructive friction for students with low levels of regulation, but it is
congruent for students with high levels of regulation (see Table S1, Supplementary Material, for an overview of conflicts between teacher and student learning regulation). Although high-regulated students experience destructive friction in this course format, it is less burdensome for them than for low regulated students. High-regulated students are better able to adapt to adverse learning conditions than low-regulated students (Beishuizen & Stoutjesdijk, 1999; Fryer & Vermunt, 2018). In other words, structured courses reduce the negative consequences of potential destructive friction.

**Signs of Persistent Destructive Friction in our Moderate-Structure Cell Biology Course**

In line with these theories, we have developed a *structured* cell biology course which qualifies as moderate-structure according to the criteria of Eddy & Hogan (2014). The format is characterized by group-based exercises and quizzes, a mid-semester exam and a low impact final exam (for detail we refer to Kramer et al, 2022). In addition to the learning-oriented advantages mentioned above (Vermunt & Verloop, 1999), a structured course in the first year also better aligns with high school teaching methods. The many knowledge tests are similar to the experience of frequent school tests, and the introduction of group activities significantly reduces the “mass experience” associated with large lecture theatres. Our presumption was that initial strong teacher guidance would help low regulated students to get engaged and develop a sense of confidence; to acquire a level of self-efficacy (Bandura, 1977). The mid-semester exam would re-inforce confidence of both low- and intermediate regulated students. Moreover, the group-based quizzes would also help to reduce the cognitive load and provide a necessary social context that would facilitate internalization of motivation and thus internalization of regulation of learning (Ryan & Deci, 2017). As we gradually guided students toward more self-regulated learning, we assumed that they would improve at all levels of assessments (both during and at the end of the course).

Consistent with the extensive literature (reviewed in Freeman, 2014), overall course performance had increased significantly in our moderate-structure cell biology course. However, this was mainly due to a significant improvement in the results of the in-course assessments. Mean final exam scores were only marginally better than in previous "classic" low-structure courses (Kramer et al., 2022). In addition, we observed a polarization in the final exam results; a larger group of very high grades and a larger group of very low grades (less than 60/200 points). It seems that the moderate-structure format had a negative impact on final exam grades of a subpopulation of students; the opposite of what we had expected.
Research Question

We were puzzled by the systematically low final exam scores of a sub-population of students in moderate-structure courses and wondered why the initial effort did not pay off for all students at the end of the semester. Why did we see such homogeneously satisfactory mid-semester scores and so little improvement in final exam scores compared to low-structure courses? Could we find evidence of some form of self-limitation at play during the final exam period, as we suggested in our previous study (Kramer et al., 2022)? We sought to gain an understanding of what students say, their intentions, and what they do, their behaviors, and how these relate to performance (scores and grades). We used student self-report, with surveys at the beginning and end of the course, and we used learning analytics, monitoring access to web-based learning documents throughout the course. In the survey at the beginning of the course, we asked students questions about their a priori mental representation of cell biology, their aspirations, and their awareness of essential cognitive skills. In a second survey, addressed to students who had failed the final exam and to students who had done very well (focus groups), we asked about the reasons why they had failed the final exam or, for the second group, why they thought their peers had failed. The analysis provides evidence that situational disengagement of a subpopulation in the second period of the course is a factor in final exam failure.

Methods

Participants Characteristics and Ethics

Participants (n = 462) consisted of science students with a mean age of 19.1 years, SD = 2.62. Females comprised 66.3% of the population. The field of study was Life, Earth and Environmental Sciences at a French university with open enrollment (for more detail see Kramer, et al. 2022). A quarter of the students are second-entry, meaning that they come from another higher education institution or are doing their first year of study for the second time.

Our university does not have an Institutional Review Board to determine what surveys or student behavior analyses may be conducted. In accordance with APA ethical compliance guidelines (https://www.apa.org/ethics/code), this study does not require written consent because it involves normal educational practices with respect for confidentiality. Information is treated and published anonymously so that disclosing responses would not expose participants to criminal or civil liability or harm their financial standing, employability or reputation. Students were informed at the beginning of the course that we were conducting a study of how they functioned in the moderate-structure format,
that participation in the surveys was voluntary, and that whether or not they participated would not affect their course grades in any way. We also mentioned that we might use the data for a scientific publication and that the results would be presented anonymously (no names revealed).

**Characteristics of the Moderate-Structure Cell Biology Course**

The current study concerns an introductory course in cell biology (3 European Credit Transfer and Accumulation System (3 ECTS)), which is offered once a year in the second (spring) semester. The course is required of all first-year biology students. For other courses offered in the spring and their instructional formats, we refer to Kramer et al. (2022).

We characterize the cell biology course as *moderate structure* (Eddy & Hogan, 2014). Essential features of the course format are: in-class group-based exercises and clicker quizzes (using Turning technologies), graded and non-graded. The course had a mid-semester exam and a comprehensive final exam. The weight of the quizzes was 0.2, the mid-semester exam was 0.4, and the final exam was 0.4. For more details and a timeline of the course, see Figure 1. In addition, all course materials, such as slides, multimedia resources, and interactive self-assessment quizzes, were online (Moodle). The cell biology multimedia resources were hosted by UniSciel (UniSciel, 2023). For more detail we refer to Kramer et al. (2022).

*Figure 1* Time line of the Cell Biology Course: Lectures, Laboratory Classes, Exams, Graded Clicker-quizzes, Surveys and Periods of Tracelogs (Learning Analytics).
In terms of clicker quizzes during lectures, students were challenged at different cognitive levels, ranging from "knowledge", level 1, to "application", level 3, of Bloom's taxonomy of cognitive levels (Bloom, 1956). Their mode of application was largely inspired by the active learning suggestions proposed by Eddy et al. (2015). In the mid-semester and final exam, we used multiple-choice questions and annotation of images of subcellular compartments. Both types of questions were at "knowledge" level 1 (Bloom, 1956). Students were given access to all possible exam questions through interactive online quizzes on the web (self-assessment of knowledge). Students were informed that the images were a selection of images presented in the course slides. Our goal was to reduce exam anxiety as much as possible, especially for low regulation students; they knew what to expect and could prepare in a focused way. Although this approach may frustrate high-regulation students, as we already mentioned, there is ample evidence that these students can adapt to different assessment styles, whereas low-regulation students are much less able to do so and clearly appreciate multiple-choice questions (Beishuizen & Stoutjesdijk, 1999; Zeidner, 1987; Sambel & McDowell, 1998; Struyven et al., 2005).

**Measures**

This is an observational study with quantitative methods.
Surveys

Pre-survey (offered to all students): We offered an online questionnaire at the beginning (first week) of the course, asking students questions about their mental representation of cell biology, how much the topic appealed to them, and how much they felt competent to complete the course. We also asked some questions about general cognitive skills. We asked students to rate the following statements: the importance of not being distracted (Baddeley, 1994); the importance of repeatedly testing knowledge to build long-term memory (Karpicke & Roediger, 2008; Roediger & Butler, 2011); the importance of understanding the material to learn effectively (Zaromb et al., 2010; Novak, 2002); the importance of enjoying learning to build long-term memory (Ryan and Deci, 2000a, 2000b). The pre-survey can be found in the Supplementary Material (S1 Pre-survey Questions). The main reason for this survey was to increase internalization of students' motivation by making the value of the learning activity explicit to both the teacher and the student (Vansteenkiste et al., 2006). A second reason was that we wanted to know what the a priori thoughts were about the cell biology course, to make sure that low grades were not simply the result of a lack of affection for the subject or a lack of awareness of cognitive skills. A total of 246 students (54%) completed the questionnaire. The course grades of the students who participated in the pre-survey were better than those of the non-participants (mean grades of 135.8/200 and 121.6/200, respectively), and thus the survey participants were not fully representative of the total population. However, they had a sufficiently large number of final exam failures (81) to be useful for statistical description and analysis (see Table 1).

**Table 1. Student Numbers and Percentages of Populations Concerned that Are Involved in the Descriptive Analysis of this Study.**
Post survey (focus groups): We also offered a questionnaire after the course to a selected number of students, divided into two groups. The first group were the students who had failed the final exam, scoring below 100/200 points, and the second group were those who had done very well, scoring equal or above 150/200 points. The students who received the survey were enrolled in the second year (third semester), which means that they had not given up the idea of continuing their biology studies. We note that 60% of the students who failed the final exam had enrolled for the third semester. We asked the high-scoring students for their opinion because they had all worked in groups of 5 or 6 members throughout the cell biology course and thus had a reasonable impression of their fellow students. Students in these focus groups received a personalized email with 4 suggestions as to why they had failed the final exam or why they thought their peers had failed, plus a 5th option in which they could provide another reason (see Supplementary Material S2 Post-survey questions and personal comments). Using a 1-5 Likert scale, students could indicate to what extent the statement was true (strongly disagree, disagree, neutral, agree, and strongly agree). Of the 135 low-scoring students, 25 responded, and of the 75 high-scoring students, 37 responded. The reason for a double focus group is to better understand what happened. The two groups have different social compliance; the high-scoring group is not exposed to possible moral judgments. The two groups are also likely to have different levels of mental awareness. For both reasons, high and low achievers would report a different reality (Holden, 2007; Zimmerman, 2008).

Learning analytics

We analyzed students' visits to key learning documents in the university's course management system (tracelogs on Moodle). The great advantage of tracelogs over self-reports is that the data are less biased by social desirability (or social compliance) and self-serving attitudes (Zimmerman, 2008). In addition, not everyone has full (mental) access to the reasons for their behavior and goals, and competencies and needs are not necessarily explicit (Holden, 2007). The learning documents concerned were: multimedia sources of course content, lecture slides, and interactive multiple-choice quizzes (self-assessment of knowledge). We divided the analysis into two periods: period one, from the beginning of the course to the mid-semester exam, and period two, from the mid-semester exam to the final exam (end of the semester). The reason for this is that the two periods have different levels of learning regulation: the first period is characterized by low (in-course quizzes) and medium (mid-semester exam) regulation, while the second period is dominated by high regulation due to students' preparation for the final exam.
We analyzed student performance by collecting individual mid-semester and final exam scores, course grades, and semester grade point averages (semester grades). We did not use the clicker quiz scores because they are group scores.

**Statistics and Data Analysis**

Version 3.5.1 of the R software, completed with the "car" 3.5.1, a "mosaic" 3.5.3 package and with FactoMiner, was used for statistical analyses ([R Core Team, 2018](http://example.com)).

**Principal Component Analysis of Students’ Self-reports, Web-visits and Achievement**

We created a single database containing, per student, pre-survey responses, gender, course scores, course grades, semester GPA, and number of visits to key online learning documents. With respect to the analysis of the pre-survey participants (n=246), Principal Component Analysis (PCA) was chosen to determine if there was any structure in the student data. We constructed a circular correlation plot around two dimensions (factors PC1 and PC2). With these approaches, we wanted to explore how self-report and learning analytics are related; in other words, how self-report data and web visits contribute to individual scores and grades (student achievement). Does the level of a priori confidence, interest in the subject, or awareness of cognitive skills play a role in failing the final exam? We note that we did not find any gender bias in any of the measures and will not address this issue.

With respect to the relationship between web visits and student performance, because we had systematically observed a significant decrease in student performance on final exams compared to mid-semester exams in moderate-structure courses ([Kramer et al., 2022](http://example.com)), we focused on what happened in the period leading up to this exam (referred to as period 2 in the course, Figure 1). We decided to transform the number of web visits in the second period into separate classes in order to limit the impact of extreme values in the analysis (the range of visits goes from 0 to 426 (Figure 3). To do this, the cohort (462 students) was divided into four classes, each with the same number of students (115). The first class had low visits (0 - 9.25), the second had low-medium (9.25 - 36), the third had high-medium (36 - 69.75), and the fourth class had high visits (69.75 - 426). We then integrated these four classes (as nominal values) into a two-dimensional PCA analysis (PC1 & PC2) of different scores and grades.

**Focus Group Survey ANOVA**

The focus-group responses to the question of why students failed the exam were grouped into two categories: external causality arguments ("the final exam was more difficult", "competition with
other disciplines") and internal causality arguments ("being satisfied with course grades", "losing interest in the subject") (see row "average" in Table 3). For these averages of each participant of the two groups, high and low exam scores, we applied a Type III ANOVA followed by a post hoc Bonferroni test to analyze pair-wise significance.

Results

Primary Component Analysis Reveals no Correlation Between Students Self-reports and Learning Analytics.

A correlation matrix of individual students' self-reports (pre-survey outcome), achievements (scores and grades) and web visits revealed no correlation between what students report and what they do (learning analytics) (Table 2). If anything, the correlation is often negative. We take this to mean that failure in the final exam is unlikely to be the result of an a priori negative view of cell biology, nor of a deficit in ambition or awareness of certain cognitive skills. This lack of correlation is clearly visible in a two-dimensional PCA circular correlation-plot (Figure 2), which shows that the data are clustered differently for the two dimensions: Factor 1 is strongly loaded by scores and grades, "what students do", whereas Factor 2 is mainly loaded by self-report data, "what students say".

Table 2. Correlation Matrix of Student Self-reports, Achievements and Web-visits
Legend. Note the lack of correlation between self-reports (ambition, confidence, ..., understanding, repetition, ...) and student achievements (in-course score, final exam score, ...). There is however an appreciable correlation between student achievements and web visits.

*Figure 2. PCA Circular Correlation-plot of Variables of Self-reports, Scores and Web Visits.*

Legend. Self-reports and learning analytics have opposing dimensions which indicate that the variation in student achievements is not explained by their perceived confidence in achieving the course or their awareness of essential cognitive skills. Dimension 1: mainly represented by values from learning analytics (web-visits to learning documents and student achievements). Dimension 2: mainly represented by the replies of students to the pre-course survey. Vp1 and vp2 are the number of web-visits in the first and second period of the course respectively.

The two, “saying” and “doing”, have completely opposite dimensions, again suggesting that self-reports have little or no relationship with achievement. The web visits in periods 1 and 2 (vp1 and vp2) make a significant contribution to the first dimension, which is dominated by student scores and grades. Note that mid-semester scores and vp1 have weak positive loadings on dimension 2, whereas final exam grades and vp2 have weak negative loadings. This is consistent with our previous observation of a shift in students' performance, and possibly a shift in their learning behavior, between the two course periods (Kramer et al., 2022).

**Very Low Web Visits in Period 2 Correlates with Below-average Performance**

Having established that students' a priori representations of cell biology and their awareness of a range of cognitive learning skills were unrelated to their performance, whether in the final exam or otherwise, we next focused on the relationship between web visits and performance. As shown in Table 2, there was a moderate correlation between the two. We observed a strong decrease in visits between the two course periods: the mean value before the middle of the semester (period 1) was 73.2 (SD =
55.56), whereas for period 2 the mean value was 48.8 (SD = 52.41). This reduction is best seen in a scatterplot with individual students (Figure 3), where the points in the grey triangle represent students with fewer visits in period 2 than in period 1 (note the much larger number of points in this triangle). The graph also shows a large population (15% of the cohort) with zero visits in the second period (zero value on the y-axis).

We note that the decrease is not necessarily explained by a reduction in the number of resources to be consulted. The mid-semester exam covered resources 1 to 6, whereas the final exam covered resources 1 to 12 (the whole course content), with 67% of the questions dealing with resources 7 to 12. If anything, students had more ground to cover, more to learn, in preparation for the final exam. It should also be noted that the reduction in numbers concerns all activities; visits to multimedia documents, slide shows and, surprisingly, interactive self-assessment quizzes. In order to see how web visits relate to performance, especially those in period 2, we divided the student population into four different classes of web visits (the one leading up to the final exam), each class with the same number of students (n = 115) (represented by the horizontal lines in Figure 3). The corresponding student performances show that all classes had lower final exam scores than mid-semester exam scores, but the reduction was disproportionately large for class 1, where the mean final exam score was only 58.1% of the mid-semester score (table inset in figure 3). The same is true for exam failures, where there was a disproportionate increase in exam failures for class 1. Further examination of class 1 reveals a significantly lower frequency of visits in the first period, with a median of 34.5, and a significantly lower score in the mid-term exam, compared to all other classes (M = 131, SD = 34.3). Overall, this is a vulnerable population.

Figure 3. Scatter Plot of Web-visits of Individual Students in Period 1 and -2.
Legend. The scatterplot reveals the differences in visits of individual students in period 1 and -2. The bisector shade has been added to demonstrate the shift to the right (more visits in period-1). Note the large group of students with zero visits in period-2 (y-axis). We have separated the population in 4 classes of 115 students each with different numbers of visits in period 2 (0-9.25, 9.25-36, 36-69.5 and 69.5-426 visits). We added the numbers of final-exam failures in each group and the mean values of their in-course and of final-exam scores. The class 1, with very low visits in p2, had a disproportionate rise in exam failures with a concomitant disproportionate drop (58.2%) of the mean score of the final-exam compared to in-course achievements.

To get a more global visual impression of how these four classes performed in general, we next integrated them into a PCA graph of individual scores with two dimensions (Figure 4). The inset shows the different loadings of the two dimensions (contributions of different scores and grades). Most of the variance (81.92%) is explained by dimension one, with high loadings of final exam scores and course and semester grades. The mean of class 1 positions in the lower than average score on the dimension 1 axis. The low and high-medium classes (2 and 3) are at the mean, while the high attendance class (4) is above the mean. The scores and grades of the classes are significantly different, with the exception of classes 2 and 3, which are similar (p-values in the range of 0.14 and 0.85 respectively).
**Figure 4. Integration of Different Classes of Web-visits in Period 2 into a PCA Graph of Individual Scores.**

Legend: The four different classes of students, based on their web visits in the period of preparation of the final exam (period 2), reveals that the mean PCA values of the class 1 (low-visit students) situates in the below-average area of dimension-1. The mean grade of the class 4 (high-visit students), on the contrary, situates on the right, in the group with above average-scores for dimension-1. The contribution of the different scores and grades for dimension 1 and -2 are shown in the PCA circular correlation-plot of individual scores on the right.

**The Post-survey Reveals Signs of Disengagement**

Having observed that low web visits (< 9.25) in period 2 were associated with low final exam scores and low overall performance (semester grades), we next asked students why they thought they did poorly in the final exam. We grouped the answers into two categories: external causality and internal causality arguments ('average' row, see Table 3). Students who failed the exam (low exam-score) gave little weight to internal causality arguments (M = 1.54, on a Likert scale of 1-5) and much more weight to external causality arguments (M = 3.26) (i.e. "the difficulty of the exam" and "competition with exams in other disciplines"). The high-score students did put more emphasis on internal causality arguments (M = 2.82); their peers failed because “they were satisfied with the grades in the course” or because “they had lost interest in the subject". They also agreed that external factors were involved, albeit to a lesser extent (M = 2.58) (Table 3). A Type III ANOVA test revealed significant differences between students with low exam scores and those with high exam scores, F(3,75) = 21.76, p < .001. Bonferroni
post-hoc tests revealed that this involved 4 out of 6 possible combinations. Two were not significant: "high exam score students internal causality" versus "low exam score students external causality" (p = 0.26) and "high exam score students internal causality" versus "high exam score students external causality" (p = 1.00).

Table 3. Student Replies to the Focus-Group Survey About Reasons of Exam Failure.

<table>
<thead>
<tr>
<th>reasons of final exam failure</th>
<th>weighting of arguments</th>
<th>weighting of arguments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>SD</td>
</tr>
<tr>
<td>final exam was more difficult</td>
<td>3.12</td>
<td>0.97</td>
</tr>
<tr>
<td>competition with other disciplines</td>
<td>3.4</td>
<td>1.32</td>
</tr>
<tr>
<td>satisfied with in-course scores</td>
<td>1.8</td>
<td>1.04</td>
</tr>
<tr>
<td>lost interest in Cell Biology</td>
<td>1.28</td>
<td>0.61</td>
</tr>
<tr>
<td>average</td>
<td>3.26 **</td>
<td>0.72</td>
</tr>
<tr>
<td></td>
<td>1.54 ***</td>
<td>0.64</td>
</tr>
</tbody>
</table>

Legend: Students' replies to the question of why they failed the final exam (students with low exam scores) or why they thought their peers might have failed the exam (students with high exam scores). The low-scoring students put a lot of emphasis on external causality arguments (M = 3.26) and little on internal causality arguments (M = 1.54). The high score students (score >15/20) report more emphasis on internal causality arguments (M = 2.82) and less on external causality arguments (M = 2.58) about the failure of their peers. The * and ** indicate the scores with significant differences between the two focus groups; they report a different reality.

In terms of personal remarks in the survey, students with low exam grades more or less repeated the answer they had given in the list of propositions. Additional comments/arguments were about: how much they appreciated the course; the loss of a close relative; having a job at the same time; being stressed by the exam despite proper revision; or discovering too late that the whole course content was affected. The additional comments from students with high exam grades were about appreciating the course (even though it was dense), their observation that some students refused to understand the subject, and the lack of investment by some peers. For details see S2 (Post-survey questions and personal comments) in the supplementary information. The collective results suggest that external factors play a role in the failure of the final exam, but that declining engagement is also a contributing factor.
Discussion

Student disengagement is a factor in final exam failure

Through the use of self-reports and learning analytics, we sought to understand why certain students performed so well in the mid-semester exam but (dramatically) failed a final exam that had the same format and similar types of learning documents and interactive self-assessment quizzes to support learning. The pre-survey data show that the drop in performance cannot be attributed to an à priori negative view of cell biology, a lack of will and ambition to do well, or a lack of awareness of certain cognitive skills. Failure is unlikely to be the result of a metacognitive illusion (Cervin-Ellqvist, et al., 2021). There is no correlation between self-report and learning analytic data. There is a moderate correlation between visiting learning documents on the web and student performance. We investigated this further and found an important shift in student behavior, with an overall reduction in web visits in the second period of the course. A large number of students, about a quarter of the population, who were active in the first period had no or very few visits in the second period. Dividing the population into four classes of web visits in the second period shows a clear positive relationship between web activity and performance. The population with the lowest number of visits (class 1) had a disproportionate decrease in mean final exam scores compared to mid-semester exam scores. Integrating these classes into a PCA plot of a larger set of individual scores and grades, including semester grades, also shows a clear relationship with overall performance, with the class 1 population scoring below average on dimension 1 and those with high attendance scoring above average. The post-survey focus group revealed that students who had failed the final exam emphasized arguments of external causality, while those who had passed the exam primarily presented arguments of internal causality as to why their peers had failed. From all the data presented here, we conclude that failure in the final exam is partly explained by the context of a dedicated exam week and the difficulty of the exam, but that unintentional student disengagement is also an important factor.

Possible Causes of Disengagement

By disengagement we mean the sharp reduction in web-based activities observed in the second period of the course. There can be many reasons for disengagement and some reduction may be considered normal, healthy or natural. For example, students may have downloaded all the slideshows in the first period. They may have found a paper version of the self-assessment quizzes and avoided the
interactive web-based version later in the course. After an initial period of exploration, they may have become more efficient; they knew what they needed to do to succeed. They may have found other learning materials that were more convenient for them. Some students may repeat the year and, after a few scouting visits, realized that they already had all the resources they needed to study. Some students may have worked in (clicker) groups in the second period on interactive self-assessment quizzes with only one person connected to the Internet. In addition, the trace logs do not show exactly what the students did with the material and for how long. However, if these were the main reasons, the drop in web visits would not be related to student performance. We can also rule out a deliberate calculation of minimum effort, as we do not observe an inverse relationship between in-course grades and final exam grades over a period of 8 years (discussed in Kramer et al., 2022). Unintentional factors must have come into play.

As mentioned by students, a major reason for exam failure was competition with other courses in the dedicated exam week at the end of the semester. Some students expressed that they had prioritized revision of those subjects in which they had not done well in the mid-semester exam. It is possible that because of the interactivity of the Cell Biology course, which was widely appreciated, they had put a disproportionate amount of effort into the mid-semester exam, only to find that they had to make up other courses in the final exam. Thus, for some, the destructive friction of the final exam (Vermunt & Verloop, 1999) was the consequence of "curriculum crowding" (Meyer, 1991). The accumulation of learning tasks towards the end of the semester had led to "dissonance", a situation in which students' learning orchestrations were no longer supported by the learning environment (Meyer, 1991). However, the observation that around 65 students had not visited any web documents in the second period, even at a time in early May when there was no competition, suggests that this cannot be the sole cause. Thus, we do not rule out the possibility that some students had had enough of their cell biology efforts and had "shut down" the subject by the end of the semester.

This form of unintentional self-limitation may be a way of coping with the pressures of learning for a subset of students (Cervin-Ellqvist, et al., 2021), even if they would characterize the course context as 'learning supportive'. Are we facing ego depletion (Baumeister & Vohs, 2007; Ryan & Deci, 2008)? Is it possible that the more these students are encouraged to engage, the greater the likelihood of 'premature' disengagement (enough is enough)? Explaining their failure in terms of external circumstances is probably a mechanism by which they mitigate their conflict between (good) intentions
(and genuine appreciation of the course) and behavior (Ryan & Connell, 1989). In this respect, disengagement may be related to procrastination (Grunschel et al., 2013). In the context of the Big Five factors of human personality, the degree of "conscientiousness" seems to explain most of the behavior of procrastinators (Costa & McCrea, 1992; Schouwenburg & Lay, 1995). Whether this is also true for disengagement is not known.

Conclusion

We developed a moderate structure cell biology course with the aim of easing the transition from secondary to higher education. Course performance increased significantly, but the final exam still showed signs of destructive friction for a one third of the student population. Here we show that this conflict has no intentional cause; individual appreciation of the subject, will to succeed, and familiarity with essential cognitive skills are in no way related to individual performance. Nor do we believe that students (intentionally) calculate their final exam effort on the basis of course scores in order to save on learning. We observe a moderate relationship between performance and visits to web-based learning documents, including self-assessment quizzes. Although there is no deterministic relationship between web visits and performance, there is a tremendous amount of variance, we show that the population with fewer than 10 visits in the second period (leading up to the final exam) performs significantly worse on the final exam, the entire course, and the semester. We argue that unintentional disengagement is an important explanation for the low final exam scores. This self-limitation severely limits the potential benefits of our learning-oriented course design.

Conflict of Interest Statement:

The lead author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References


Supplemental material

Table S1. Interplay Between Teacher-Regulation Styles and the Degrees of Student-Regulation of Learning (drawn from Vermunt & Verloop, 1999).

<table>
<thead>
<tr>
<th>Degree of student-regulation of learning</th>
<th>Degree of teacher-regulation of learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Strong, Destructive friction</td>
</tr>
<tr>
<td>Intermediate</td>
<td>Shared, Destructive friction</td>
</tr>
<tr>
<td>Low</td>
<td>Loose, Congruence</td>
</tr>
</tbody>
</table>


S1 Pre-survey questions

With regard to cell biology, your ambition is to be:

1. weak student (score <100)
2. average student (score around 100)
3. no opinion
4. good student (score >120)
5. excellent student (score >140)

Do you want to learn cell biology?

1. No
2. Rather no
3. No opinion
4. Rather yes
5. Yes

Do you think you will pass the cell biology course?

1. Not confident
2. Somewhat not confident
3 No opinion
4 Somewhat confident
5 Confident

In your opinion, do you have the necessary skills (prerequisites) to understand cell biology?

1 No
2 Rather no
3 No opinion
4 Rather yes
5 Yes

In your representation of the cell biology course, your à priori impression is:

1 Bad
2 Somewhat bad
3 No opinion
4 Somewhat good
5 Good

Cell biology is a priori:

1 A subject you are not interested in
2 A subject you are not very interested in
3 A subject among others (no particular opinion)
4 A subject you are interested in
5 A subject you are very interested in

To pass the course, understanding the topic is:

1 Not at all important
2 Not very important
3 No opinion
4 Important
5 Very important
In your opinion, in order to develop a long-term memory, is it important to enjoy learning?

1 Not at all important
2 Not very important
3 No opinion
4 Important
5 Very important

In your opinion, in order to develop a long-term memory, should you review regularly?

1 Not at all important
2 Not very important
3 No opinion
4 Important
5 Very important

In your opinion, is using your smartphone for private use or talking with your neighbors bothersome for learning in class?

1 Not at all bothersome
2 Only slightly bothersome
3 No opinion
4 Rather bothersome
5 Very bothersome

Your age:

Your gender:

Male / female / rather not mention
S2 Post-survey questions and personal comments

A) focus group: students who failed the final exam in Cell Biology (low score <100/200)

Survey

Dear student (add a name to personalize the request)

You did well in the mid-semester exam in the cell biology course, but were unable to pass the final exam. You also have informed us that you appreciated the subject of cell biology. In an attempt to improve the course, we would like to know why you think you did not pass the exam. Please answer the following questions on a scale of 1 - 5 (1-Strongly Disagree, 2- Disagree, 3- Neutral, 4 – Agree, 5-Strongly Agree). You can have more than one reason for the exam outcome.

I did not pass the final exam because: strongly disagree – strongly agree

I revised hard but the subject was much more difficult than the in-course tests.  

I had to give priority to the exams of other courses (for which I had no good grades yet).  

I was satisfied with my in-course results and felt I did not need more.  

During the course I had lost interest in the subject of cell biology.  

Other reason(s) (Please describe):

Extra comment:

Other reason(s)/extra comment:

-I didn't revise anything because I didn't like university anymore

-I also had a job

-If I didn't pass the final exam, it's only my fault. I am aware that I did not work on cell biology as much as I should have.

-I had revised and taken the MCQs proposed multiple times but I may not have revised the other points of the course enough.
-The amount of course work I had to do in addition to Cell Biology was substantial, but it wasn't necessarily longer, but I had bad grades, so I prioritized the "small" subjects that just needed the formulas rather than a lot of rote work that took a long time to assimilate (late work, of course)

-Motivation problem due to a change of orientation

-I followed the courses at the beginning which explains my correct grade at the mid-semester but I was overwhelmed with work and I was still trying to find a good method of work. I had to reread all my lessons for the semester without having the time to study them in depth, which explains my final-exam score.

-I wasn't really thinking about exams at that time as my grandmother died a few weeks before in a very sudden way.

-The course is very interesting and it is easy to understand. The fact that the exam is in the form of MCQs is also a good way to reassure the student, it seems more affordable, while the knowledge to acquire remains the same (as if there was an OCR). It is much more encouraging and less stressful to know that a MCQ is coming, it allows to work in a climate with less stress and thus a better comfort of study.

-I put a lot of pressure on myself (stressed-out) in front of the exam copy while I had learned correctly and understood the course.

-I had some health problems which meant that I could not attend many classes during the first 9 weeks of the semester. My revisions were based on the course slideshows and notes from my classmates.

-I had given more importance to other subjects

-I may have also revised a little less given my first grade, thinking that would be enough.

-I find your approach to monitoring student performance very useful and interesting. Seeing that a teacher pays so much attention to us helps motivate and challenge us to find another way to study and succeed.

-I was surprised shortly before the exam because I had not revised some chapters and I learned 2 days before that they could be treated during the exam. Moreover, it seems to me that there had been
questions on the practical work and it seems to me that I had not succeeded very well because perhaps bad analysis of the images and I was mixed on certain concepts.

-I find this kind of questionnaire very relevant and interesting for the continuous improvement of the course and of the learning in general, but it is true that to have "hot" answers, more recent and true, it would be better to send the survey while the course is still running (during the second semester of L1).

B) Focus group: students who passed the final exam (high score >150/200)

Survey
Dear student (add a name to personalize the request)

You have been good both in your mid-semester and in your final exam in the cell biology course. You results are in contrast to 175 students (36% of the course attendants) who did well in the mid-semester but failed their final exam. As a consequence some (unnecessarily) failed the entire cell biology course.

Perhaps you know of some your group mates (clicker groups) that did not do well in final exam? Would you have an idea why they failed?

<table>
<thead>
<tr>
<th>They did not pass the final exam because:</th>
<th>strongly disagree – strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>They revised hard but the subject was much more difficult than the in-course tests.</td>
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<tr>
<td>They had to give priority to the exams of other courses (for which they had no good grades yet).</td>
<td>🟩 🟩 🟩 🟩 🟩</td>
</tr>
<tr>
<td>They were satisfied with their in-course results and felt they did not need more.</td>
<td>🟩 🟩 🟩 🟩 🟩</td>
</tr>
<tr>
<td>During the course they had lost interest in the subject of cell biology.</td>
<td>🟩 🟩 🟩 🟩 🟩</td>
</tr>
</tbody>
</table>

Other reason(s) (Please describe):

Extra comment:
Other reason(s)/extra comment:

- Some students may have underestimated the difficulty of this final exam by already having the questions available.

- I think that in the first year at University, there are a lot of people who rely on their knowledge or don't work hard enough because they haven't realized that they have to be autonomous, hence the repetitions.

- Then, when they arrived at the final exam, the students found themselves unable to revise their knowledge of the entire course on MOODLE and answer the questions asked.

- I know that the cell biology course was very lively and interested most of the students.

- Having a good memory, I was able to get through it. Other people didn't have the courage to do that, and those people dropped out because your subject wasn't the easiest to learn (complexity of content).

- They did not prepare enough for the final exam

- In my opinion, the course was very attractive and the understanding was quite simple: moreover, with the questions on Moodle, the preparation for the exam was greatly facilitated. I find the functioning of this course very good (even though I'm not very interested in Bio Cell, I think that you have made the subject captivating).

- This is a very dense course with a lot of complex information, I think that it is difficult for students to assimilate everything correctly. The best thing would be to create summary cards (in the form of diagrams for example) with the students, to make the course clearer.

- They are not trained enough with the MCQs present on Moodle and with the circulating exam questions of previous years. Indeed the questions were very similar to the one of the final exam.

- The cell biology course was a bit complicated for the first year (more adapted for the second) and as a result many people memorized the MCQ that was available on Moodle without understanding the questions and answers and without revising the course properly.

- Certainly a lack of regular work is to be noted

- One of the reasons for this loss of points may be that they felt confident enough not to revise further for the final exam, having already answered the questions correctly during the course.
-For the final exam, from what I remember, having the quiz (and thus the solutions) beforehand does not necessarily allow for the development of logic or good understanding and thus, lead to some misunderstandings if the effort to go back and review the course is not made.

-I have no idea why some students failed their exams, for me your course was lively and having us participate continuously allowed me (personally) to stay focused on your course.

-I think that proposition 3 ("They were satisfied with their test in class and felt they didn't need more") is the main reason, but maybe the participation was not equal in the clicker groups.

-I think that online MCQs are only useful if everyone goes through the trouble of understanding instead of just learning by heart. Unfortunately, you can't do anything about that. So there is an important part of responsibility of the students too in their failure.

-This exam is very well thought out in my opinion because you can practice easily and in a similar way to the exam

-I think that most of them were satisfied with the marks they got with the in-class quizzes since those I talked to had good marks on the in-course test and didn't spend much time on the final exam.

-They didn't use the Moodle interactive tests enough to review.

-I think we were not used to this type of exam because there was a real need to think about it, but we are more used to doing it by heart. In class it was fine because we were asked the question directly after having seen the concept, but not in the final exam.

-The course was quite dense and because of this some people may have been lost.

-I would like to thank you for the interactivity in class and the interactive quizzes on Moodle, it was fabulous to discover how interactivity stimulates curiosity, especially for a course that seemed really complex at that time.

-The fact of having exam questions similar to those available online gave too strong an impression of "ease" in the subject, for many people, who did not really bother to work on the course and who paid the price on the day of the final exam.