Implementing an Alternative Curriculum Design to Improve Learning in Higher Science Education

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Abstract

Procrastination behaviour, a tendency to superficial learning and the fact that students remember only 10 to 30\% of traditionally taught concepts are inherent to learning in a traditional educational context. The Faculty of Science at the University of Leuven (KU Leuven) aims to remediate this by implementing an alternative curriculum design (OASE) at different time levels.

Introduction

All programmes in higher education aim at enabling students to become independent, critical-thinking professionals. The University of Leuven (KU Leuven) empowers this with a research-based educational approach that corresponds to the Dublin Descriptors. The objectives of this approach stimulate students to acquire academic competences, including thorough knowledge and skills in the discipline, coupled with a critical and research-oriented attitude and a broader interdisciplinary perspective. Within this context, students are responsible for their own learning process, while the didactical teams provide optimal support.

However, lecturers and students indicate some discordance between the approach theory and practice, mainly caused by the standard curriculum design at KU Leuven. For instance, the applied semester system, consisting of 13 weeks of classes followed by two or three contact-free weeks and three examination weeks, typically causes students to procrastinate active studying. Moreover, students tend to lose track of the course content after a few weeks, resulting in passive class attendance and didactical guidance that is not used optimally. Deep learning and long-term retention of knowledge and skills are therefore not always reached.

Five years ago, the Faculty of Science at the KU Leuven started investigating the potential of changing curriculum design to tackle this problem and improve learning. After a thorough preparation by integrating existing academic research and own in-field experience in a feasibility study, an ultimate curriculum design within the university’s boundary conditions was defined. This alternative approach, named \textit{Onderwijsorganisatie met Alternatieve Semesterindeling en Evaluatie} or \textit{Educational Organisation with Alternative Semester Layout and Assessment} (OASE), was implemented in September 2013 in the first year of the mathematics and physics bachelor programmes.

This paper describes the different elements of OASE and investigates its implementation process, with respect to change management and follow-up.
Theoretical background of OASE

In an explorative feasibility study established concepts from literature and personal findings were linked at different levels in order to configure an ideal curriculum design for an optimal learning experience, regardless of decreital standards or practical constraints. In a next phase this ideal scenario was translated into a feasible scenario within the constraints of the existing educational system at the Faculty of Science at KU Leuven (Peeters, Lievens, 2012). Finally, the feasible scenario evolved to OASE through discussions with all involved stakeholders.

Figure 1 illustrates the traditional KU Leuven curriculum design, the ideal and feasible scenario mentioned above, and the OASE system.

OASE entails different components at the curriculum level, the course level and the lecture level. Furthermore, the student evaluation process is taken into account.
**Curriculum level**

At a curriculum level, the typical number of different courses programmed a day is decreased to only one, allowing optimal focus on this course. Several studies indicate that teaching less courses simultaneously is more efficient in terms of student learning (e.g. Jansen, 2004; Ruijter & Smit, 1995; Vaughan & Carlson, 1992). Additionally, two weeks of the exam study period at the end of each semester are repurposed for teaching and guided studying, hereby anticipating students’ tendency to postpone studying.

**Course level**

At the course level, contact hours are reduced to a maximum of four hours a day – typically two lecture hours and two hours of practice sessions – and students are encouraged to use the generated free time for self-study to improve study efficiency. Indeed, many studies show that reducing contact hours has the potential of significantly improving study efficiency, as students have more time available for active self-study (e.g. Jansen, 2004; Schmidt et al., 2009; Vos, 1998). In order to stimulate active self-study, classrooms are available for an additional two to four hours a day allowing students to work or study alone or together (OASE sessions). Regularly a teaching assistant or professor is present to help them (OASE² sessions). Each course has an online study guide, with detailed instructions and expectations, indicating what students may study during OASE(²) sessions. An example of an OASE week in the first year of the bachelor physics is given in Figure 2.

![An example week in OASE for first year students in the bachelor physics](image)

**Lecture level**

Reducing contact hours implies that lecture hours gain importance, as they are necessary to stimulate students for self-study. Therefore, cognitive load is reduced during contact hours and student-centred teaching methods are applied to allow students to actively process new knowledge and skills. The traditionally applied presentation-assimilation model, where students discover course material for the first time during a lecture, is replaced by a preparation-feedback model (flipped classroom). Interactive-engagement methods during a lecture aim at increasing retention of thought concepts. Indeed literature shows that students only remember 10 to 30% of traditionally taught concepts (Deslauriers et al., 2011; Wieman & Perkins, 2005). Moreover, active teaching results in more study progress among first-year students (Van den Berg & Hofman, 2005) and improve the acquisition of competencies (Meng & Heijke, 2005).
Assessment
Within OASE, different forms of continuous assessment activate students, provide regular feedback and evaluate the extent to which students reach curriculum goals. Frequent testing also increases the involvement of students (Marcell, 2008) and improves retention of the learned knowledge and skills (Roediger and Karpicke, 2006). All courses therefore organise regular formative assessment and most courses additionally use summative assessment, giving the opportunity for students to spread examination effort in time. The timing of the assessment is aligned between different courses in order to avoid high stress peaks.

Implementing OASE
OASE was implemented in the first year of the mathematics and physics bachelor programmes in September 2013. Implementation was thoroughly prepared, however establishing the necessary conditions to implement OASE as an alternative curriculum design successfully was and remains a challenge.

Change management
A well balanced change management integrating a top-down with a bottom-up approach was necessary to proceed towards implementation. This entailed actions at different levels, ranging from didactical teams over administrative staff and policy makers to students. The didactical teams were involved from the beginning, allowing flexibility for translating the OASE approach towards the course level. Administrative faculty staff were committed to assure practical feasibility of implementing OASE, and students were consulted regularly in order to keep an active link with the target group.

Short-term follow-up
During implementation, careful monitoring of the students’ learning process and of the didactical teams’ experiences allows fast intervention when problems occur. Formal and informal lunch meetings with all involved groups are organised regularly to stimulate an open atmosphere and to early detect potential improvement scenarios. Weekly pointers based on the outcome of the meetings are given to the students as well as the didactical teams through the online platform.

Long-term evaluation
Several effect measurements will give insight in the long-term effectiveness of OASE. Success rate, prior knowledge, motivational aspects and retention of knowledge and skills were measured before implementation, and this monitoring of key performance indicators is currently continued in the OASE approach. Furthermore, drop-out students are interviewed. Together with a survey of the general consent by students and didactical teams, this will help the faculty to evaluate OASE and to make a well-founded decision on the potential implementation of OASE in other programmes.

Overview of effect measurements and tests
The following student questionnaires, student interviews, tests and measurements are done before and during OASE:
- Prior knowledge tests;
- Questionnaires about educational systems and study preferences;
- Regular informal and formal meetings with a delegacy of the students;
- Questionnaires about motivation and self-concept;
- Questionnaires about study skills and guidance;
- Qualitative study time measurements;
- Continuous assessment for different courses;
- Examination for most courses;
- Short-term retention test in April/May about knowledge and skills obtained during the first semester of the same academic year;
- Longer-term retention test in September about knowledge and skills obtained during the first semester of the previous academic year.

Furthermore, the didactical teams are interviewed in regular informal and formal meetings, and in a questionnaire about OASE in general.

Results and discussion

After one semester of OASE implementation some initial observations are presented. However it is too early to draw firm conclusions. The group of new students in the first bachelor year of mathematics and physics is rather small (typically ~30 new mathematics students and ~50 new physics students) and variable in terms of student characteristics. Hence, a statistically relevant evaluation becomes possible after several years of implementation.

General experiences during the first semester of OASE

In general, students provide positive feedback about the OASE system. They are satisfied about the didactical teams and the available guidance. In their opinion, the continuous assessment is feasible and produces valuable feedback. Most of the students indicate the OASE² sessions as useful, although their attendance on these sessions is variable. The use of the OASE sessions is very personal. In a questionnaire about the available guidance, 34 out of 47 students indicate that the available guidance during the first semester of OASE was more than sufficient. Additionally, students express their preference for more interactive lectures and they appreciate the added value of effective preparation. Finally, students prefer very clear instructions and value detailed study guides.

The feedback of students generally corresponds well to what the didactical teams say. They are also overall optimistic about the first semester of OASE. However, they do notice that students need sufficient instructions and guidance, especially in the beginning of the semester. This requires balancing between instruction and guidance on the one hand and freedom and student responsibility on the other hand. The continuous assessment indicates the progress of the students well. During the semester, didactical team members noticed a decrease in attendance to the OASE and OASE² sessions. Although this does not necessarily point to important problems, it is important to investigate the causes. Furthermore, they notice that students tend to focus on doing exercises and meanwhile neglect the theory. As this is unexpected and may cause deprivation, it is therefore followed up closely. Finally, some didactical staff members are concerned about the stress level of the students. Indeed, some students complain about high expectations throughout the semester. As these are first-year students, they cannot compare to the traditional system with a very high stress peak during the study period preceding examinations.
Caution is advisable when drawing conclusions at this stage. Some observations are not new but did only emerge now because of the continuous measurements and tests. However, all feedback must be investigated thoroughly to form theories that lead to solutions.

This has already been done for each first semester course. Plans for optimisation towards the next academic year have already been made. For some courses the didactical team members will give more detailed instructions to students, through the study guide and lectures, practice and OASE(²) sessions. For instance, course theory will receive more attention in these instructions, so that students realise its importance in relation to exercises. Another type of adjustment implies a stricter application of the preparation-feedback model, with consequences for students who did not prepare class. Finally, other remediation plans involve adaptations to the selection of classrooms, daily schedules or assessment methods, in order to lead students towards optimal learning activities.

**Attendance in OASE/OASE² sessions**

As mentioned above, attendance in OASE(²) is highly variable and decreased during the semester. Therefore, the students were asked in a questionnaire what the reasons are for (non-)attendance in these sessions for different courses (Fig. 3). The main reasons to take part in the OASE and OASE² sessions are to perform exercises together with peer students, to ask questions to peers and/or teaching staff, and to be able to stay on the campus. The students that do not show up in these sessions ascribe this to the fact that they prefer studying elsewhere or that they have no questions.

![Graph showing reasons for attendance and non-attendance in OASE and OASE² sessions](Fig. 3)

- A. Because I can do exercises better together with other students
- B. Because I wanted to ask questions to other students
- C. Because I wanted to ask questions to the teaching staff
- D. Because I don’t like studying on my own
- E. Because in another place on my own I would not have the self-discipline to study
- F. Because then I did not have to move between the campus and my room/home between classes
- G. Because otherwise I would feel guilty
- H. Because I didn’t have the time
- I. Because I didn’t find the sessions useful
- J. Because I didn’t have any questions
- K. Because I lost track of the course anyway
- L. Because I studied at other moments
- M. Because I studied somewhere else (home, library ...) at the same time
- N. Because I studied somewhere else (home, library ...) at other moments
- O. Because I forgot
- P. Because I have difficulties studying in a room with other people
- Q. Because I was distracted by other students

Fig. 3 Reasons of attendance or non-attendance in OASE and OASE² sessions during the first semester, as indicated in a questionnaire (total for six courses) (n=47).
Attendance in OASE(²) sessions correlates to a positive influence on study success. The pass rate of the group of students who indicate that they are regularly present in these sessions is higher for most courses than for the total group of students (Table 1). This corresponds to earlier findings reported in literature, saying that class attendance is a significant predictor of obtained credits and results (e.g. Plant et al., 2005; Torenbeek et al., 2013). Although OASE(²) sessions are not the same as the more typical lectures or practicals, we do believe that they are highly relevant for students to practice skills, gain enthusiasm for the course content, and comprehend complex material together with peers.

### Table 1
Pass rates of students who attended to OASE(²) sessions regularly (as indicated in a questionnaire – n=48) in relation to general pass rates in January 2014.

<table>
<thead>
<tr>
<th>Course</th>
<th>OASE(²) attendance &quot;always&quot; or &quot;most of the time&quot;</th>
<th>Number of selected students who passed</th>
<th>Percentage of selected students who passed</th>
<th>Percentage of all students who passed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course 1</td>
<td>39</td>
<td>33</td>
<td>85</td>
<td>63</td>
</tr>
<tr>
<td>Course 2</td>
<td>35</td>
<td>14</td>
<td>40</td>
<td>35</td>
</tr>
<tr>
<td>Course 3</td>
<td>34</td>
<td>18</td>
<td>53</td>
<td>48</td>
</tr>
<tr>
<td>Course 4</td>
<td>24</td>
<td>14</td>
<td>58</td>
<td>49</td>
</tr>
<tr>
<td>Course 5</td>
<td>34</td>
<td>16</td>
<td>47</td>
<td>49</td>
</tr>
</tbody>
</table>

Study results of the students

One of the goals of OASE is to help students keeping track of the course material during the semester, and to tackle typical procrastination behaviour. Ideally, students gradually reach the partial objectives of their courses during the semester through continuous active learning activities. With sufficient prior knowledge, students should obtain at least 10/20 for tests during the semester, indicating that they have the knowledge and skills that are expected of them at that moment. Students should then be able to reach all the objectives of the different courses by the end of the semester. Figure 4 illustrates by means of three basic courses in the physics and mathematics bachelor programmes that this was not always the case during the first semester. An ideal student would have a horizontal or rising line, indicating that the expected level of a student with a certain prior knowledge is reached continuously.

![Fig. 4 Average study results (/20) for three basic courses at different moments during the first semester in 2011-2012 (n=90), 2012-2013 (n=85) and 2013-2014 (OASE) (n=87).](image)

In 2011-2012, a year with a high average score on the prior knowledge test, there is clearly a retard in study progress. The score for a test in November was on average far below 10/20 for all three courses. However, the students did catch up by the end exam in January. In 2012-2013, prior knowledge of incoming students was below expectations. Students caught up the
deprivation a little, but the average score for the test in November (there was only a test for the basic Mathematics and Linear Algebra course) as well as January remained below 10/20. During the first OASE semester, we see a similar evolution. For the basic Physics course, the test in November of 2011-2012 was replaced by two take-home assignments, which delivered better results but are difficult to control. However, by January the average score is still below 10/20.

Table 2 shows end results averages and pass rates for all courses of the first semester before and during OASE. After one semester, the pass rate of students has slightly improved compared to the previous year, but is lower than two years ago. In Figure 5, the percentage of obtained credits after the first semester is plotted for the last five years. Similarly, the results vary significantly between different years. Obviously, this is not only related to the learning environment, but to the characteristics of incoming students as well. Apart from curriculum organisation, high school results and self-regulation (motivation, self-discipline, time management) of incoming students also have an impact on student learning and academic achievement (Torenbeek et al., 2013). In any case it is too early to draw any definitive conclusions.

<table>
<thead>
<tr>
<th>Course</th>
<th>January 2012</th>
<th>January 2013</th>
<th>January 2014</th>
<th>OASE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average /20</td>
<td>Pass rate %</td>
<td>Average /20</td>
<td>Pass rate %</td>
</tr>
<tr>
<td>Course 1</td>
<td>8.79</td>
<td>47</td>
<td>10.17</td>
<td>63</td>
</tr>
<tr>
<td>Course 2</td>
<td>9.00</td>
<td>48</td>
<td>7.01</td>
<td>34</td>
</tr>
<tr>
<td>Course 3</td>
<td>9.49</td>
<td>52</td>
<td>7.19</td>
<td>29</td>
</tr>
<tr>
<td>Course 4</td>
<td>9.03</td>
<td>47</td>
<td>9.03</td>
<td>47</td>
</tr>
<tr>
<td>Course 5</td>
<td>10.93</td>
<td>67</td>
<td>8.82</td>
<td>35</td>
</tr>
</tbody>
</table>

Table 2 Study results in January 2014 for the different courses compared to study results before OASE in January 2012 and January 2013.

Fig. 5 Cumulative study efficiency (CSE - % obtained credits) of the first year mathematics and physics generation students in February 2010 (n=50), 2011 (n=72), 2012 (n=75), 2013 (n=65) and 2014 (n=60). A generation student is a student who has subscribed for the first time in higher education.

Conclusions and future work

This paper presents an alternative curriculum design (OASE) that was implemented in the first year of the mathematics and physics bachelor programmes in September 2013. OASE entails different components at the curriculum, course and lecture level, including the assessment process. The implementation of OASE was thoroughly prepared, with a well-balanced change management and a close follow-up.

Preliminary results are not sufficiently supported with data to draw definitive conclusions. Furthermore, as it takes time to adjust for all involved stakeholders (change management), it is important to permit this time before drawing any conclusions. Nevertheless, the overall
consent of didactical teams and students is positive, while study results and pass rates have not changed significantly compared to previous years. Attendance to facultative OASE and OASE² sessions, where a room and optional guidance is provided, does have a positive influence on study success during the first semester.

As ongoing effect measurements continue, more data can be collected. For instance, long-term retention of knowledge and skills will be tested and compared with retention results before OASE implementation. Including high school study results and prior knowledge test scores will allow for more objective conclusions, as the level of incoming students, an important predictor for study success, differs significantly between academic years. Furthermore, efforts will be done to include variables of self-regulation such as motivational aspects, self-discipline and time management. Finally OASE drop-out students will be queried such that results can be compared to drop-out research of previous years.

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**Practical implications**
Procrastination behaviour, a tendency to superficial learning and the fact that people remember only 10 to 30% of traditionally taught concepts are inherent to learning in different contexts from primary school over high school, to university and companies. The presented results are hence relevant and easily transferable to these other contexts. Furthermore, lessons learned from implementing OASE in terms of change management can help ICED delegates who are involved in innovation projects.

**References**


