LEARNING ANALYTICS IN EDUCATION DESIGN: A GUIDE

SURF NET

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INTRODUCTION

Why learning analytics?
Better insight into the teaching process and targeted feedback to students, ultimately resulting in improved education: that is the idea behind learning analytics. Learning analytics makes it possible to follow students' digital footsteps. From the moment students browse the higher education institution's website for information until the moment they are registered as alumni, they leave behind a digital trail. This digital trail can be recorded and analysed, leading to the creation of comprehensive data collections. With this data, it is possible to make predictions about, for example, the quality of the teaching materials used, how teachers and students interact with the material, how the digital learning and working environment is used, etc.

Learning analytics offers a great many possibilities, but how can a study programme or institution use it successfully? This will depend entirely on how learning analytics is applied in educational practice. Learning analytics only works if you learn to ask the right questions about your data. For example, when creating an online education, you should start as early as the design phase, and ask yourself exactly which questions you want to answer using learning analytics.

Purpose of this report
Learning analytics is an important topic for SURFnet. Together with Dutch higher education institutions, SURFnet is examining how learning analytics can contribute to tailored education. In this report we will demonstrate how learning analytics can dovetail with education design and which questions learning analytics can answer. We will also show how this can work out in educational practice in a number of scenarios.

The report provides teachers and education designers support and inspiration in applying learning analytics when designing online education. Learning analytics allows you to collect data from a student's every mouse click in an online environment, the videos they watch and other digital traces they leave behind that might tell you something about their learning behaviour.

Design
For this report, we conducted a literature survey together with representatives from higher education on models for educational design and combined these with examples of effective use of learning analytics in education.

In Chapter 1 we will address the application of learning analytics in education, after which we will discuss the relationship between learning analytics and educational design. We will show how learning analytics fits into an educational design model. In Chapter 2 we will further develop this model on the basis of the questions that emerged in the workshops and to which learning analytics can provide an answer. Based on these answers, interventions are possible, such as the identification, contacting and activation of students who are at risk. Chapter 3 contains a number of examples of applications of learning analytics (from different countries). The report concludes with a number of tips in Chapter 4.

1. WHY LEARNING ANALYTICS?

Learning analytics provides all manner of new opportunities to support students in learning. It offers teachers and education designers a new and practical source of information to complement their own observations and evaluations: a gold mine of data about student behaviour and learning needs. Thus, learning analytics can:

- Provide teachers with real-time information about the quality of the learning materials and the structure of the course.
- Provide real-time insight into student behaviour, which the teacher can respond to themselves, or which can be responded to automatically.
- Provide students with insight and guidance about their learning behaviour.

Creating and evaluating a lesson design

Evaluation and improvement of teaching is made much simpler with learning analytics. Most teachers evaluate a teaching module at the end, with the help of questionnaires, feedback from students and tests. Learning analytics can provide information at any time. It can be applied before, during or after an assignment or module. Learning analytics allows education designers and teachers to ask new and different questions during the teaching process, such as:

- Which parts of my learning environment are widely used?
- What information are students reading and who is reading what?
- Who actively participates in discussions in the forum and are students' contributions on relevant topics, or quite the opposite?
- Which students are active in the learning environment and are these the same students who actively participate in class?
- Which students are lagging behind and what kind of support do these students need to get going?

Of course, this information will be limited to what can be digitally measured about students' actions. Nevertheless, this information can be very supportive and valuable for both students and teachers. Learning analytics helps teachers to create a lesson design and assess its effectiveness.

1.1 Getting started

Where should you start if you want to make use of learning analytics in education? To answer this question, we will first describe the generic process of learning analytics.

Clow (2012) and SURF (2013) present learning analytics as a cyclical process (see Figure 1). Learning analytics follows the behaviour of the student in the learning environment: what exactly does the student do in that environment? How often do they log in, which pages and videos do they click on and what do they contribute? How often do students respond to contributions from fellow students and are these responses focused on the content or not? Every mouse click, the time the student spends of a page, etc., is logged and stored in a database.

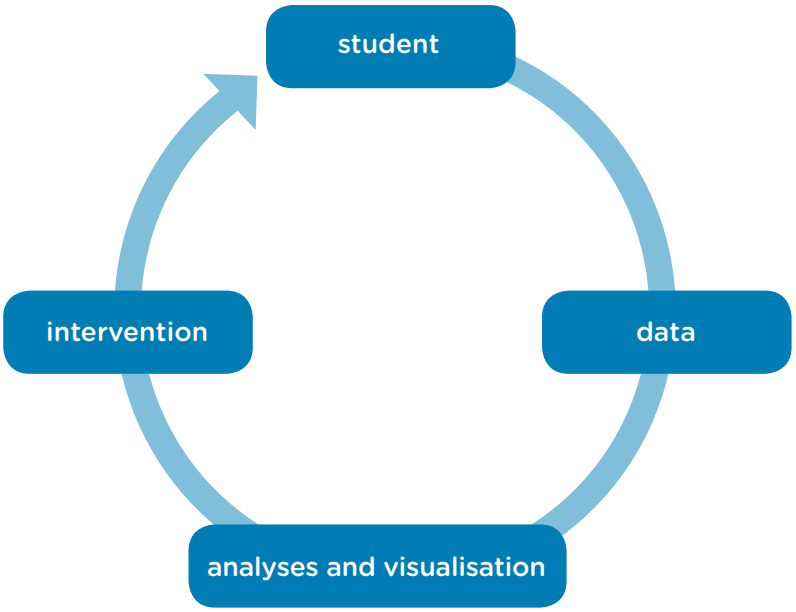


Figure 1: Learning Analytics Cycle (Source: SURF, 2013)

Visualisation and analytics

Subsequently, all the data is analysed and interpreted. This can be done using a smart algorithm, by the teacher, or through a combination of both. Because learning analytics can generate such a large amount of data, good visualisation is very important. All the information can be easily accessed via a dashboard. For example, a dashboard can show at a glance what a student is spending their time on, or how they are doing compared with the other students in the group. The teacher can use learning analytics to get a handle on students' online activities in the learning environment via digital classroom management. In this way, the learning environment becomes an open environment in which the teacher can easily monitor what's going on and intervene if necessary.

Interventions

Based on predictions or experiences with previous courses, a teacher can identify risk factors and visualise which students fall into a risk group. The teacher can then use this warning system as a reference point for performing an intervention. Such an intervention can be relatively small, such as sending an email to the student or speaking to the student during a class, but a teacher can also choose a different approach.

In this report, we follow the circle from the above diagram, excluding the analysis and visualization portion. The emphasis is on obtaining the right data and the interventions that help the student a step further in the educational process.

In the next chapter, *we will help you to get started* with learning analytics.

2. LEARNING ANALYTICS IN THE EDUCATION DESIGN PROCESS

Want to get started with learning analytics? The first thing you should do is think carefully about what data you want to collect, or rather, which questions you want to answer with the data, and then take this into consideration in the education design process. But how can you do this? This chapter will help you get started.

2.1 Phased plan

To date, little research has been done into how useful educational theories are when working with learning analytics. We have therefore chosen to focus in this report on generic educational design questions that are relevant to several theoretical frameworks. We have tried to arrive at a number of general indicators that are relevant to learning analytics.

Educational design is the process in which a teacher or education designer runs through a number of steps, from establishing learning objectives to assessing whether they have been achieved. In between, there are a variety of choices relating to appropriate learning activities and their order and content, teaching methods, assignments, teaching materials and other teaching resources that contribute to achieving the learning objectives. These days, teaching materials and resources are increasingly IT applications. This offers opportunities for using learning analytics as part of the learning environment and educational design.

Duisterwinkel et al. (2014) have developed a general step-by-step plan for creating an educational design (see Appendix 1 for more information). Three phases are distinguished in this plan:

1. orienting oneself with regard to the subject; formulating learning objectives and assessment;
2. designing the educational functions, content and associated learning activities;
3. making choices with regard to teaching materials (books, articles, syllabuses, assignments), teaching methods (e.g. collaboration) and practical factors (location, time, group size, etc.).

In this report we shall also add a fourth element to these three phases, the context:

4. the characteristics of the course and the student will also require further consideration.

Questions per phase

Teachers and education designers can use this model to formulate questions that can be answered using learning analytics. Learning analytics could be used in all phases of this model:

- In the first phase, you can think about which parts of the assessment take place in the online learning environment.
- The second phase revolves around the question which learning activities can be employed in an online learning environment.
- The third phase, for example, might consider online collaboration and the contributions of the students towards a joint assignment.
- The fourth phase mainly involves questions about characteristics of the students and making links between the different components of a learning environment.

2.2 The questions

Questions relating to orienting oneself with regard to the subject: learning objectives and assessment

Two components are of great importance to students orienting themselves with regard to a subject: the course prospectus and the course description. Often these documents are available online, for example, in a digital learning environment. The documents contain information on exactly what is expected of the student in the course and how the learning activities contribute to the assessment.

We have formulated three questions for this phase, which you can answer using learning analytics.

Questions: Subject orientation
Has the student read the learning objectives?
Has the student read the information about the assessment?
Does the student review the learning and assessment goals during the course?

Questions relating to learning activities

You can find out a lot about how students orient themselves with regard to learning activities using learning analytics. The questions listed here can help you monitor the learning environment. For example, free-riding is a problem in many group assignments. By having students work together in an online environment, it is easier to spot or prevent such behaviour.

Questions: Learning activities
Has the student read the instructions for the learning activity?
When students work together on a group assignment: Who did what part of the assignment?
Did the student hand in the assignment(s), and when?
When and how often does the student contact the teacher/adviser with questions and what kind of questions do they ask?
When and how often do students ask fellow students for help and what kind of questions do they ask?
Which learning pathways do students follow through the learning activities, and are certain pathways more effective than others?
At what point does the student perform the learning activities?
How much time do students spend on a learning activity? Is the time spent consistent with the planning of the teacher?
Do students follow their own progress?

Questions relating to group activities

Learning analytics allows you to answer various questions relating to group activities. A group discussion is an example of a group activity. Group discussions are used in digital learning environments relatively often. It is often difficult for teachers to follow what is going on in a forum or track the input of individual students. Are students making substantive contributions or are they merely ‘liking’ what others have written? Learning analytics can offer many insights in such cases.

Questions: Group activities
What has a student contributed in a group discussion?
How many times has a student responded to discussions in a forum or social space?
How extensive was the contribution of a student in a group discussion?
What are the main topics that the students discuss?

Questions relating to assessment

Assessment is an essential part of learning because the student is given feedback on their progress and how well they have understood the course material. Would you like to know what effect midterms or formative tests are having on a student's final mark? If so, learning analytics can help you figure this out if you administer all of the tests digitally. Learning analytics allows you to perform a very detailed analysis which can show you which items on a midterm are contributing to better scores on a final test. Below you will find some more questions learning analytics can answer for you regarding assessment.

Questions: Assessment
How close is the student to achieving the learning objectives?
How often does the student do a formative assessment?
Does the student review learning objectives and learning activities based on their scores for a formative test once they have received them?
Do formative assessments support the student in passing the summative assessment?
Are courses with many small summative assessments better for academic performance than one large summative assessment at the end?
How many attempts does a student need to complete an assessment?

Questions relating to learning materials and resources

The questions in this topic relate to how the students interact with learning materials and resources in a digital learning environment. The most relevant questions are the questions about what materials are most commonly used and what materials the students consult on their own initiative. Behind this lies the question of whether students are doing more than is required for the course.

Questions: Learning materials and resources
How long did the student view/read the material?
Did the student download the material?
What material is viewed the most frequently, or is most commonly used?
What material or additional resources does the student use on their own initiative?
Did the student watch the videos (how often, when did they fast-forward and rewind?)
What do the students highlight in the text, what kind of notes do they make?

Questions relating to context, student characteristics and course

The following questions mainly relate to making links between the various components of a learning environment.

Questions: Context
How successful was the student before they began the course?
What prior knowledge does the student have? Do they have the right prior knowledge?
What is the student's background or motivation (previous education or other programmes)?
Has the student followed the set curriculum or did they create their own track?
Is there a link between the student's score on the summative assessment and their study habits (does the student do all the activities, do they read all the materials, do they deliver their work on time, etc.)?
Is there a link between how the student uses the learning materials and activities and their score on the formative tests?
Has the assessment method contributed to the learning objectives?
When is a student likely to quit, or be forced to quit, their study programme?

Several successful applications of learning analytics will be discussed in the case studies in Chapter 3. Some of the questions from this chapter return in these case studies. For example, in all case studies, the question of whether a student logs into a learning environment is taken into consideration as a factor for student success. Participation in tests, test results and activities within the system are also important indicators for student success in the case studies in the next chapter.

3. INTERVENTIONS IN EDUCATION

The previous chapters discussed the first two parts of the Learning Analytics Cycle, and the relationship between learning analytics and educational design. We also talked about the educational questions data from learning analytics allows you to answer. To complete the Learning Analytics Cycle, the next step is to think about possible interventions. Important questions relating to interventions are:

- When should you perform the intervention?
- Whom should the intervention be directed at?
- What is an effective intervention?

This chapter explains what you need to look for if you want to create effective interventions aimed at preventing risky behaviour. Finally, we will discuss a number of case studies of effective interventions.

3.1 Characteristics of effective interventions

Effective interventions in education have several characteristics:
- they take place in a timely manner;
- they are based on a personal approach;
- they have a goal and a means.

You can read more about these characteristics in the following section.

Timeliness

An intervention must be performed before the learning activity (assignment, lecture or course) has ended. Otherwise, the intervention will have no effect. Research into early predictors of risky behaviour by Baker et al. (2015) shows that there are indicators in a learning environment that can already predict who the at-risk students will be on the first day. You can thus intervene very early, if you know what these indicators are. A practical example of early intervention is the RioPACE system of Rio Salado College (see Case Study 1).

Personal approach

The second characteristic of an effective intervention is a personal approach. You can perform interventions personally or automatically. In four of the five study cases that we will discuss in Section 3.3, the parties concerned employ a personal approach. Teachers who decide to intervene actually perform the intervention themselves.

You can also set up an automatic intervention with a special computer agent, such as in the study by Wise (2014), or use a decision-making model based on a set of rules or a decision tree, such as in the study by Murnion and Helfert (2012). For example, if a student fails to log in to the digital learning environment for a few weeks you can have an email sent to the student automatically. In this email, you can recommend that the student use the learning environment more actively or that they contact the teacher. One important caveat is that Dutch legislation requires human intervention. That is, systems may not be fully automatic and can only make recommendations. You are allowed to prepare an intervention in advance in the learning environment, but a teacher should decide to perform an intervention themselves (SURF, 2015a). You can therefore combine automation with a personal approach. A practical example of this is ‘Course Signals’ (see Case Study 3).

Goals and means

The previous two characteristics mainly concern the application of interventions, but what about goals and means? When designing interventions, it is important to know what your ultimate goal is and what means you will use to achieve this. For example, the goal might be to promote cognitive, metacognitive and social activities. Means here might include questions, explanations and instructions. A practical example, in which different means are used, can be found in Case Study 2 on the OAAI system.

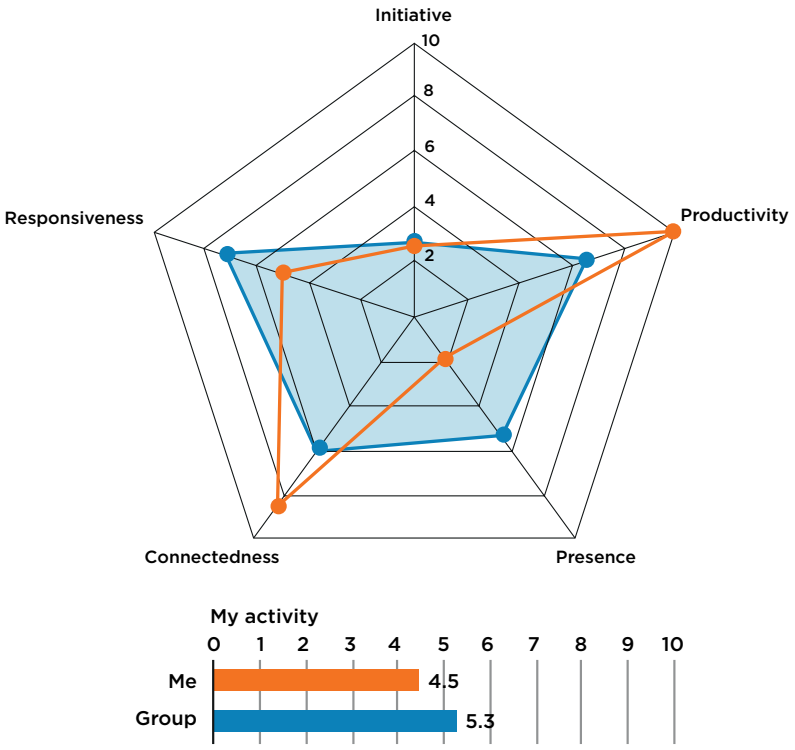
3.2 Points to consider with regard to interventions

Various studies on learning analytics systems have shown that interventions can contribute positively to education.[1] However, there are also a few caveats that can be made with regard to interventions. For example, in the study of Lauría et al. (2013), students stopped with a course more quickly if they had received an intervention. It should be noted that this study mainly concerned electives, but in their study, Lonn, Aguilar and Teasley (2015) also found that students adjusted their goals downwards when they received an intervention. We therefore recommend that you think carefully about the potential impact of an intervention. After all, you want to encourage students to modify their study habits, rather than give the impression that they should stop because their chance of success is low.

One last comment about interventions concerns the increased workload for teachers. If learning analytics are having a positive effect on learning activities and performance, you would do well to free up resources for this purpose. This would allow you to prevent time pressure from becoming an inhibiting factor for learning analytics and interventions.

[1] *Smith, Lange & Huston, 2012; Arnold & Pistilli, 2012; Jayaprakash et al., 2014; Whale, Valenzuela & Fisher, 2013.*

3.3 Examples



Case Study 1: Learner Analytics for Sustaining Europe's Resources (LASER) of the Open University

LASER is a *group awareness widget*. The system provides insight into the group dynamics of students learning in online study groups. In the LASER project, the university can use learning analytics to develop new ways to raise awareness among students and teachers of activities in the learning environment of the *European Virtual Seminar* (EVS). The EVS is a joint programme of European universities aimed at stimulating an international, multidisciplinary dialogue on sustainable development among students from all over Europe. The students work in small virtual teams. The learning environment enables communication with other students and teachers that is independent of time or location. One challenge is to keep the groups of students and teachers up to date on the activities and performance of the group and its members.

Performance is measured using the *LASER activity widget*. With this widget, a tutor or student can determine whether a group is collaborating well or if an intervention is needed. The widget keeps track of performance during the entire course. The student can thus modify their study habits at any time. Variables that are measured by the widget mainly relate to activities within the learning environment. The interventions focus mainly on awareness creation and communication.

The figure above contains a visualisation of the data in the widget. The widget provides different types of feedback and visualises the feedback in a spider web chart and bar charts. Different user activities are distinguished in the spider web diagram and the bar charts present all the activities. Users can also see the activities of other group members if they have themselves also switched on the *data sharing* option.

Case Study 2: RioPACE of Rio Salado College.

RioPACE is the *early warning system* of Rio Salado College in Arizona in the United States. The system conducts weekly analyses to identify students who are performing poorly at an early stage. The system classifies the students into one of three risk classes using a predictive model. The model uses five variables for the classification:

- the frequency at which a student logs in to the online learning system;
- the extent to which a student uses the system;
- the number of assignments that the student hands in;
- the number of points the student has earned within the course;
- the current workload of the student.

A teacher has an overview in the system of the risk status of all students and can take action if needed. The interventions in the system vary by programme, but the main type is telephone contact with the students. RioPACE is an example of an intervention with a successful personal approach. Research suggests that students that are contacted immediately are more successful than students that are contacted indirectly or not at all. It was also found that students who logged in to the system at an early stage were more successful than students who only did so later. Furthermore, students who had received a welcome message requesting them to log in to the course site one evening before the start of a course dropped out less often than students who had not received this email (Smith, Lange & Huston, 2012).

Case Study 3: Open Academic Analytics Initiative (OAAI) of Marist College

The Open Academic Analytics Initiative (OAAI) is a system of Marist College in New York in the US. It was later also rolled out at four partner institutions. The system has a clear goal: to determine whether a student is at such a risk that an intervention is required. Interventions via OAAI are performed early in the semester so that the student still has enough time to change their study habits or deregister themselves from the course without negative consequences. The level of risk is predicted using the following variables:

- standardised test scores;
- whether the student is studying part-time or full-time;
- the weighted average mark;
- the extent to which the student uses the online learning system.

The interventions in the OAAI system are divided into two strategies: *awareness creation* and the *Online Academic Support Environment* (OASE). Awareness creation might take the form of the teacher sending a message to the student, containing suggestions for certain follow-up actions, such as a meeting with the teacher or participation in a study group. OASE might mean the teacher provides cross-curricular or interdisciplinary help, for example, by recommending open learning materials or offering coaching. The effectiveness of the system has been studied by Jayaprakash et al. (2014), and Lauría et al. (2013). The study showed that some students responded well to interventions and showed improvements in their behaviour. On the other hand, another group of students did not improve, although they had received multiple messages. The OAAI is thus an example of a system in which intervention is not equally effective for every student.

Case Study 4: Mapping risky behaviour at the University of New England Business School

The University of New England Business School in Australia uses login details from their digital learning system to perform targeted interventions for students exhibiting risky behaviour. To this end, they check whether the student has at all used the system after the start of the trimester and some time before the deadline of an assignment. The school has developed four different interventions:

- Students who log in on less than seven days in the first two weeks of the trimester, receive a message by telephone and email reminding them to make a study plan and asking if there are any problems.
- Two other interventions take place if a student fails to log in for a voluntary or compulsory assignment for seven days.
- The last intervention is performed if a student fails to submit a voluntary assignment or if their mark is insufficient. The student will then receive an offer for additional support by email.

According to research by Whale, Valenzuela and Fisher (2013), students appreciate the interventions. The interventions encourage them to get started with the course material, help them prepare for assignments and increase their learning experience. This example shows that it is possible to perform successful interventions at different times within a course using relatively simple data and actions.

Case Study 5: Course Signals of Purdue University

One of the best known learning analytics systems is 'Course Signals' of Purdue University in Indiana in the US. The system uses a predictive model to classify the students in each course into one of three risk classes by using data from different computer systems. The model classifies the students based on performance, effort, academic history and standardised test scores. The system shows the results in a 'status traffic light' on the student's course page. The colours green, amber and red indicate whether the student has a high, medium or low chance of success. Teachers can view the status of a student at any time and intervene if necessary. Of course, the student can also take action themselves, if the traffic light indicates that it is necessary.

The staff intervenes by sending the student an email or text message, referring the student to a career counsellor or student guidance counsellor or inviting them for a personal interview. The research of Arnold and Pistilli (2012) suggests that interventions have a positive impact on student success. Moreover, the students interpret the automated emails sent by staff as personal communication. This example therefore makes it clear that automation (which makes the intervention less of a burden on the teacher) can be a good addition to a personal approach.

4. RECOMMENDATIONS AND CHALLENGES

Learning analytics has enormous potential. It can make an important contribution to study success, help prevent completion delay and reduce the drop-out rate. Learning analytics can provide students with feedback on their own learning process. In addition, it can give feedback to teachers regarding their students' performance, the effectiveness of the learning environment and possible improvements. However, selecting and interpreting the data is not easy.

As we hope this report will help you to get started using learning analytics, we would like to make the following recommendations.

4.1 Recommendations

Learning analytics as part of the education design process

It is important to realise that learning analytics can form a supplemental part of the educational process between teacher and student. When designing education, we recommend thinking about the information that is needed, in each phase, to support your students as effectively as possible.

Start on time

Designing online education with learning analytics requires a few extra steps. During or after the end of a course, it is too late to see what data is available and the information it can provide. The data is often not easily accessible or needs to be edited considerably before a teacher can use it. We expect these restrictions to be removed in the coming years as advanced learning analytics systems become available. However, this is a complex issue, which will require the attention of both SURFnet and higher education in the coming years.

Ask specific questions

If you want to get started with learning analytics, ask specific questions for each phase of the education design process (see Chapter 2). Determine exactly which information you want to record and analyse. This is important for the developers and consultants who – together with teachers – design an environment in which learning analytics takes place. After all, not everyone will find it as easy to make sense of the data.

Start small and share experiences

Start small. Select a small component of the course to practice with, such as one lesson, or one component of the learning environment. Take the time to learn. Make sure to also tell people you are working with learning analytics. Not all instructors are always aware of each other's initiatives and as a result miss the opportunity to collaborate. In short, make contact with like-minded people, such as teachers with practical questions you may be able to answer using the data.

Effective interventions

Important considerations when designing interventions are a clear objective, timely implementation and a personal approach. Teaching remains a job for human beings.

4.2 Challenges

The use of learning analytics in education poses a number of challenges that must be jointly examined by SURFnet and the educational institutions.

What data?

The biggest bottleneck in learning analytics is collecting the right data: what data is meaningful when it comes to learning? This report provides a first step towards answering that question. A definitive answer will require elaboration in the following areas:

- **Technology:** how can the required data be extracted from the systems? Which standards can be used for this purpose and are they mature enough?
- **Visualisation:** when large quantities of data become available with which you can monitor the student's learning process in detail, a convenient dashboard is needed within the learning environment. There are a number of examples of dashboards in education, although as of yet, little is known regarding which visualisations are effective and efficient (SURF, 2015b).
- **Effects:** once the correct data is accessible and transparent, the effects of learning analytics in the educational design process can be investigated. The LACE project collects examples of learning analytics applications. The examples can be found on the LACE Evidence Hub (http://evidence.laceproject.eu/).
- **Legally and ethically:** Working with learning analytics falls under specific legislation. You should therefore read the Guide to Learning Analytics under the Personal Data Protection Act published by SURFnet. You may also wish to consult the ethics committee of your faculty and your institution's legal specialists for advice on properly managing the data.

Educational practice

We have shown how learning analytics can be applied in the design of a teaching module. Through the corresponding questions, we have shown that we can get targeted feedback during online learning from logged data from the learning environment. However, this also needs to be tested in educational practice. SURFnet wants to test these learning analytics questions in an educational setting, together with educational institutions in the Netherlands. This will create a stronger connection between learning analytics and educational practice and lead to increased insight into students' learning processes. In this way, we will be able to learn what data and interventions really have a positive impact on student success.

APPENDIX 1:
PHASED PLAN FOR AN EDUCATIONAL DESIGN

Duisterwinkel et al. (2014) have developed a general phased plan for creating an educational design. They based themselves on the spider web model for curriculum design by Van den Akker (2013), but they categorised his components and placed them in a specific order. Teachers or education designers can create a coordinated course, module or lesson design by working through the various phases.

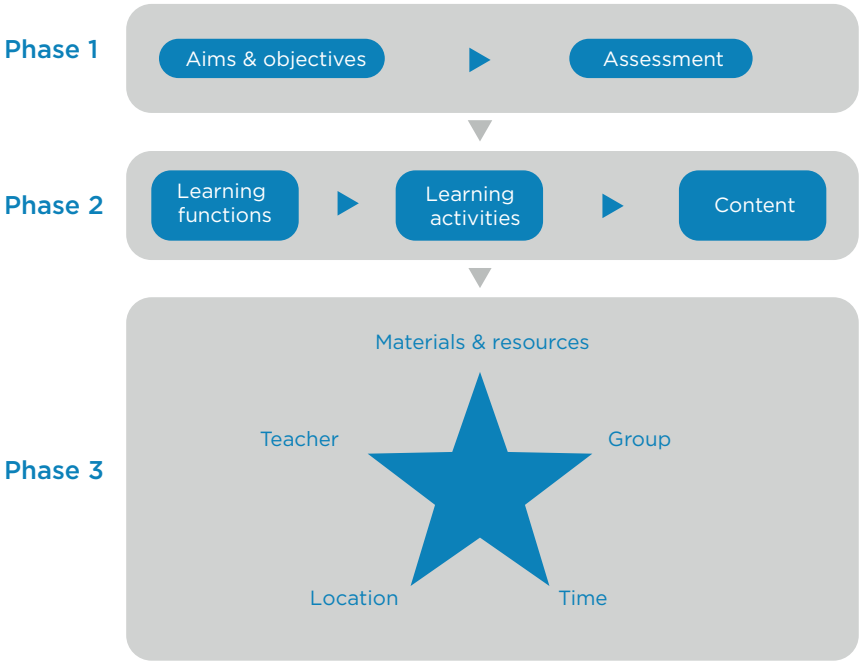


Figure 3: Flowchart course design, Duisterwinkel et al. (2014)

In the first phase, learning objectives and assessment take centre stage. The learning objectives and assessment are linked. Formulate the learning objectives such that they provide clear points of reference for the knowledge, skills and attitudes that students should be able to demonstrate during the assessment. In this way, you will be able to determine whether a student has achieved the learning objective and which form is appropriate for the test.

The second phase described by Duisterwinkel et al. (2014) deals with the educational functions, content and associated learning activities. To establish the learning activities, you should first think about the various skills or learning functions that you want to appeal to. If students need to be able to model a complex issue during a test, this will need to be practised.

The content that students will need to be able to master is also specified in the learning objectives. In this second phase, the theories and important concepts are further defined and elaborated. To this end, the education designer must consider how to integrate theory and learning function, and which learning activities will enable the students to achieve the learning objectives.

In the third and final phase, the learning activities from phase two are concretised by selecting the teaching material. This could involve things like books, articles, syllabuses, online lectures, screencasts, assignments, and so on. The teaching methods are also defined in this phase: will the students be working together and if so, how? And what role will the teacher then play? Choices about the location and class times must also be made. You should also look at situational factors in this phase, such as group size, type of student and the diversity of students in a group. This phase will also involve all manner of choices relating to the use of IT in education. Although the use of IT in education is not an end in itself, it is required if you are to apply learning analytics.

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