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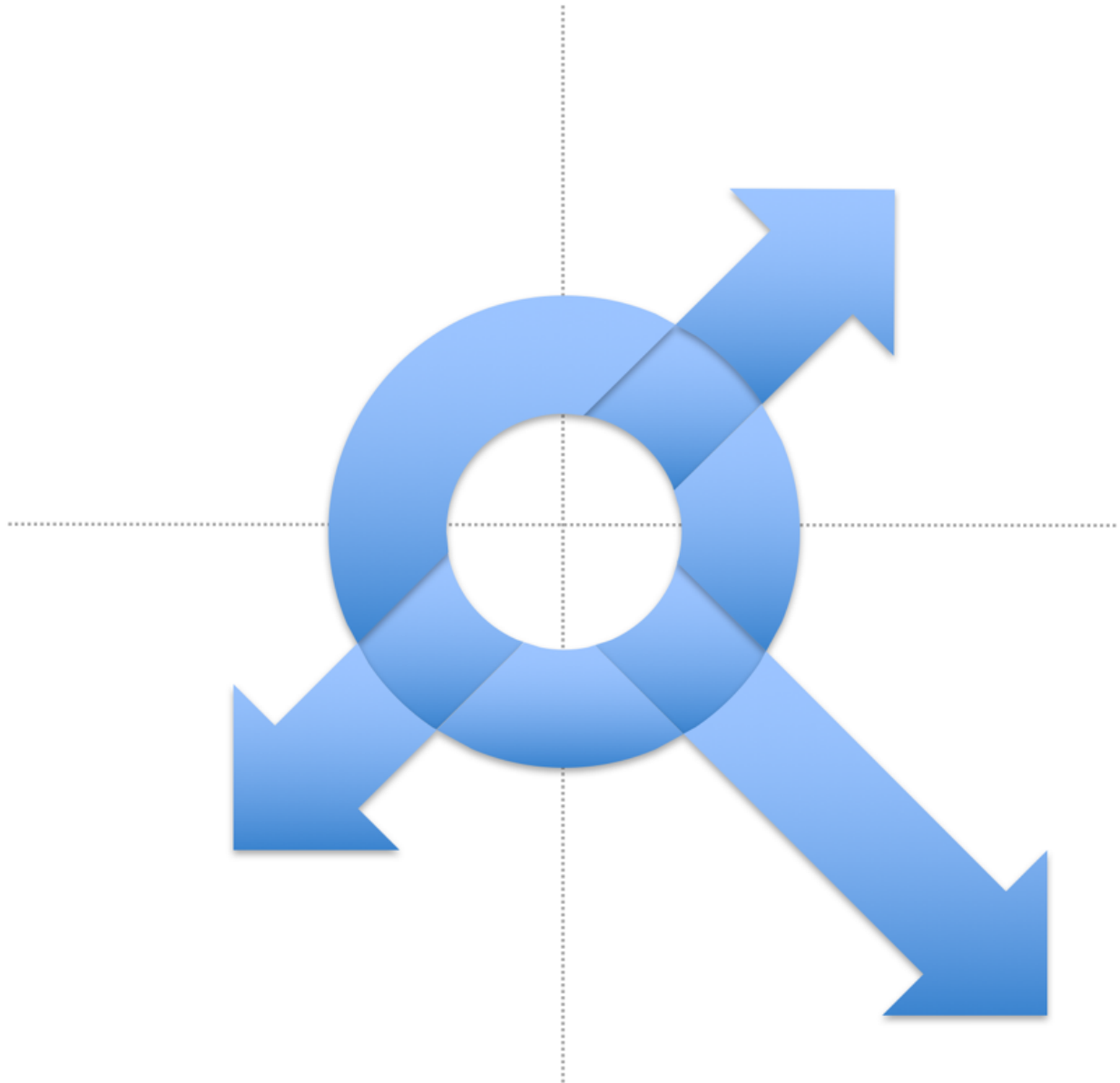
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# Improving STEM Undergraduate Education with Efficient Learning Design

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MSc IT, PG Cert ODE

Thesis submitted for the Doctor of Education (EdD) programme within the field of Educational Technology, The Open University.

October 2017

This thesis is 55,000 words including references, index, tables, and figures, but excluding appendices.

NB: Parts of this thesis has been published elsewhere during the project, in Godsk (2014a; 2014b; 2016), Godsk et al. (2015), Godsk et al. (2017), and Bjælde et al. (2015), see References.

# Abstract

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The project investigates the potential of Learning Design for efficiently improving STEM undergraduate education with technology. In order to investigate this potential, the project consists of two main studies at Aarhus University: a study of the perspectives of the main stakeholders on Learning Design based on mixed methods, and a study of how to deliver Learning Design efficiently in four undergraduate STEM modules based on an action research methodology.

The project revealed that all stakeholders at AU had a direct interest in the business, teaching, and/or learning affordances potentially provided by technology-enhanced learning based on Learning Design, and in particular students' learning was of a high common interest. However, only the educators were directly interested in Learning Design and its support for design, reuse in their practice and to inform pedagogy. A holistic concept of Efficient Learning Design and its related assessment methodology is proposed in which efficiency is expressed as a vector sum of the weighted ratios of effort for and impact on the three main stakeholders: the institution, the educators, and the students, and assessed according to their stakes by means of four outcome scenarios: outperforming, underperforming, progressive, and regressive. The assessment of the four modules identified both outperforming and progressive interventions, a series of direct and indirect factors for Efficient Learning Design as well as an important temporal aspect of Learning Design uptake.

The project concludes that it is possible to improve STEM undergraduate education with Learning Design for technology-enhanced learning efficiently and that Efficient Learning Design provides a useful concept for qualifying educational decisions.

**Keywords:** Learning Design; Efficient Learning Design; action research; mixed methods; technology-enhanced learning; educational technology; STEM education; science education; higher education; STREAM.





# Preface

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Working with educational and professional development for more than a decade implementing technology-enhanced learning (TEL) at a university has made me realise that such institutions are full of passionate educators using technology to enhance their teaching. However, this decade has also made me realise that the use of technology can often be perceived as a "one-hit wonder" in the sense that technology interventions may rely deeply on the individual educator (also referred to as a *lone ranger*, Bates, 2005), a specific module, and can even merely relate to a single delivery of a module. Obviously, this is an unsustainable and cost-ineffective practice. Thus, I believe that there is a genuine need to find a more systematic approach to enhance learning with technology at my university as well as at other educational institutions.

In 2012, while studying the H800 module on TEL provided by The Open University, I came across the topic *Learning Design* as presented by Conole (2012) and defined by Agostino (2006) with its inherent ideas of theory-informing practice through pedagogic models and representing and sharing teaching practices. Later in 2012, I decided to include the Learning Design topic in the Science faculty's professional development programme for assistant professors and in 2013 the STREAM Learning Design model (Godsk, 2013) was conceived from well-established educational strategies within science and STEM education, such as *active learning* (Bonwell & Eison, 1991), *Just-in-Time Teaching* (Novak et al., 1999), *Flipped Classroom*, and *Peer Instruction* (Mazur & Hilborn, 1997), as a way of presenting pedagogical ideas to science educators in a systematic and potentially efficient manner. Towards the end of 2013, the model had gained footing and in order to qualify the work and address the initial desire to find a sustainable alternative to the one-hit wonders, I decided to apply for the EdD programme at The Open University with this project and was accepted in 2014.

## Acknowledgements

Special thanks to my supervisors: Professor Martin J. Weller, Dr Simon J. Cross, and Assoc. Professor Christian N. Dalsgaard; my family: Nikolaj, Emil, and Betina; educators and staff participating in the research at AU (you know who you are); the OU EdD administration and OU Learning Design team; Nina V. Adolfsen, Michael E. Caspersen; Patricia Daniels; Anna H. G. Rasmussen; colleagues at Science and Technology Learning Lab; and Centre for Teaching Development and Digital Media.



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# 1. Introduction

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## The Political Agenda

Today's general political view on higher education (HE) is expressed by UNESCO (2004) in the following assertion in the context of their World Conference on HE in 2003:

‘At no time in human history was the welfare of nations so closely linked to the quality and outreach of their higher education systems and institutions’.

The view is supported by the underlying UN educational agendas: the *2015 Millennium Development Goals* (MDGs) from 2000 (United Nations Millennium Development Goals, 2000) and the *2030 Sustainable Development Goals* (SDGs) from 2015 (Sustainable development goals, 2015), which all member states have committed to. In the MDGs the focus is on primary schooling but in the SDGs the focus has been expanded to also include HE with the stated goal of ensuring ‘inclusive and quality education for all and promote lifelong learning’ and ‘by 2030, [ensuring] equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university’ (Sustainable development goals, 2015). That is to say, the common ambition is to provide affordable and quality HE for all. In addition, it is considered essential that a higher share of future generations obtain a higher level of education in order to ensure prosperity and economic growth. In Denmark, this agenda is expressed in a national strategy and a so-called *profile model*, which states that 95% of future cohorts must complete an upper secondary education by 2015, 60% must complete a further education such as academy and professional bachelor degree, and 25% must complete a HE such as Master's degree by 2020 (The Danish Government, 2013, p. 7). Furthermore, the political ambition is to provide ‘free and equal access [to the Danish educational system] regardless of background and depth of pockets’ (Larsen & Nørby, 2015).

However, in spite of the good intentions and political ambitions concerning education, the view on tuition fees and grants in particular, is currently undergoing a shift in attitude. Historically, HE has been free in large parts of Europe with underlying ideological rationales such as ‘the returns to society from an educated population are very high’, ‘education is ... a fundamental right’, and ‘tuition fees ... [have] negative impacts in terms of social equality and social benefits’ (Marcucci & Johnstone, 2007, pp. 26–27).



Currently, however, arguments such as the increased lifetime earnings and status of graduates, a persistent socially imbalanced number of graduates in spite of free access, and the increasing costs associated with providing education to an increasing number of students has changed the political view on tuition fees and grants (Marcucci & Johnstone, 2007). In 2012 in Denmark alone, the public expenditure on education was 17 billion EUR equivalent to 8.8% of the GDP. In comparison, in the UK the expenditure was 116 billion EUR, equivalent to 6.1% of GDP, and in the EU an average of 5.3% was spent on education (eurostat, 2017). These are considerable amounts, which regardless of funding model, place an emphasis on increasing efficiency as the number of students entering HE increases. As an immediate consequence, The Danish Government introduced a so-called *reprioritisation contribution* (translated from Danish 'omprioriteringsbidrag') in 2016, which in practice means that the educational sector must cut costs by two per cent each year (Finansministeriet, 2015). In addition, the *study progress reform* was initiated in 2013 to provide additional savings, which entails that universities must reduce the average degree-completion time in order to avoid cuts in funding (The Danish Government, 2013). Furthermore, there is a move to student fees, for example in the UK, where a legislation was passed in 2012 allowing universities to increase their annual tuition fees from £3,290 to a maximum of £9,000 in order to compensate for cuts in funding and still maintain a high quality (BBC, 2012; Browne, 2010).

Despite the aforementioned cost-cutting measures, it is evident that governments and institutions are interested in quality in education as well. As an example, Aarhus University (AU) has explicitly expressed its ambition to continuously improve learning by means of 'up-to-date' educational technologies for teaching and learning as well as pedagogical (and technical) assistance to the educators and students in a *policy of educational IT* (Aarhus Universitet, 2011). The policy states that 60% of all educators should receive an offer of "rethinking assistance" by 1 February 2015 and in line with the national quality report (Kvalitetsudvalget, 2015) and a recent chronicle by the Minister for Higher Education and Science (Larsen & Nørby, 2015), the Pro-Vice-Chancellor for education (PVC) announced that quality should be improved by making good use of technology (Correll, 2014). In other words, politically the technology is seen as a tool for improving teaching and learning as well as a business capacity for improving efficiency.

An even more significant role of technology is identified in The Open University's (OU) vision for teaching and learning 2025, where technology is considered as 'both a driver and enabler' (n.d., p. 6) and one of the university's five main priorities for 'transforming

... business and pedagogic practices and improving efficiency for staff and students' (n.d., p. 8). Due to the many online programmes at the OU this significance is not surprising. What is interesting, however, is the fact that a university like the OU aims at using technology to transform their business and improve learning efficiently while simultaneously scoring well in the National Student Survey (HEFCE, 2016). That is to say, it is possible for a university to provide quality teaching and good learning experiences without the need for building lecture halls and other cost-intensive facilities, and cost and quality are not necessarily contradictory aspects of providing HE. Former Vice-Chancellor Sir John Daniel refers to this assumption as the *iron triangle*, meaning that 'quality, exclusivity, and expense necessarily go together' (Daniel et al., 2009). However, as pointed out by Daniel (2010a; 2010b; 2010c; Daniel et al., 2009) educational technology used for 'open and distance learning (ODL) and eLearning' may help in 'breaking the iron triangle'; that is to say, improve quality, widen access, and lower costs at the same time. In other words, the political agenda is clear and educational technology is often portrayed as a possible solution. However, the question is how technology can support this ambition.

## Technology-enhanced learning as a means of provision

The concepts of *technology-enhanced learning* (TEL) and *e-learning* are ill defined, inclusive terms, often used synonymously to refer to any kind of teaching and learning electronically or technically supported by educational technology (Bates, 2015; Kirkwood & Price, 2014). Some even consider TEL as any kind of teaching and learning, where any kind of tool or technology plays a role in education — be it an abacus, a writing slate, or a blackboard, which in practice dilutes the concepts and expands the past history to approximately a thousand years.

Definitions of e-learning, however, tend to put emphasis on the technology as for instance in Clark and Mayer's frequently quoted definition of e-learning as '...instruction delivered on a digital device such as a computer or mobile device that is intended to support learning' (Clark & Mayer, 2011, p. 8) and implies that the technology is used to improve the learning (Price & Kirkwood, 2011). And de facto, the concept of educational technology is being used to refer to communication, multimedia, electronic machines, IT and information systems, and other information and communications technologies (ICT) that support teaching and learning and therefore covers the same part of the continuum as TEL and e-learning (see Figure 1 for an expanded version of Bates and Poole's e-learning continuum, Bates, 2005).

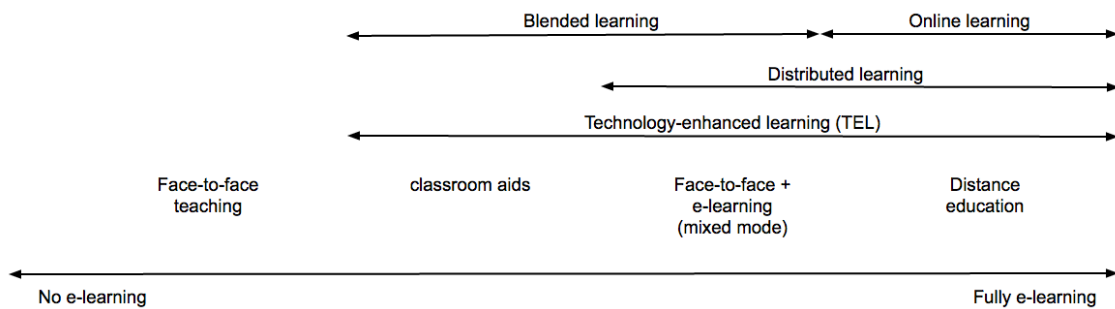


Figure 1. The continuum of e-learning.

This conception of TEL narrows down the time frame to approximately 100 years starting with the early educational films such as *The Unseen World* from 1903 by film producer Charles Urban and nature documentary pioneer F. Martin Duncan documenting mites (Figure 2); Thornton's introduction of educational radio in the Canadian National Railways and hotels in 1923 (Buck, 2006); Psychology Professor S. Pressey's teaching machines in the 1920s; and their further development by Psychology Professor B. F. Skinner in the 1950s (Figure 4).

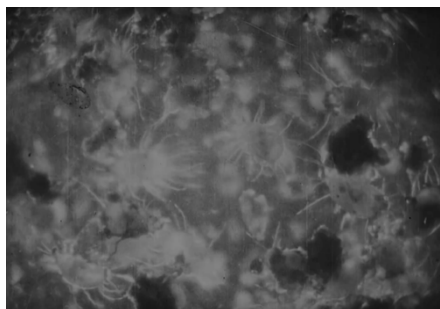


Figure 2. Cheese mites documented in *The Unseen World* from 1903.

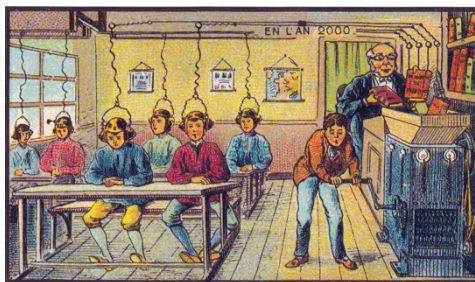


Figure 3. Villemard's vision of a classroom anno 2000 from 1910.



Figure 4. Skinner's teaching machine from 1954.



Figure 5. *The Lawnmower Man* from 1992.

Nevertheless, the e-learning vision and dream is probably better expressed in fiction. In films, literature, and arts, TEL has played a prominent, if not notorious, role as a potential hyper-effective learning method. This includes Villemard's famous postcard drawing from 1910 envisioning a classroom anno 2000, where books are transformed into

knowledge through a machine and electronic devices connected directly to the learners' head (Figure 3), and the feature film *The Lawnmower Man* (Leonard, 1992) from 1992 suggesting that virtual reality and multimedia materials could be used to develop an immersive and hyper-effective learning technology (Figure 5). But though the visions exemplify creative thinking about what would characterise optimal teaching and learning in the future they both share the common, persistent belief that learning happens in a machine-learner interaction "vacuum" and that learning is an individual process predominated with (passive) acquisition of information.

However, in reality and in the context of HE, the history of TEL is less dramatic and gained footing with TV-based *telecourses* such as OU's *Open Forum* in 1971, the introduction of *computer assisted learning* (CAL) for distance education in the early 1980s as an alternative to correspondence and telecommunication-based formats, and WWW for distance and blended learning in the early 1990s (Bennett et al., 1999; Garrison, 1985; Gibson, 1997; Kerka, 1996). Technologies such as teaching machines did primarily support the aforementioned passive acquisition of information and later research and awareness in academia suggest that active (Bonwell & Eison, 1991), participatory (Sfard, 1998), situated (Brown et al., 1989; Lave & Wenger, 1991), and/or socially constructed (Vygotsky, 1978) teaching and learning is more fruitful.

Research on TEL is characterised as 'investigating the role of technologies in education and testing out and evaluating new learning interventions' (Conole, 2013, p. 27) and definitions of educational technology tend to emphasise the process of facilitating and improving learning:

'educational technology is the study and ethical practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources' (Robinson et al., 2008, p. 15).

Summed up, the agenda of TEL in HE has been and still is concerned with facilitating and improving teaching and learning with technology in an effective and efficient way. And despite the discrepancy between the visionaries and researchers they still share a common dream and goal: that technology can enhance and transform teaching and learning effectively. Evidence has been found of TEL's effectiveness and efficiency in terms of both a *business potential* for increasing market shares, reputation, student progression, recruitment of geographically remote students, and cost-effectiveness as well as a *pedagogical potential* in terms of increased flexibility and widened access to

curriculum, support students' revision, increased engagement, improved assessment and feedback, support for skills training, professional and personal development, linking theory to practice, support interaction and collaboration, and improve the students' discernment skills (Blumenfeld et al., 1991; Conole, 2013; Conole & Dyke, 2004; Price & Kirkwood, 2011).

## Learning Design as a possible efficient solution

Though TEL holds a pedagogical and business potential in HE, realising this is far from trivial and often entails barriers such as increasing costs and investments in technology, quality issues, and limited or no evidence of improved learning outcomes (Bates, 2010, p. 8). Both costs and quality are obvious barriers to the integration of technology but also practical, organisational, and cultural aspects associated with introducing technology in education may constitute major barriers. Initiatives often require substantial budgets, expertise and assistance from educational developers and media producers, and particularly enthusiastic educators (Earle, 2002; Romiszowski, 2004; Weller, 2002), and, unfortunately, this may at the same time be the reason why many initiatives turn out to be unviable one-hit wonders tailored for very specific situations and thus not reusable (Godsk & Hansen, 2016), or driven by the lone ranger approach where enthusiastic and self-taught educators transform their teaching with technology by themselves (Bates, 2005).

Ertmer stresses in her review of literature on technology integration that: 'achieving technology integration is a multifaceted challenge that entails more than simply acquiring and distributing computers' (1999, p, 53). Instead, she suggests distinguishing between so-called *first-order* and *second-order barriers* to technology integration and that it will be most effective to address both orders simultaneously (Ertmer, 1999). First-order barriers are described as 'being extrinsic to teachers and include lack of access to computers and software, insufficient time to plan instruction, and inadequate technical and administrative support' and mistakenly considered as the main barriers under the assumption 'that if teachers had access to enough equipment and training, classroom integration would follow' (Ertmer, 1999, p. 47). Second-order barriers are 'intrinsic to teachers and include beliefs about teaching, beliefs about computers, established classroom practices, and unwillingness to change' (Ertmer, 1999, p. 48) as well as poor handling of the autonomy of educators and their academic freedom and no common pedagogical language among educators (Bates, 2010; Marshall, 2010).

Although universities usually are aware of first- and second-order barriers and even address them in various ways through ‘sufficient facility, rich digital instructional resources, positive attitudes or strong beliefs toward technology integration’ (Tsai & Chai, 2012, p. 1058) and some universities even adopt institutional models such as the *e-learning maturity model* for improving adoption of e-learning and moving beyond *ad hoc approaches* (Marshall & Mitchell, 2002), it may not necessarily result in a successful integration. Thus, Tsai and Chai (2012) suggest considering what they refer to as *third-order barrier* in terms of ‘lack of design thinking by teachers’. They stress that educators should ‘rely on some design thinking to re-organise or create learning materials and activities, adapting to the instructional needs for different contexts or varying groups of learners’ (Tsai & Chai, 2012, p. 1058). Though *design thinking* is an ambiguous concept that usually refers to ‘the act of creating new products, services, or experiences’ in general (Koh et al., 2015, p. 535; see Appendix D), it does highlight an active educator role where s/he is developing her/his teaching practice according to the context. To support this role and process in a potential cost-effective way, a possible solution could be to adopt the more systematic and scalable Learning Design (LD) approach and its inherent ideas of making technology interventions explicit and best practices reusable and sharable using resources such as pedagogy-informed models and *toolkits* (Agostinho, 2006; Conole, 2013; Conole & Oliver, 2002; Dalziel, 2016; Koper & Tattersall, 2010; Laurillard & Masterman, 2010).

## Research questions

In summary, the agenda of providing quality HE to a growing number of students is challenged by limited funds and diverse political priorities — universally, in Denmark, and in STEM undergraduate education at AU. TEL has demonstrated its ability to improve teaching and learning in a potentially cost-effective way; however, a closer look at initiatives and interventions show a strong dependency on the context in which it has been developed and applied. This often renders the results and experiences of little value in addressing the universal challenge of providing quality HE cost-effectively due to the limited transferability of the findings and/or integration to other contexts (Earle, 2002; Romiszowski, 2004; Weller, 2002; 2011).

Instead, it is proposed that a more systematic approach such as LD with its built-in language to represent and disseminate teaching practices is required to support the transferability and ultimately provide quality education cost-effectively. However, in order to look further into how to deliver quality education cost-effectively within the scope of

this project, it is important to understand what we mean by *quality education*, that is, what are the main stakeholders' perspectives on this in the context of STEM undergraduate education, and *cost-effective*, which in practice may be an oversimplified concept not covering the complexity of the actual ratio of *efforts* and *impacts* of educational initiatives.

That is to say, in order to address the ultimate aim of this project, which is to identify a sustainable approach to educational development capable of realising the TEL ambition of efficient educational technology in a STEM undergraduate context, LD is being trialled by means of the three research questions (RQ) provided below by identifying the main perspectives on LD (RQ1), conceptualising LD efficiency and the related assessment methodology (RQ2), and scrutinising how to deliver LD efficiently by means of the STREAM model (Godsk, 2013) (RQ3).

RQ1: What are the perspectives of the main stakeholders on Learning Design for TEL in STEM undergraduate education?

RQ2: How can Efficient Learning Design for TEL in STEM undergraduate education be conceptualised and assessed?

RQ3: How to deliver Efficient Learning Design in STEM undergraduate education with STREAM?

In the context of this thesis, the Learning Design concept may refer to a *process*, a *product*, and/or a *practice* of educational development (based on TEL). Further clarification is provided in the literature review.

In order to analyse how STREAM delivers efficient learning design, the concept of "affordance" is used throughout the thesis to describe the potential and/or possibilities of TEL based on LD — that is to say, what it potentially can actualise. Thus, affordances may include cost-effectiveness, student satisfaction, and support for repetition of curriculum, all depending on the technology and intervention. Nevertheless, the thesis acknowledges that the concept of affordances is ontologically contested and in other contexts can be used to refer to technological features, functional properties, constraints, and the perception of the properties of technology (Gaver, 1991; Norman, 2002; Parchoma, 2014).

## Structure of the thesis

The overall logic of the thesis is that:

- the 'Introduction' provides an overall motivation for the project and frames the research questions;
- the 'Literature Review' provides an understanding of the LD concept as well the context in which it is placed;
- the 'Conceptualisation of Learning Design efficiency' develops the efficiency concept based on literature and is subsequently used in the 'Methodology' (this section also includes a Figure 12 illustrating the methodological structure);
- the 'Learning Design perspectives' analyses the general perspectives on LD for TEL in STEM HE, whereas the 'Learning Design cases' documents how LD was delivered as well as the associated efforts and impacts;
- the 'Discussion' and 'Conclusions and recommendations' sections provide discussion of findings, interpretations, and recommendations for (future) practice and research.

In addition, a number of appendices are provided to further elaborate and document the main thesis. These are structured so that Appendix A–C are related to thesis formalities as well as the terminology of the thesis; Appendix D–F are related to literature, theory, and methodology; and Appendix G–T are related to methods, data, and data analysis.





## 2. Literature Review

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### Understanding Learning Design

LD emerged as a research field around 2000 and is currently gaining footing as a way of 'devising new practices, plans of activity, resources and tools aimed at achieving educational aims' (Open University, 2013) as well as for supporting reusability of teaching practices, reducing time spent on the development, and making effective use of educational technology (Britain, 2004; Conole, 2013; Conole & Fill, 2005; Cross et al., 2008; Oliver & Conole, 2000). Some of the early well-known resources for LD are the IMS Learning Design specification (2014) developed in 2003 for 'modelling learning processes' and Sims concept of *Design Alchemy* (2001). However, the ideas and much of the work have been built on earlier research on ICT mediated learning and *pedagogical frameworks* (see Agostinho et al., 2011; Goodyear, 1999; Oliver, 1999; Oliver & Herrington, 2001). In addition, previous and related works such as Salmon's (Salmon, 2004; 2013) and Laurillard's Conversational Framework from the early 1990s (Laurillard, 2002) may also be considered as LD models though they were not originally associated with the concept and one could even argue that LD dates back to Pressey's teaching machines in the 1920s if *instructional design* is considered as an overlapping area. In addition, there is a series of rival concepts, including *curriculum design* (Jisc, 2013), *educational design* (Goodyear, 2005), and *modelling languages* (Dalziel & Dobozy, 2016) which are used both synonymously or to describe, respectively, the "big picture" of education: '... from aligning its portfolio of courses to its mission, through market research and course development to quality assurance and enhancement, resource allocation, timetabling, recruitment and assessment' (Jisc, 2013) and the idea of *pattern language* as an improved way of capturing and sharing teaching practices (Goodyear, 2005).

Research on LD is particularly prevalent in Australia, UK, the Netherlands, Canada, Spain, and USA judging from the number of articles, the affiliation of the most cited authors and articles on the topic. For instance, of the two most cited handbooks on LD, the *Handbook on Learning Design and Learning Objects* (Lockyer et al., 2009) and *Learning Design* (Koper & Tattersall, 2010), 19 of the 86 contributions were from Australia, 18 from UK, 17 from the Netherlands, 10 from USA, seven from Spain, and seven from Canada. Though these figures may be partly explained by the location of the editors, a search on Google Scholar and the American Education Resources Information

Center's search engine of education research (ERIC) revealed a similar distribution. Of the top 25 'most relevant' results on Google Scholar (in 2014) and the seven most cited authors on ERIC on 'learning design' (as of 6 April 2017) all were either Dutch, American, Australian, British, Israeli, or Spanish. Though the prevalence of research on LD may not provide a representative picture of practice, the Google Trends interest index revealed a very similar interest with Australia being most interested in LD (index 100), India came in second (index 47), followed by UK and US (index 38), and France (index 5) (per 29 August 2017). No index was available for Denmark due to too little interest.

A closer look at the contributions reveals a large difference in the understandings of LD ranging from the American, Dutch, and Spanish researchers being highly concerned with software and system architecture to the Australian and British researchers focusing more on pedagogical aspects. This difference is also expressed in the various definitions of the concept ranging from highly standard-oriented and technical understandings such as represented in the *IMS Learning Design* (2003) and in *design patterns* (Laurillard, 2012) to more open-ended definitions put forward by Koper and Olivier (2004) and pedagogical and educator role-oriented understandings as represented by Australian and British researchers. This dichotomy between the technical and the educator-oriented understandings is also referred to as *two lines of inquiry* (Agostinho et al., 2011) or *approaches* (Mor & Craft, 2012), where the technical understanding is concerned with 'how to represent teaching practice from a technical perspective in the development and delivery of online learning environments' design' (Agostinho et. al., 2011, p. 97) and the pedagogical-oriented understanding is concerned with 'how to represent teaching practice in an appropriate form to enable teachers to share ideas about innovative online pedagogy and think about the process of design' (Agostinho et. al., 2011, p. 97). Nevertheless, many of the recent and commonly used understandings and definitions share a more inclusive perception that LD is about supporting the development and use of educational technology in (online) teaching practice in a pedagogy-informed way (Agostinho, 2006; Conole, 2013; Conole & Fill, 2005; Cross & Conole, 2009; Oliver & Conole, 2000; The OU Learning Design Initiative (OULDI), 2014a).

Some of the more widely used definitions are put forward by Agostinho (2006, p. 3):

'A learning design is a representation of teaching and learning practice documented in some notational form so that it can serve as a model or template adaptable by a teacher to suit his/her context'.

And by Koper and Tattersall (2010, pp. 3–4):

‘A learning design is ... the application of learning design knowledge when developing a concrete unit of learning, e.g. a course, a lesson, a curriculum, a learning event.’

And extended by Mor and Craft (2012, p. 86) to include educational aims:

‘LD [sic] is the act of devising new practices, plans of activity, resources and tools aimed at achieving particular educational aims in a given situation’.

This definition is also adopted by The Open University (2013) in the context of their Inquiry for Learning Design project and OULDI together with the elucidation that LD refers to ‘a range of activities associated with better describing, understanding, supporting and guiding pedagogic design practices and processes’ (Cross & Conole, 2009) and the ambition to empower educators in developing learning activities (denoted as “provide scaffolds”).

Nevertheless, in order to further substantiate the LD concept a group of researchers teamed up in September 2012 and devised a manifesto entitled ‘The Larnaca Declaration on Learning Design’ (Dalziel et al., 2016). Although the manifesto does not provide a precise definition of the concept it does outline a list of ideas, stresses its pedagogic neutrality, and points out that it may refer to a product, process, and a practice (see also Cross & Conole, 2009). However, other research suggests that LD may populate no less than seven different roles: a methodology, a role or stage in a process, an object or artefact, a support to decisions on resource, a means to promote new pedagogic approaches and tools, an aspiration, and an interpretation suitable for reuse (Cross et al., 2011, p. 30). In particular, educators use the term as a verb to designate their teaching development practice/process (Dalziel et al., 2016), and, as Mor and Craft (2012) point out with reference to Smith and Ragan (2005), it is important to consider what is being meant by *design* and that ‘LD might be more accurately described as Design for Learning’. The wording ‘design for learning’ is often used synonymously with LD but, as Sims (2001) stresses, also emphasises the focus on the learning and is a way to differentiate the field from instructional design and its focus on teaching materials. LD is learner-centred instead of teacher-centred and outcomes-based instead of content-based (Sims, 2013; 2014).

However, the concept is still evolving and more recently, that is, 2015, LD at OU was described by merely three principles: 'Mechanisms to encourage design conversations across disciplines and expert roles', 'the use of tools and instruments as a means of describing and sharing designs', and 'the use of information and data to inform the conceptual tools and frameworks that guide the decision-making process' (Galley, 2015, p. 6; Open University, n.d.). That is to say, there is currently a strong focus on providing an educational language and a potential link to data-oriented educational development such as learning analytics (LA) and scientific teaching (more on this below).

Though the definitions and understandings capture important characteristics of LD one could argue that many of them have a misleading focus on the educators suggesting that the aim is to design *teaching* instead of designing for actual learning. As a consequence, the aforementioned definition provided by Mor and Craft (2012) which includes educational aims provide a somewhat more precise description of LD as it includes a focus on the learning outcome and thus also on the aspect of impact on students' learning. Nevertheless, there is still room for developing a description of LD, which more explicitly captures the essence of the concept.

## The role of resources

The variety of interpretations and their level of concreteness are also reflected in the many different types of LD tools, models, resources and their role in the process. Some provide entire storyboards concerning how the learning materials should be designed and implemented, what the students are supposed to do, instructions to the educator, and sometimes even plans for development workshops and tools to support this process (Bennett et al., 2014; Coeducate, 2012; Course Tools, 2014; e4innovation.com, 2015; University of Cambridge, 2013; University of Leicester, 2014; Viewpoints, 2012). Others merely provide a pedagogical framework of how teaching and learning could be facilitated and no roadmap for the actual development or adoption (Atkinson, 2014). Conole and Oliver (2002) identify a whole range of LD models and resources such as *tool*, *toolkit*, *framework*, *templates*, *wizards*, *good practice*, *best practice*, and *model*. Though they ascertain that the terms are used inconsistently, they do identify an inherent continuum ranging from *frameworks* offering 'a theoretical context and scope for work but leave the user to devise their own strategy for its implementation' to *wizards* and *templates* providing 'high levels of support and step-by-step guidance but little possibility of user-adaptation' (Conole & Oliver, 2002, p. 4). This continuum is further elaborated in Conole and Fill (2005, p. 1) by presenting a toolkit as an intermediate, structured resource in the continuum for planning, scoping, costing, and guiding 'practitioners

through the process of creating pedagogically informed learning activities which make effective use of appropriate tools and resources'. According to Conole and Fill (2005, p. 6) 'toolkits are designed to be easy-to-use for practitioners; provide guidance, but not be prescriptive; be adaptable and easy to customise to the local context; provide a comprehensive resource of relevant material; and provide demonstrable benefit to users'.

To the more guiding end of the range one may add design patterns — sometimes referred to as *pedagogical patterns* (Koper, 2005; Laurillard, 2012; Mor & Winters, 2007), *exemplars* (AUTC, 2003b), and the LDTool's collection of designs (University of Wollongong, 2017). The concept of patterns originates from architecture and is used to describe:

'a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice' (Alexander et al., 1977, p. x).

In the context of LD, the idea of patterns is that a standardised template is used to describe a good educational practice for a specific educational challenge and situation and as such makes it sharable to other contexts.

In addition, tools for representing, visualising, and even implementing LD are sometimes provided. This includes the so-called *pedagogical planner tools* and various tools for visualising LDs. Pedagogical planners are defined as 'tools ... purpose-built to guide teachers through the construction of plans for learning sessions that make appropriate, and effective, use of technology' (Masterman, 2009, p. 210) and includes Phoebe (2014), London Pedagogy Planner (2014), DialogPLUS (Conole & Fill, 2005), Learning Design Support Environment (also referred to as Learning Designer) (LDSE) (2014), and many others (Conole, 2013; Cross et al., 2008). Tools for visualising designs include CompendiumLD (2016; Conole & Weller, 2007; 2008), WebCollage (2014), CADMOS (2014), and the Learning Activity Management System (LAMS) (2014). LAMS is, by the way, an example of a tool which can be directly integrated with learning management systems (LMS) and thus includes mechanisms for the actual implementation of LD.

In other words, the role of tools, models, and technologies for design and implementation varies. In some practices, there is a predefined toolkit with models and technologies for

the educator to adopt. In other practices, it is up to the educator to find the appropriate tools and models. The level of detail of the tools, models, and resources ranges from open-ended frameworks guiding the educator to highly guiding and orchestrating technologies and models. However, this raises at least two fundamental concerns related to transferability in educational research. Firstly, education is not an exact science, where experiments can be reproduced and outcomes predicted. Secondly, the idea of patterns and transferrable practices presupposes that teaching and learning contexts are comparable. It is, however, doubtful that any setting and context is even close to being similar. Even in online settings the students will still be located in a complex context making it impossible to predict the exact learning process and outcome.

### The orchestration of practices

The role of LD is considered differently ranging from a product, a design process, a change agent promoting certain pedagogical approaches and tools, and as a stand-alone tool for planning and development (Atkinson, 2014; Cross et al.; 2011; Cross & Conole, 2009). However, in the reviewed initiatives and practices, LD is typically associated with deployment activities such as a design process (OULDI, 2014b), workshops (Cross & Conole, 2009; Mor, 2014) and things to do and read (e.g., Course Tools, Norman, 2012), and the processes are orchestrated in various levels of detail. In the context of OULDI (2014a), LD aims at not only providing methods for 'supporting and guiding learning design', but also being embedded in for instance, workshops, staff development, and supported by dedicated communities (Cross & Conole, 2009, p. 1). Similarly, the Learning Design Studio (LDS) defines a process for engaging practitioners in applying technology in their practice using a cyclic design process (Mor, 2014; Mor & Mogilevsky, 2013a; 2013b). It does not, however, prescribe a specific pedagogical approach or technology. Rather, it encourages participants to learn from past innovations and practices and thus offers a flexible and pedagogically open-ended approach to educational development. Correspondingly, a "lightweight widget toolset" including an inquiry-based framework is developed at University of Bolton for the educators to develop the pedagogical, organisational, and assessment structure of modules (Coeducate, 2012; Powell & Millwood, 2008) without advanced technological skills.

Conole and Oliver's (2002) continuum of tools, Agostinho et al.'s (2011) two lines of inquiry, and Mor and Craft's (2012) identified approaches, suggest that there are great variations among both the pedagogical, technical, and organisational aspects of LD initiatives and, thus, LD is, per definition, multidimensional and multifaceted. Though not described explicitly in the literature, it appears that in particular a continuum of the *level*

*of orchestration* of LD processes is already prevailing and, at the same time, useful for understanding a LD practice as well as its associated effort. This continuum is characterised by its two extremes with *open-ended provision* of LD in one end and *orchestrated practices* in the other.

The open-ended provision is characterised by pedagogy embedded in provided models, pedagogical frameworks, patterns, wizards, exemplars, and other resources, and it is up to the educator to apply this in her/his teaching practice. That is to say, the models are not pedagogically neutral as suggested by Dalziel et al. (2016) and pedagogy theory is inducted into the process in which the educator plays the main role in both developing and implementing the LD. Pedagogy, media, and technical support may be provided on an ad hoc basis as "guide on the side". The reuse and sharing of the LD rests on her/his dissemination practice as well as how the design is being articulated and any potential ripple effects. Open-ended LD approaches include the use of LD exemplars (AUTC, 2003b) and the LDTool (University of Wollongong, 2017), the provision of toolkits (Conole & Fill, 2005) and patterns as well as the STREAM project (Godsk, 2014a; 2014b; Godsk & Hansen, 2016).

At the other end are the orchestrated practices in which educators and other relevant stakeholders participate in workshops and other kinds of process facilitation where the design is typically deducted based on pedagogy theory, experiences, and LA supported by various design aids. The concrete designs may be represented by means of pedagogically neutral design aids such as templates, flowcharts, cards, and IT systems for representation, which are also used for later reuse and sharing the designs among educators. Orchestrated practices may include OULDI (2014a), PALET (Williamson, 2012), Carpe Diem (2017), Coeducate (2012), 7Cs (University of Leicester, 2014), and UG-Flex (2012). However, as with the open-ended LD practices, tools and designs may be used differently and therefore also lie differently along the continuum depending on the actual practice.

In theory, both lines of inquiry as well as the entire range of models and resources could be in use in both extremes. However, in practice this would make little sense as, for example, an open-ended provision without concrete design aids and/or models would not qualify as LD and barely qualify as educational development at all, just as orchestrated practices with highly concrete models would render the educators superfluous and thus not qualify as LD either. Nevertheless, the idea of an orchestrated practice with a structured involvement of participants, and in particular educators, is



consistent through most of the initiatives but at the same time not without cultural, practical, and/or resource barriers. In the DS project's executive summary, it is concluded that:

'Innovation was ... often held back by cultural ... constraints: for example by a tendency for curriculum approval to be "owned" by a small number of senior staff in a department, or by widely held "organisational myths" about what kinds of curriculum can be approved' (The Design Studio, 2013b).

In addition, the Coeducate initiative concluded that its approach to innovating and transforming practice was too radical and should include additional support to educators, learners, and administrators for adopting and deploying the new practices (Powell & Olivier, 2012). Furthermore, the LDS turned out to include barriers as the process was potentially resource intensive and time-consuming. As Mor (2013) suggests, a workshop of up to a day will only provide a "taste" of the process and a series of workshops and/or lessons would be required to facilitate the process. In other words, approaches such as the Jisc Curriculum Design Studio's (2013a) curriculum design projects will inevitably require comprehensive resources for facilitating the process as well as effort from the participants and facilitators compared to more open-ended approaches.

The highly orchestrated approach to LD may, however, be substantiated in the well-known finding that professional development must offer 'practical ideas that can be efficiently used to directly enhance desired learning outcomes in students' (Guskey, 1986, p. 6) and that 'significant change in teachers' beliefs and attitudes is likely to take place only after changes in student learning outcomes are evidenced' (Guskey, 1986, p. 7). In this context, workshops may serve as a way of making LD more practical to the educators and potentially also share data about students' learning outcomes. Nevertheless, none of the LD definitions presuppose this high level of orchestrated process. They merely suggest some *level of intention* and/or *enactment* by referring to LD as, for instance, an 'act of devising new practices' (Mor & Craft, 2012, p. 86) and highlight the importance of having pedagogy ideas represented 'in some notational form so that it can serve as a model or template adaptable by a teacher to suit his/her context' (Agostinho, 2006, p. 3).

## The five characteristics of Learning Design practice

Summed up, LD is a concept with no common, precise definition or understanding, and that in some cases is used synonymously or associated with instructional design,

educational design, or curriculum design, and sometimes it is used as a positive word to signify the intended introduction of more modern, student learning-oriented approaches to teaching. However, where it is not used as a synonym or merely as a positive word, it may be described as a systematic educational development *practice* focusing on students' learning, where a *LD product* is being developed during a *LD process* actively involving the educator(s) and supported by concrete and practical aids such as pedagogical models, tools, and resources for theory informing, representing, reusing, and/or sharing designs.

However tempting it may be to try frame LD in the provided description above or in the series of already provided definitions by researchers, in diverse SIGs, large-scale projects, and manifestos such as the ASCILITE Learning Design SIG (2016), the Jisc *Design Studio* (2013) and the Larnaca Declaration (Dalziel et al., 2016), none has yet been able to provide a clear and concise definition. At best, one or more key characteristics are highlighted and this may well be the essence of LD practices: they share a series of common ambitions and characteristics but actual practices may have diverse aims, include diverse tools and resources, and have different approaches to deployment. Revisiting the already presented literature as well as the definitions, descriptions, and cases it provides, a wide consensus of the following five characteristics of LD practices can be identified (which can be remembered by the acronym "PLADR"):

#### *Pedagogy-informed teaching (with technology)*

LD is characterised by pedagogical theory made operational and practical to the educators, thus supporting them in making pedagogically-informed development of their teaching practice. Educational technology is often considered as an integral part of the process and/or design; however, many of the commonly used definitions disregard this aspect (Agostinho, 2006; Conole & Fill, 2005; Cross & Conole, 2009; Koper & Tattersall, 2010; Mor & Craft, 2012; Oliver & Conole, 2000). The actual deployment is organised differently ranging from highly orchestrated processes with structured involvement of participants and aids to open-ended provision of non-neutral pedagogical models through which theory is inducted.

#### *Learning-centred*

There is a declared focus on designing the learning or *for* learning depending on ontological position, that is to say, not merely designing the teaching or teaching materials (Conole, 2013; Sims, 2013). How this is put into practice differs, but it stresses an underlying ontological position: that it is possible to design (for) learning. In the context

of this project, the learning-centeredness is addressed by assessing the impact on the students.

### Design aids

Different kinds of training programmes, materials, pedagogical models, and/or activities are provided to the educators to support their design decisions (Conole & Fill, 2005). This may include workshops, supervision sessions, templates, printed cards, pedagogical models and frameworks, exemplars, design patterns, and IT tools for representing, analysing (e.g., LA), and sharing designs (see Figure 6) (CompendiumLD, 2016; Koper, 2005; LAMS Foundation, 2016; LDSE, 2014, Learning Designer, 2016; University of Wollongong, 2017). These aids may be described according to a continuum of their role ranging from frameworks in one end which merely provide a pedagogical concept to the educators, to patterns, wizards and templates with a predefined teaching practice in the other end (Conole & Fill, 2005).

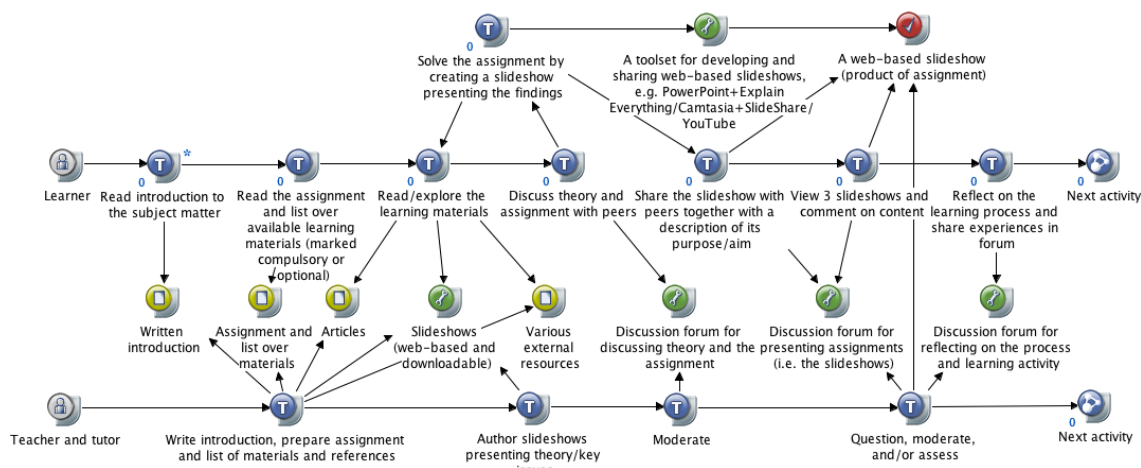


Figure 6. Screenshot of a LD represented in CompendiumLD (Godsk, 2012).

### Design-centred

The development and implementation is a process where various stakeholders are actively involved to inform the design of the teaching and learning. Educators play an active role in the process — for instance by means of workshops (see Figure 7) or other design thinking activities (Agostinho, 2006; Conole, 2013; Cross & Conole, 2009). In the context of this project an action research methodology is adopted (see Chapter 4), whereas others may adopt a more traditional design approach.



Figure 7. LD workshop (Photo: Yishay Mor, 2016).

### Reusability and shareability

At the conceptual level LD should be considered as a 'general descriptive framework that could describe many different types of teaching and learning activities' (Dalziel et al., 2016, p. 15). The desire is to articulate pedagogy and to explicate teaching practices in order to make them reusable and sharable through various means of representation and/or through a *notational system* (Dalziel et al., 2016, Koper & Tattersall, 2010; Laurillard, 2012; Mor & Winters, 2007). This may include templates and tools for outlining designs as well as portals for sharing designs (see Figure 8).

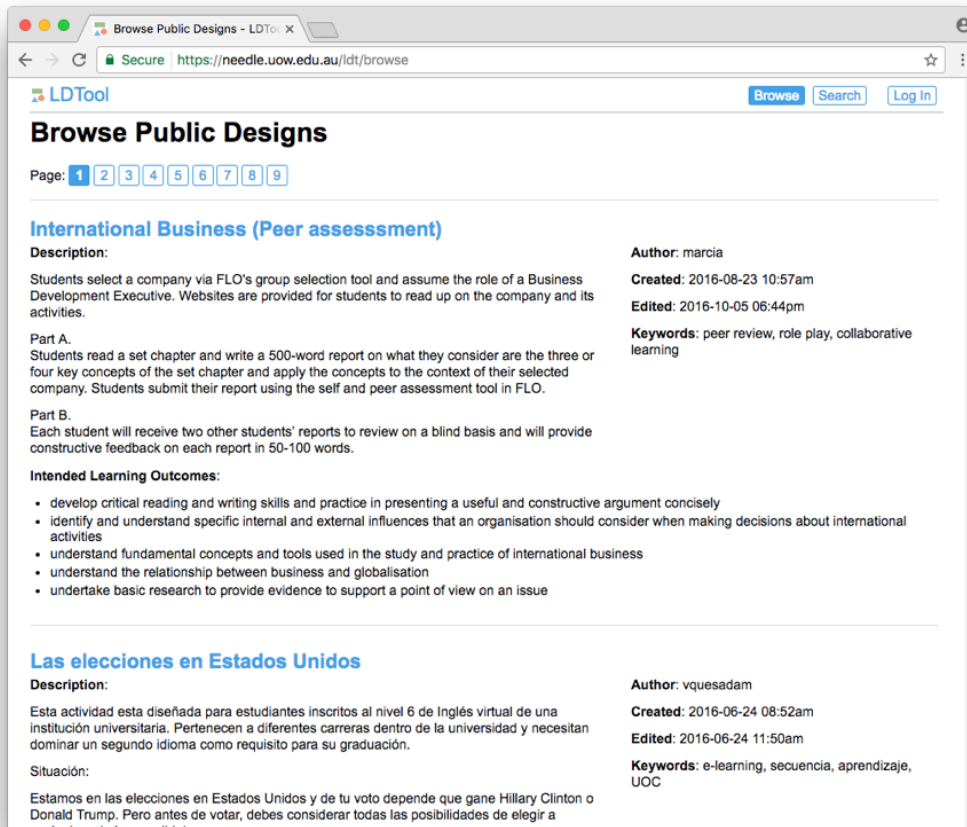


Figure 8. University of Wollongong's portal (2017), LDTTool, for sharing LDs.

## Related research areas

LD is a relatively young field of research that emerges from a whole series of related research areas. This includes *TEL*, *e-learning*, and *instructional design*, which have a much longer tradition dating back to Pressey's teaching machines in the 1920s. Instructional Design is, arguably, closely related to LD and often defined as a:

'systematic and reflective process of translating principles of learning and instruction into plans for instructional materials, activities, information resources, and evaluation' (Smith & Ragan, 1999, p. 2).

However, as Conole (2013, p. 35) points out, instructional design differs as it is typically characterised by dedicated designers developing instructional materials for certain settings and learners. That is to say, the educators usually play a passive role and do not develop the materials themselves. As further stressed by Merrill et al. (1996, p. 2) and Sims (2006, p. 1), there is a focus on 'acquisition of knowledge' by means of 'pre-determined pathways that, if undertaken rigorously, will ensure a transfer of knowledge'.

Therefore, although instructional design and LD share the same overall goal of supporting teaching and learning with technology, the difference lies in the focus and ontological position. In oversimplified terms: instructional design focuses on teaching, and LD focuses on learning and tries to adopt a more holistic view on providing teaching for learning.

Furthermore, the idea of design patterns, which is commonly used in the more orchestrated LD approaches, has a longer history dating back to the architect Christopher Alexander and his book *A Pattern Language* (Alexander et al., 1977, p. x) and related to the *design science* approach (Laurillard, 2012). The design science approach is, again, related to the learning sciences (Sawyer, 2006), design-based research (Brown, 1992), design, and design-thinking in general (Rowe, 1987; Simon, 1969). The applied methodology for research on LD is often inspired by the design-based research methodology (Brown, 1992) or an action approach (Lewin, 1946) due to their expediency for conducting research on actual practice and set up as a mixed methods study drawing on both qualitative and quantitative methods available in the context in question. See Appendix D for further details about the design and learning sciences.

In addition, the parallel research field LA is currently being developed. LA is a broad concept for evaluating large sets of data about the students' activity and thus often used for grading and retention purposes (Arend, 2012; EDUCAUSE, 2011). Over time, LA may also be useful for informing LD practices and processes as well as function as a research methodology for collecting data, analysing the impact of LD on students' learning, and explaining correlations (Galley, 2015; Toetenel & Rienties, 2016).

Each of these areas are important for understanding the background and context of LD and how this research area has evolved. However, in the context of this thesis the focus is on scrutinising the efficiency of LD for TEL in STEM undergraduate education with the already derived definitions and characteristics as the point of departure. Thus, these areas are mentioned to place the thesis in context rather than providing complete evaluations.

## Science and STEM education

Science education is a wide research and applied field, which ultimately seeks to improve 'science teaching and learning throughout the world' (Abell & Lederman, 2007, p. xiii). Science education research focuses on a range of interconnected areas, such as *science learning*; culture, gender, society related to science learning; *science teaching*;

curriculum and assessment in science; and *science teacher education* (Abell & Lederman, 2007). *STEM education*, the acronym for Science, Technology, Engineering and Mathematics, is related to science education and refers to 'teaching and learning in the fields of science, technology, engineering, and mathematics' (Gonzalez & Kuenzi, 2012). Compared to science education, however, STEM has often been used as a political term for emphasising engineering skills in teaching and learning, including science skills, problem solving, and innovation (Bybee, 2010; Sherman et al., 2010). In the context of this project, the use of the STEM acronym does not serve the same political purpose, but it does emphasise that also engineering modules as well as modules with skills training and problem solving are included.

As suggested by Abell and Lederman (2007) science education research should be grounded in actual practice and applied, that is, make sense in real world, be open to new theoretical frameworks and research methods besides traditional science approaches, and strive to translate findings into knowledge accessible to practitioners. This position is shared with other researchers and their agendas on improving teacher training as well as enhancing existing teaching practices, which include the issues related to the traditional science teaching format of one-way, non-interactive, *transmission-of-information* lectures, "cookbook" lab activities, disconnected exercises, isolated individual homework, and limited feedback. Various studies show that this kind of teaching, characterised by passive listening and limited involvement of the students, is ineffective in fostering conceptual understanding and scientific reasoning (Handelsman et al., 2004; Hill et al., 2003; Kember & Wong, 2000; Knight & Wood, 2005).

Recently, a special issue of *Science* (2013) highlighted in its editorial the importance of developing science education and that scientists must play a central role in '...turning the fire of the natural curiosity of students into effective, flexible, and well-grounded outcomes' (Hines et al., 2013, p. 291). In total, the issue listed 20 'grand challenges for Science Education' based on invited articles and the expert literature reviews in the journal. Seven of these grand challenges are directly related to technology in education and most of the remaining 13 challenges are to some extent influenced by technology or could obviously be supported by it (Hines et al., 2013, p. 290). Though the list does not provide an exhaustive picture of all challenges in science education, it does highlight some major issues and that appropriate methods have to be found for the use of technology in education for improving pedagogy, supporting students' individual needs, and developing educator skills.

Fortunately, studies show that technology can be used to address some of these grand challenges by replacing the traditional lectures and other teaching activities with active, blended and online alternatives and even provide additional affordances (Conole & Dyke, 2004; Price & Kirkwood, 2011), and a number of pedagogical strategies are currently emerging. In particular, the pedagogical strategy of *active learning*, concretised by Bonwell and Eison (1991) and operationalised in *Flipped Classroom*, *Peer Instruction* (PI) (Mazur & Hilborn, 1997), *Just-in-Time Teaching* (JiTT) (Novak et al., 1999; Simkins & Maier, 2010), and *Inquiry-Based Science Education* (IBSE) (Minner et al., 2009) as well as *authentic learning* for providing meaningful practical experience (Argles et al., 2017; Herrington et al., 2003), have been developed and successfully adopted in various blended and online STEM teaching practices by means of, for instance, learning paths (see Appendix A for a definition), multiple-choice quizzes (MCQs), video, virtual field trips, and virtual labs.

## Summary: The emerging concept of Learning Design

As pinpointed by Mor et al. (2015, p. xiii) with reference to Goodyear and Dimitriadis: 'the rapid technical and practical growth of the field [LD] is outpacing its theoretical development, running a risk of building high castles on slim foundations', and to some extent, this is also the risk in the context of this project. This "slim foundation" is partly confirmed in this literature review in the sense that LD is an emerging concept with numerous definitions, inherent continua, diverse views on learning, diverse roles and applications, and situated in a complex context of related research and practice areas. Furthermore, the term 'learning design' may refer to a practice and/or process of educational development as well as a product.

Nevertheless, despite the diverse conceptions five common characteristics of LD practices have been identified (PLADR): (1) pedagogy-informed teaching (P), (2) learning-centred educational development (L), (3) the use of design aids (A), (4) a design process (D), and (5) reusability and shareability of practices and products (R). However, with regard to actual LD practice these characteristics unfold very differently depending on the context, the stakeholders, the level of orchestration of the process, the role of aids, and how it is pedagogically informed. This diversity may further relate to the efficiency of LD as the institution and support staff may potentially play a much less significant and time-consuming role in open-ended provision compared to the more resource-intensive process facilitation in orchestrated practices. On the other hand, impact on the students, the desired uptake of LD, and the reuse of designs may better



be ensured in the orchestrated practices. Obviously, this diversity calls for further theoretical development of the LD concept and/or further specialisations, such as for understanding and assessing the efficiency of LD interventions as well as understanding the perspectives on LD.

### 3. Conceptualising Learning Design efficiency

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This chapter will develop the concept of LD efficiency, which informs the basis of the interventions subsequently described in Methodology.

Considering the aims of the different LD initiatives there are diverse perceptions of what efficiency entails. In some cases, efficiency is associated with the impact on students' learning and others with the amount of effort the institution or the educator has to invest in order to transform his/her practice (e.g., UG-Flex, 2012; University of Cambridge, 2013). As stressed by encyclopaedias such as Encyclopedia Britannica (2014) and Wikipedia (2016) the concept of efficiency is vaguely defined and has different meanings in different contexts. However, a common and general understanding relates to the ratio between the time, effort, and/or costs spent on achieving a certain goal. The more time, effort, and/or costs spent to achieve a goal the less efficient. In the context of LD initiatives, efficiency will then per definition depend on the goals and effort of the involved stakeholders such as the institution, the educators, and the students. Each stakeholder may have their own interests in LD such as cost-effectiveness, efficacy compared to specified aims, and sustainability for the institution; impact on teaching and viability for the educators; and impact on students' learning, grades, satisfaction, and flexibility.

A search on ERIC and Google Scholar for "efficient learning design" returned a total of 19 hits per 6 October 2014 and 41 hits per 18 June 2017 (of which eight in 2017 were directly related to this project). A more open search on ERIC for 'efficient'/'efficiency' and 'learning design' returned merely 30 peer reviewed articles in 2014 of which 10 or more, depending on the rigidity of the understanding, were only marginally associated with LD. This number had increased to 43 hits per 18 June 2017 of which 27 were related to HE. Despite the limited number of results, they do provide insights on the different perspectives of efficiency associated with the use of technology for teaching and learning. The most common concerns are related to the development of teaching material; efficiency in terms of reusability, shareability, and sustainability (Bai & Smith, 2010; Brown & Voltz; 2005; Elliott & Sweeney, 2008; Pankratius et al., 2005); the effectiveness of the materials for learning (Pejuan et al., 2012); and students' learning experience and the usability of materials (Davids et al., 2013; Dawson et al., 2010). In addition, the introduction of a specific technology, a specific learning activity, and various

subject related characteristics are important efficiency concerns (Mtebe et al., 2011; Thomassen & Ozcan, 2010; Zahn et al., 2010). Only one of the articles adopts a more holistic approach to efficiency by including different perspectives (see Atkinson, 2011). The articles demonstrate the complexity in looking at efficiency and the many important aspects of the concept. Efficiency is both associated with institutional processes and requirements, the development and reusability of materials, the underlying systems, different subject areas and teaching activities, and students' learning and experience.

The institutional processes are particularly in focus in the UG-Flex initiative at the University of Greenwich, which aims at:

'... greater business efficiency and effectiveness by: reducing the number of manual workarounds ... to promote more flexible use of the university's estate for teaching and learning over the entire academic year' (UG-Flex, 2012, p. 5).

By adopting a more holistic, collaborative approach and engaging a large number of stakeholders they experienced 'significant impact on attitudes and practice that will be sustained after the project's lifetime' (UG-Flex, 2012, p. 2). Another aspect of sustainability and efficiency has to do with reusability, and in the Learning Designs Project (AUTC, 2003a) this aspect has been a primary concern as a means to ensure low costs. This project included a process of identifying and selecting LDs suitable for redevelopment, a further development of the resources, and subsequently making them accessible on a common platform (AUTC, 2003a). A narrow focus on efficiency, however, may also result in drawbacks as Doering and Veletsianos (2008, p. 137) stress:

'Our focus on effectiveness and efficiency however, has led to the development of electronic learning environments that often results in disappointed students and instructors, limited motivation, wasted efforts, and ultimately an absence of interesting, meaningful, and engaging learning'.

This is an important reminder that efficiency is more than addressing institutional needs and should involve the perspectives of different stakeholders.

## Stakeholders in Learning Design

These highly diverse perceptions of efficiency in the context of LD interventions are dependent on the stakeholder and, thus, a narrow understanding focusing on one perspective only would potentially overlook important aspects. Thus, a more holistic

concept is required to assess the efficiency of LD, which takes the interests and influence of the different stakeholders into consideration. Sims illustrates the context of LD with a Venn diagram of six intersecting stakeholders (Figure 9), and additional external stakeholders with an interest in teaching, learning, and the general role of universities may be identified such as employers, informal learners, partners, librarians, governments, professional bodies, parents, and various other collaborators (Open University, n.d., p. 7).

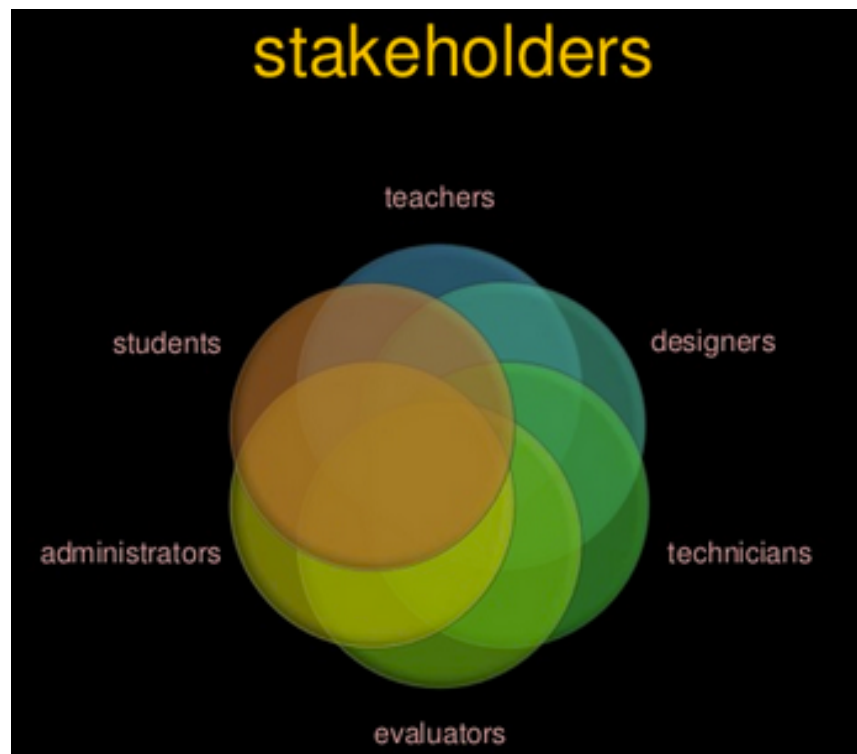


Figure 9. Stakeholders in LD (Sims, 2013, p. 41).

Some of these stakeholders, such as the teachers, designers, and students, usually play an active role in the process as either producers or consumers of the LD, while others, such as administrators, technicians, and evaluators, may play a more indirect and secondary role as supporter or facilitator. The exact number of stakeholders and their perspective on LD depends on the setting and should be treated with respect to their influence on the LD efficiency and only included if they play a significant role. However, at least three primary stakeholders, as listed below, are persistent in formal educational settings and represent different perspectives to LD (Marshall & Mitchell, 2002). First, is the institution, which defines/provides the context, budget, digital strategy, and support, and which may include the *administrators*, the *designers*, and *technicians* and whose budget and general practice is defined by the government. Second, is the educator (or *teacher*) who may be the *designer* at the same time and whose teaching will be

transformed using LD. The third group is the students whose learning will be affected by the technology. Each of these primary stakeholders with stakes in LD, may be impacted differently — both positively and negatively — and may have to put effort into either implementing, teaching, or learning with the design. This dependency can be illustrated as in Figure 10. The secondary stakeholders, which are non-persistent in the educational settings, are beyond the scope of this project but may be indirectly represented in the main perspectives.

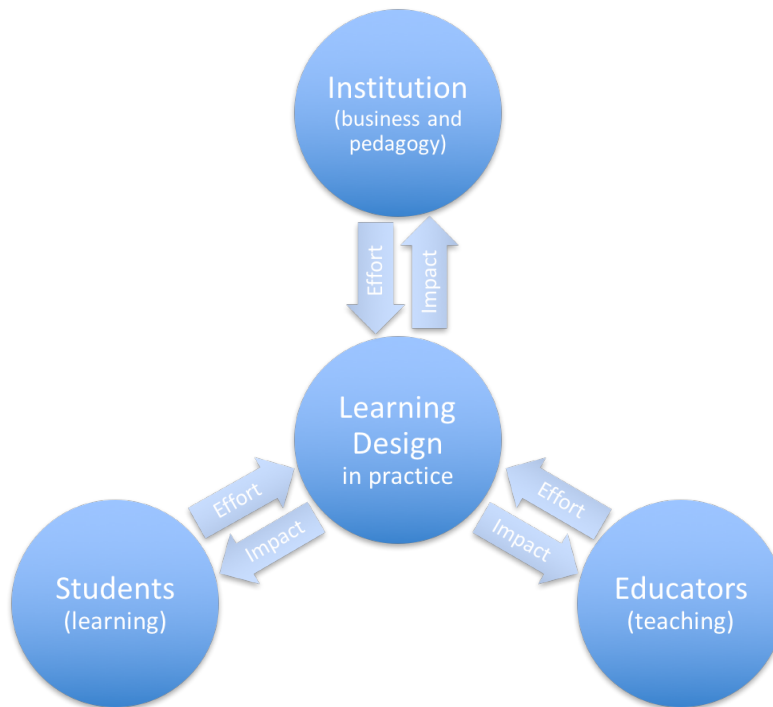


Figure 10. *Learning Design in Practice* illustrated as a dependency of three primary stakeholders and their perspectives.

In this context, it is important to stress that Figure 10 illustrates LD *in teaching practice*, which also includes LD interventions and other processes involving the three main stakeholders. Thus, it does not apply to LD considered as merely a product or any other perception in which LD is not applied to a teaching practice.

## The institutional perspective

The institutional perspective is generally defined by the stakes of several players on different levels, such as the government level, which defines the national budgets and political agendas; the institutional senior management level, which deals with the components of the iron triangle (i.e., cost, assess, and quality) (Daniel et al., 2009), strategies and policies for educational technology, funding for educational development,

and technology initiatives; and the educational developer level which typically provides the pedagogical, media, and technical support to the educators and thus also facilitates the LD process. In other words, the institutional perspective on LD is characterised through directives, institutional policies, educational strategies, budgets, and other relevant documents at institutional level that explicitly or implicitly express the institutional expectations and stakes in educational technology and LD, including the associated effort and impact. In the Danish context, the study progress reform and profile model, which states that more students should complete their studies faster — that is to say, reduce costs, increase intakes, and increase completion rates (and thus also module pass-rates), and the later reprioritisation contribution, which dictates an annually cost-reduction of 2% on the education budgets (see The Danish Ministry of Education, 2014a; 2014b; Finansministeriet, 2015), play dominant roles.

Institutions typically have additional aims such as a high employability of their candidates, effective teacher training, recruitment of the best students, good study environment, internationalisation, declared pedagogical principles, and being ranked well in various national surveys such as the National Student Survey (NSS, 2017) and the Teaching Excellence Framework (TEF, 2017) in the UK, as well as having specific aims for the role and impact of educational technology. This means that the institutional perspective may not include nor express any direct interest in LD, and especially not at the government level, but it may have an indirect interest in LD in terms of strategies on TEL potentially related to LD or institutional aims that are in some way supported by LD. Furthermore, the institutional perspective may have overlapping interests with the educator and student perspectives regarding aspects such as teaching quality. As suggested by the OU (n.d.), these aims can be grouped in two main categories: *business reasons*; which includes aspects such as economy, retention, branding, and recruitment; and *pedagogic reasons*, which covers quality aspects of teaching and learning.

## The educator perspective

Teaching with LD draws attention to the educators and their potential reluctance towards implementing technology in their teaching practice (i.e., resistance to change). The reluctance may be due to low enthusiasm, a low confidence with technology, the absence of obvious or identified benefits and/or justifications for using technology (Weller, 2002; 2011; Zhao & Cziko, 2001), complexity, or practical barriers associated with the uptake (Godsk, 2009). In addition, and as stressed by Richardson (2005) and Kember (1997), educators' conceptions of teaching and their perceptions of the teaching

environment shapes their approaches to teaching and are based on a number of disciplinary characteristics and situational factors. This means that not only could potential barriers and motivational factors play an important role for the uptake of LD, but also that the educators' perception of the concept and various contextual factors are important for the uptake. Thus, the assessment should pay regards to the general stakes, such as the educators' perception, prior experiences, general attitudes, attitudes towards practical aspects of TEL, and other stakes in educational technology and LD as well as the specific stakes of LD interventions such as time spent on transforming and teaching the module, the educator experience, the provided flexibility, and other actualised affordances.

## The student perspective

Students would most likely not know or have any particular interest in whether their module has been through a LD process or not. However, as illustrated in the concept of Learning Design in Practice, they will be interested in the required effort for studying in a transformed module and how the LD actually impacts their learning, including the affordances provided by the technology in LD interventions. Some studies seem to equate *student effort* with *time consumption* (see Natriello & McDill, 1986); however, a more exhaustive understanding of effort would need to be taken into account. Assessing student effort is more than merely measuring time and money spent on studying, it is a subjective and biased measure which depends on the students' perceived effort, which again depends on their interests, approaches, attitudes towards learning, their preferences, engagement, incentives, motivation, and how much effort they are willing to invest in a module. Thus, analysing the student perspective requires a look into STEM students' overall motivations and incentives for studying, their approach to studying/learning, and their preferences.

As pointed out by Brown and Duguid (1996), academic and career aspirations are often tightly entwined but the incentives and motivations for studying are numerous and diverse. Some see education as an end in itself while others see it as a career investment, a way to gain social status, a job with a good salary, just a job in general, or as a step in a lifelong learning practice and enculturation (Brown & Duguid, 1996). Incentives with a predominant extrinsic motivation for studying STEM also include family influence and cultural factors, occupational interests, gender, salary, and career factors such as job security and stability, good prospects for promotion, flexibility in terms of the work schedule, tasks, business, and opportunities to work abroad (Alexander et al.,

2011; Dick & Rallis, 1991; Tang et al., 1999; Woolnough, 1994). However, studies also show that a series of intrinsic factors play an important role for STEM students. Students are inspired by enthusiastic science teachers in school or by parents engaged in science, they are driven by the sense of accomplishment related to working with the STEM area, driven by their self-efficacy for a specific science career, and by a genuine interest in the topic (Alexander et al., 2011; Dick & Rallis, 1991; Fenning & May, 2013; Tang et al., 1999; Woolnough, 1994).

The student perspective also includes students' approaches to learning, their perception of the technological affordances and positive learning experiences, and their incentives for studying (Price et al., 2007; Richardson, 2005). As documented by Säljö (1979) and further elaborated by Richardson (2005) students' approaches to studying are shaped by a series of factors and should be seen in the context of their different conceptions of learning, which are influenced by various demographic factors and their perceptions of the academic context. This means that obtaining a complete picture is a complex affair and would potentially involve a selection of supplementary methods, such as the Approaches to Studying Inventory (ASI) by Entwistle and Ramsden (1982) or the Approaches and Study Skills Inventory for Students (ASSIST) by Entwistle (1997), in order to identify the students' approaches to teaching and learning: deep, surface, and strategic (Price et al., 2007). Inventories like ASI and ASSIST are designed to identify the relative strengths and preferences of the students according to these three main approaches (Entwistle et al., 2013) and in particular, the ASSIST inventory has proven to be reliable and valid (Byrne et al., 2004; Diseth, 2001; Entwistle et al., 2013).

To further elaborate on the students' approach to studying and their preferences, including their attitude towards effort and interest in impact, it is important to have a closer look at their perceptions and experiences of good teaching and the relevant criteria to describe this aspect. For more than two decades the Course Experience Questionnaire (CEQ) by Ramsden (1991) has been used to evaluate the students' experiences of HE and through various studies the method has proven to be both reliable and provide valid results (Graduate Careers Australia, 2010; 2013; Kreber, 2003; Ramsden, 1991). CEQ draws attention to the many important aspects of being a student on a module with regard to the actual teaching, goals, and assessment, but also with regard to qualities such as student confidence, motivation, and experiences, the range and quality of the learning resources and support, the learning community, and collaboration. This further leads to a consideration of the role of the technology and how it may influence the teaching in the specific module in question by providing new



affordances such as more flexible access to the teaching materials, support more mobility, support revision, reflection, and feedback as identified by Price and Kirkwood (2011).

## The Learning Design process and product

In order to assess LD and its efficiency, the characteristics of the LD process, the module, and the actualised LD product, such as the revised teaching practice and materials, should be included in the assessment. As identified in the literature review, LD may be a highly orchestrated practice or a more open-ended approach. If a specific LD model or toolkit has been used for the transformation, it is relevant to have a further look at the transformation (design) process. This should include what role the model and toolkit has played, and include an assessment of the compliance with this underlying model, its compliance with the five general characteristics of LD practice, and a description of the teaching form of the module. In addition, a module is typically characterised by a set of formalities such as European Credit Transfer System credits (ECTS) and/or full-time equivalents (FTE), level (undergraduate or postgraduate), duration, and a description with a set of learning goals and teaching components, such as lectures, group work, and assignments. The actualised LD is expressed by the teaching and learning activities and materials, the structure, and the level of transformation. The level of transformation refers to the delivery method and may be assessed according to the degree of technology (blended versus online learning) as represented by Bates' (2005) continuum of TEL or the revised SAMR model (Godsk, 2014a).

## Summary: Towards a concept of Learning Design efficiency

As revealed by the literature, a more holistic understanding of the efficiency of LD rather than a calculation of the institutional cost-effectiveness of an intervention is needed. Also, as suggested by the Learning Design in Practice (Figure 10) and further documented by the literature, the educator and students have a two-way relationship to LD as well, which includes effort and impact aspects and which can be negative or positive, intended or unintended, shared or stakeholder specific, and general or intervention specific. These impact aspects may be characterised differently and depend on the interests of the institution, educators, and students and how it affects their business, teaching, and learning. Likewise, the effort aspects can be assessed in many currencies, such as funding, time consumption, strategies, endorsement, provided training activities, attitude towards technology, teaching and learning preferences, motivation, and relate to individual stakeholders. An overview of the perspectives and identified indicators is

provided in Figure 11, and two collected inventories of the educator and student perspectives, respectively, are provided in Appendix E.

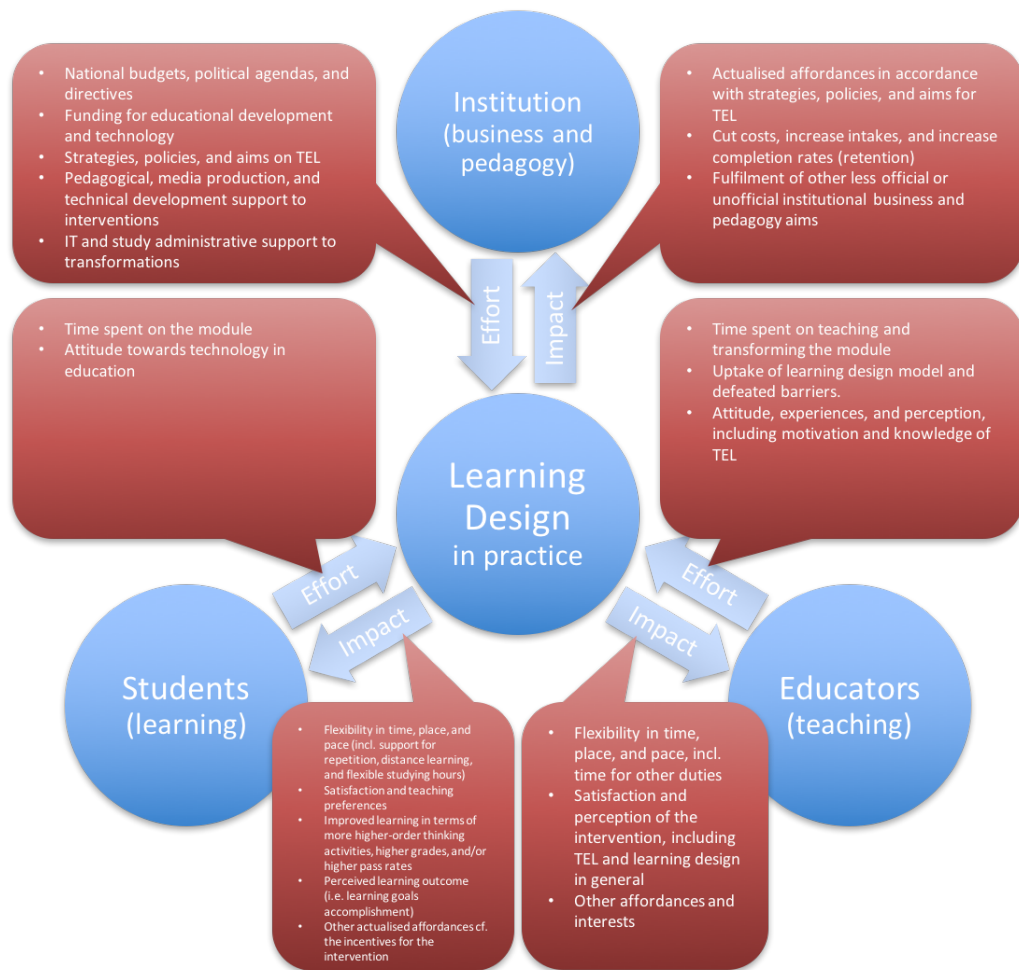


Figure 11. Overview of perspectives and indicators of LD in Practice.

When considering the efficiency of LD, it is important to consider whether an impact is positive (and intended) or not. Negative impacts may counterbalance positive impacts and unintended positive impacts may be of little value. For instance, improved grades may counterbalance decreased student satisfaction within the impact on students aspect and a positive, unintended increased place flexibility may be of little value to the students if the majority prefers studying on-campus. With this in mind and the effort-impact balance illustrated in Figure 11 leads to the following approximate expression of *efficiency* of a LD intervention:

$$LD\ efficiency: \frac{\text{Positive impact (on the institution, educators/teaching, and students/learning)}}{\text{Effort (for the institution, educators, and students)}}$$

The expression describes LD efficiency as a ratio: the lower effort and/or higher positive impact, the higher LD efficiency of the intervention. The process and product aspects of

LD are indirectly included in the expression typically associated with the effort of the institution and educator, and the impact on the students. This ratio also means that "Efficient Learning Design" (ELD) occurs when the total positive impact of the LD intervention is (much) greater than the associated total effort, and that the indicators become direct factors for ELD.

*Efficient Learning Design: Total positive impact > Total effort*

However, though this ratio expresses the concept of Efficient Learning Design, it will not function as an actual tool for assessing LD efficiency for three reasons. Firstly, as revealed by the literature effort is not a common dominator. Secondly, effort may be zero (e.g., if a module is being repeated as is) and impact and effort may be negative yielding nonsense values. Thirdly, impacts and efforts are not necessarily comparable and may have different weightings. Instead, the effort-impact balance for each stakeholder should be assessed individually by subtracting the effort from the impact and subsequently add the values. Furthermore, the literature on the three perspectives revealed a series of general as well as intervention specific impact and effort aspects, which needs to be uncovered and included in assessments in order to yield a valid result. These aspects, and how assessments could be carried out methodologically are further explored in the following chapters.

# 4. Methodology

## Overview of the methodology

The literature review as well as the conceptualisation of Efficient Learning Design and Learning Design in Practice revealed that studying the impact of technology and LD in education is a complex matter, which needs to support taking the setting and process of LD in practice into account, including the different stakeholder perspectives and the impact LD has on teaching and learning. Thus, in order to do so a mixed methods, action research (AR) methodology has been adopted, whose overall structure may be expressed by means of Figure 12 aiming at supporting the researcher being a critical realist and making use of expedient methods. Based on the overall aim (to the left), three overarching research questions have been devised. The first two overarching questions are answered by means of a perspective analysis supported by an interview, two surveys, and a literature review. The findings are used to conceptualise LD efficiency. The third overarching research question trials the concepts by means of AR where the STREAM model (more on this later) is used for transforming four STEM undergraduate modules and the efficiencies are analysed by means of observations, educator interviews, student surveys, and data reviews. Based on the transformations, the concepts are informed and factors deducted for ELD, which, ultimately, contribute to improving STEM undergraduate education.

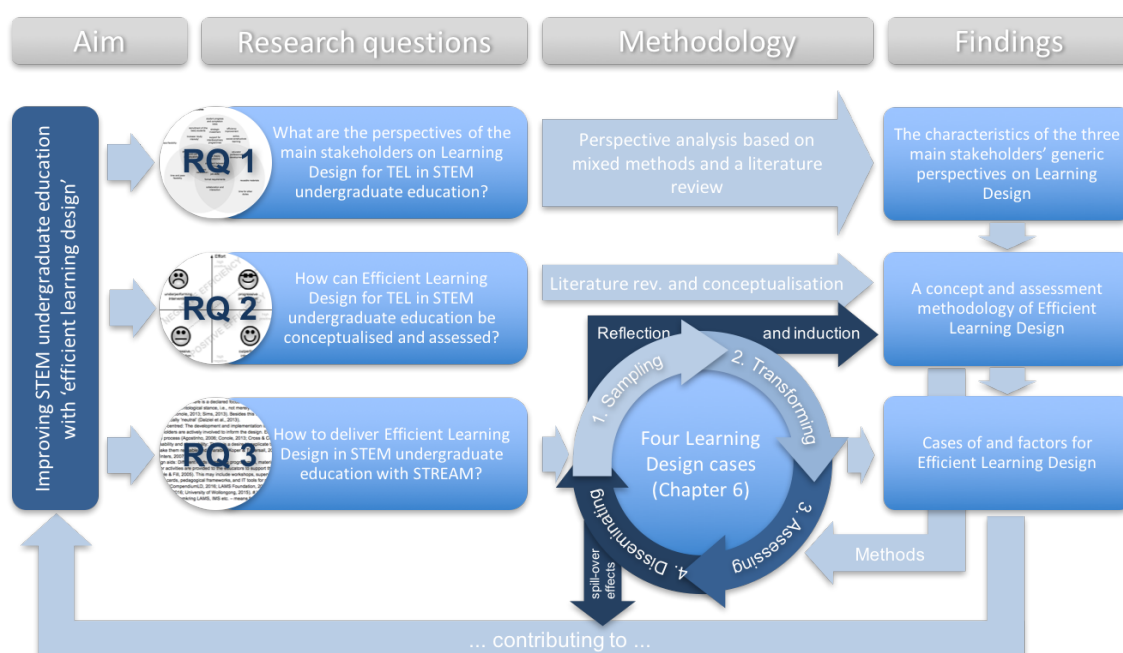


Figure 12. The overall structure of the methodology.

## Research paradigm

The methodology combines evaluative and pragmatic approaches characterised by the researcher being a critical realist who made use of the most expedient methods oriented towards actual teaching and educational development practice in the STEM university context in which the researcher is located (Duram, 2010; Patton, 2002). The research strives to provide well-founded answers to actual concerns such as ‘effective types of interventions and the conditions under which those efforts are effective’, and potential ‘recommendations for improvements’ (Patton, 2002, p. 224). Thus, the methodology aims at supporting the researcher in evaluating practice both formatively and summatively and taking an active part in the educational development at the same time. That is, the research is not to be considered as basic research nor applied research (Patton, 2002); however, to the extent possible the results are made transferrable to other contexts and documented through studies and methods that are appreciated by the STEM university community in order to maximise their impact. While a traditional positivist approach consisting of controlled experiments would be appreciated, it would not allow for the researcher to take an active part in the evolving practice and development and it may also overlook important aspects of the process due to its inherent rigidity of testing predetermined hypotheses (Alexander, 2007; Amiel & Reeves, 2008; Creswell, 2014; Handelsman et al., 2004; Sawyer, 2006). Furthermore, the positivist paradigm operates with a concept of objectivity, which is problematic when conducting educational research, among others, due to the complexity in assessing learning and the efficiency of a LD, including identifying explanations, factors, and underlying conditions (Davis, 2006; Eisner, 1992). Instead, the research is guided by a post-positivist paradigm striving to gain impact by means of objective, valid, and reliable findings based on solid data. The goal of the research is objectivity to the extent possible, but the project acknowledges that pure objectivity is impossible when assessing efficiency and impact of LD, and that a more pragmatic framework-dependent approach is necessary to support the transformation of modules, collect the data, and understand the practice (Eisner, 1992). However, by being open about potential biases, conceptual understandings, and the deficiencies of the concepts and methodology it is possible to provide a frame of interpretation of the project’s findings on *improvement* and *efficiency* and identify potential rival causes.

Dealing with the efficiency of LD and educational technology raises important ontological and epistemological considerations, such as whether we can design learning or merely design teaching, what improving really means, and how to measure efficiency in the

context of educational technology and LD. As identified in the literature review there are different understandings of LD and while it is impossible to design and predict a precise learning outcome, an important focus of LD is the actualised learning, that is, not merely the actualised teaching or teaching materials (Conole, 2013; Sims, 2006), and the view of LD as way of 'achieving educational aims'. Thus, as further clarified in the conceptualisation of LD in practice, it is not sufficient to merely look at the impact on teaching practice and/or the design process, it is also necessary to study the impact on students' learning when studying LD efficiency. In order to do so the project adopts the ontologically more moderate position: that it is possible to develop LDs that actualise certain educational aims (also referred to as *affordances*).

Due to its focus on utility and expediency for actual practice (Duram, 2010), the project combines an AR, pragmatic approach inspired by, among others, John Dewey (1916) and William James (1922) for analysing the perspectives of LD and the transformation of modules with LD. The term 'action research' was originally coined by social-psychologist Kurt Lewin in the 1930s and nourished by the philosophy that there can be 'no action without research; no research without action' (Adelman, 1993; Creswell, 2014). He described the background and incentive as:

'The research needed for social practice can best be characterized as research for social management or social engineering. It is a type of action-research, comparative research on the conditions and effects of various forms of social action, and research leading to social action. Research that produces nothing but books will not suffice' (Lewin, 1946, p. 35).

In general, AR is characterised by being practical, that is to say, 'aimed at dealing with real-world problems and issues, typically at work and in organizational settings', 'dealing with practical problems' and with 'change ... regarded as an integral part of research', including a so-called 'feedback loop in which initial findings generate possibilities for change which are then implemented and evaluated as a prelude to further investigation' (Denscombe, 2003, pp. 73–74), and with collaboration and active participation from both the researcher and participants (Creswell, 2014). AR thus allows for the researcher to continuously share her/his findings with the participants in order to inform and develop their later practice.

The pragmatic approach is concretised by means of a research matrix of mixed methods such as surveys, interviews, and observations as well as reviews of data and documents

providing information about the impact and effort of the LD interventions (Phillips et al., 2012). The data is subsequently subject to partly a post-positivist approach looking for — potentially transferrable — patterns and correlations that explain the efficiency, and partly a more interpretivist approach trying to identify factors for ELD by means of primarily qualitative data (interviews, survey comments, and observations) accepting that factors for efficiency are contextual (Hurworth, 2005). Thus, following the logic that ‘the key issue in selecting and making decisions about the appropriate unit of analysis is to decide what it is you want to be able to say something about at the end of the study’ (Patton, 2002, p. 229) this also means that the unit of analysis relates to the efficiency of the LD interventions, including the perspectives of the stakeholders and the actualised LD.

## Research matrix of mixed methods

Returning to the epistemological concern of how to measure LD and efficiency, the answer lies in a patchwork of actualised efforts such as costs and time consumption, and impacts such as learning goals, student satisfaction, and flexibility analysed in the context of the general stakes of the institution, educator, and students in teaching and learning with technology. Documenting this will inevitably include a scrutiny of diverse formative and summative data sources, such as teaching materials, examination results, and usage statistics, and involve some degree of mixed methods, such as interviews, surveys, observations, and data analysis (Phillips et al., 2012). Phillips et al. (2012) propose a series of research matrices for evaluating the different aspects of technology interventions in which a common denominator is that they acknowledge that a mixed methods approach is required to perform an in-depth analysis and for ensuring a desirable methodological triangulation (Phillips et al., 2012; Reeves & Hedberg, 2003). By combining the different stakeholders and indicators as identified in the context of the conceptualisation of Efficient Learning Design (Chapter 3) with appropriate methods, the overarching research matrix in Table 1 emerges.

Table 1  
*The research matrix for assessing LD interventions*

Aspects	Indicators	Methods			
		Observations	Interviews	Surveys	Data reviews
The module and learning design	Formalities: credits, level, duration, and learning goals				Module catalogue examination
	Rationale for intervention, including strategic aims		Educator interview		Review of documents

	Level of transformation	Observation of teaching and LD			
	Teaching materials, learning activities, and structure				
	Role of LD, including compliance with the underlying LD model and LD in general				
Institutional effort	National budgets, political agendas, and directives (government level)				Review of documents*
	Funding for educational development and technology (strategic level)				
	Strategies, policies, and aims on TEL** (strategic level)		Senior management interview*		
	Pedagogical, media production, and technical development support to interventions (educational developer level)		Educator interview		Review of documents*
	IT and study administrative support to interventions (administrative level)		Educator interview		Research journal
Institutional impact	Actualised affordances in accordance with strategies, policies, and aims for TEL**	Observation of teaching and LD		Student survey	Module catalogue examination
	Cut costs, increase intakes, and increase completion/pass-rates (retention)				Review of data
	Other less official or unofficial institutional business and pedagogy aims	Observation of teaching and LD			Data from the study administration
Educator effort	Time spent on teaching and transforming the module		Educator interview	Educator survey*	
	Uptake of LD model and defeated barriers	Observation of teaching and LD			Research journal
	Attitude, experiences, and perception of TEL**			Educator survey*	
Impact on educator	Flexibility in time, place, and pace			Educator survey*	
	Satisfaction and perception of the intervention, TEL, and LD in general				
	Other affordances and interests				
Student effort	Time spent on the module			Student survey	Review of data
	Attitude towards technology in education			Student surveys*	
Impact on students	Flexibility in time, place, and pace			Student surveys*	Review of data
	Satisfaction and teaching preferences				
	Improved learning in terms of more higher-order thinking	Observation of teaching and LD			



	activities, higher grades, and/or higher pass-rates				
	(Perceived) learning outcome (learning goals accomplishment)				
	Other affordances of the incentives for the intervention	Observation of teaching and LD	Educator interview		

\*This also includes a general aspect, which is covered by the perspective analysis.

\*\*This also includes educational technology and LD (if applicable).

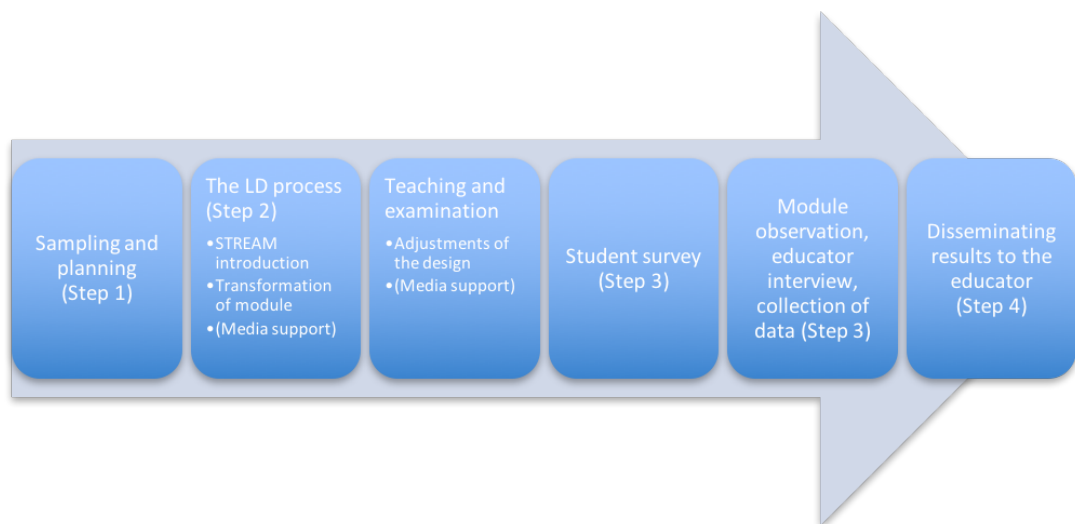
Some of these indicators are directly related to the LD efficiency as it is defined by the concept. Others such as *the module and learning design* aspect and the educators' *attitude, experiences, and perception of TEL* are contextual information which is useful to understand the setting and context as well as looking for underlying, indirect factors related to the efficiency. Indicators that measure or reflect interests and stakes, such as costs, time consumption, grades, perceived learning outcome, and satisfaction, may be specific to a LD intervention. Others, such as policies for TEL, basic funding, and pedagogical values, may be general and common to all modules, the entire institution, and/or the entire educator and student cohort though potentially interpreted differently. The general stakes do not need to be analysed for each intervention but they are important for the weighting of the module specific stakes. Furthermore, the exact set of indicators and their individual weighting depends on the specific context. For instance, an institution may have a general interest in educating and passing as many students as possible at a low cost at the expense of the learning experience. In this light, the LD efficiency should be assessed with a weighting of the module specific stakes related to pass-rates and scalability, while other stakes, such as student satisfaction and perceived learning outcome, may be disregarded.

## Research design

As outlined by the research questions and further illustrated by the methodology overview (Figure 12), the project consists of three overarching research questions answered by means of literature reviews, a perspectives analysis, and an empirical investigation trialling Efficient Learning Design and its assessment methodology by means of AR.

The research starts by characterising LD in general by means of a literature review in Chapter 2. This leads to the derived concept of Learning Design in Practice and the concept of Efficient Learning Design (ELD) in Chapter 3. These concepts form the basis for the mixed methods analysis in Chapter 5 identifying what the perspectives of the main stakeholders in LD for TEL in STEM HE are (RQ1) and tentatively conceptualising LD

efficiency for TEL in STEM undergraduate education. The efficiency concept is being developed and trialled by means of mixed methods AR transforming four undergraduate STEM modules as described in Chapter 6 and Figure 13. The outcome is a refined concept of ELD, a related assessment methodology, and an identification of which direct and indirect factors influence the delivery of ELD by means of a framework-based LD model (STREAM), described in Chapter 7 (RQ2–RQ3).



*Figure 13.* Flow diagram of the methods in use for each intervention.

### The perspective analysis

The perspective analysis is carried out by means of three descriptive analyses based on the qualitative and quantitative data provided by two surveys, one interview, and a review of documents specified below. Identifying the perspectives and their weighting is carried out in the context of the conceptualisations of ELD and Learning Design in Practice and as further documented in the inventories of teaching and learning with LD (Appendix E) and the research matrix (Table 1).

The institutional perspective is analysed by means of within-case analysis (Miles & Huberman, 1994) supported by two methods:

1. A review of policies, strategies, working documents, announcements, and websites that directly or indirectly express the institutional perspective (on a governmental and strategic level — see the research matrix, Table 1) on TEL and LD, including effort for LD and desired impact of LD.

2. A semi-structured interview of senior management (i.e., the PVC) about their perspectives on TEL. The aim of this interview is to clarify the actual prioritisation of the focus areas explicated in the policies and strategies, to further elaborate the policies and perception of TEL, including to scrutinise to what extent TEL is considered a business and pedagogic capacity, and to reveal future expectations (see Appendix G for the interview guide).

The initial categories deducted in the research matrix and the conceptual framework in Chapter 3 are used for coding the senior management interview and additional categories and subcategories are identified for the later coding of the policies, announcements, and other data (Appendix G).

The educator perspective is likewise treated as a within-case and analysed by means of a survey based on the Inventory of teaching with Learning Design (Appendix E), including their attitude towards TEL, their prioritisation of the potential affordances of TEL, their experiences with TEL, and factors important to their uptake (the questionnaire is provided in Appendix H). The qualitative data in terms of various comments in the educator survey are coded by means of a coding frame based on the research matrix, including the new categories that may have been deducted during the coding of the institutional perspective (Appendix H and J).

The student perspective is analysed through a survey of students' general incentives and motivations for studying, their attitude towards technology in education, the common learning approaches, and their teaching preferences as prescribed by the Inventory of learning with Learning Design in Appendix E.

In order to ensure that the findings of the three perspectives are associated with LD and that related practices are not overlooked; four guiding questions have been used throughout the analyses of the data and included in the coding.

- Are there any *direct* references to LD?
- Are there any *indirect* references to LD, that is to say, products, practices, or processes relating to any of the five identified LD practice characteristics (see the literature review)?
- Are there any *direct* references to affordances potentially provided by TEL based on LD?
- What are the associated efforts and impacts?

Four guiding questions for analysing the perspectives on LD.

In addition, it is anticipated that all three stakeholders would have a direct interest in its impact on education. Thus, in order to draw parallels between the three stakeholders' perspectives, a battery of Likert questions on the affordances of LD and TEL based on the Inventory of learning with Learning Design (Appendix E) is included in the interview and surveys. The battery is based on the CEQ scales combined with the identified affordances of educational technology as presented by Price and Kirkwood (2011) and asks the same question: 'What do you find important for your studies/studying [or 'the students']'.

Finally, the results of the three analyses are combined into an in-depth matrix display according to the research matrix. Based on this, a display for expressing the perspectives, including any shared interests regarding effort and impact as well as potential interrelated expectations, is developed according to the Learning Design in Practice concept and the overview presented in Figure 12. The quantitative data from the common survey battery is included in the in-depth matrix display in order to more accurately identify common interests as well as their individual weighting.

### Trialling Efficient Learning Design with Action Research

Analysing how and to what extent ELD is delivered is carried out by means of AR, which in the context of this project entails a process of two iterations. Stringer (2007) refers to the process as an *interacting spiral*, where the researcher alternately looks, thinks, and acts, and by others as a four-phase process consisting of planning, acting, observing, and reflecting (Coleman, 2009). Each iteration consists of four steps involving the sampling of modules, their transformation, assessment using the research matrix, and dissemination of main results (Figure 14). The educators adopting LD may use the results during the project and the researcher does not need to conceal findings. However, this continuous sharing which could potentially influence practice requires special caution and reflection about the role as researcher and attention to what has been done, shared, accomplished, and learned from the actions as well as the role, knowledge, and interests of the educators (Creswell, 2014). Thus, a research journal is kept by the researcher with details about the dialogue with the educators and dissemination activities.

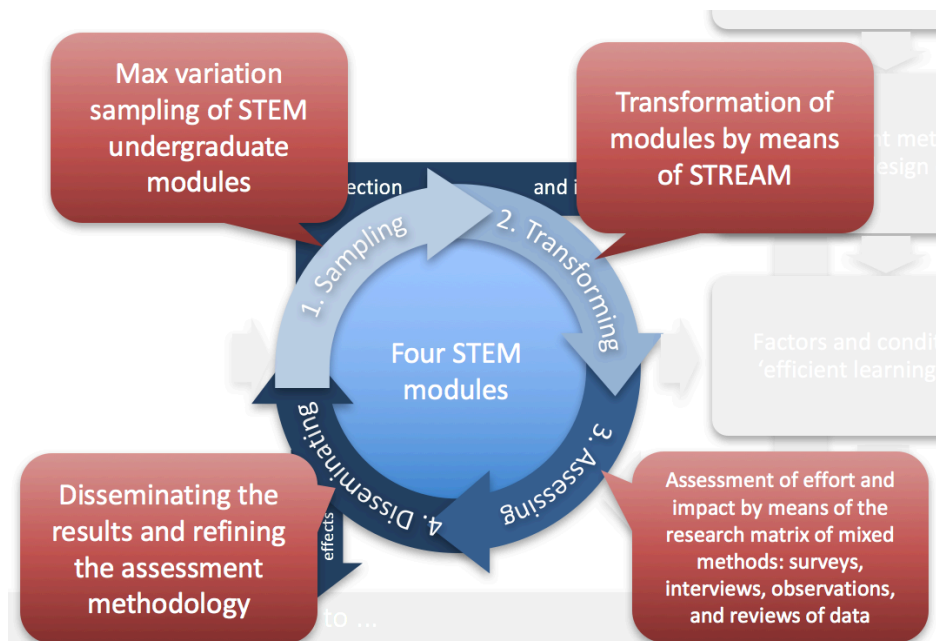


Figure 14. Close-up illustration of the AR process for trialling ELD.

### Step 1: Sampling and planning

Each iteration starts with sampling, that is, the recruitment of educators and their module for transformation. The modules and educators are recruited through various channels such as strategic initiatives, the professional development programme, and individual initiatives. The aim of the recruitment is to select information-rich cases which provide both enough subject area breadth to cover the four letters of the STEM acronym and enough depth to understand and assess the interventions individually — and, where possible, over time/more iterations (Patton, 2002). This kind of *purposeful sampling* is also referred to as *maximum variation sampling*. In contrast to statistical sampling, it is less concerned with confident generalisation but more concerned with in-depth understanding (Patton, 2002). The sampling strategy ‘aims at capturing and describing the central themes that cut across a great deal of variation’ (Patton, 2002, pp. 234–235). Whereas maximum variation is sometimes considered a weakness in order to ensure depth and validity, the logic of this strategy is that:

‘any common patterns that emerge from great variation are of particular interest and value in capturing the core experiences and central, shared dimensions of a setting or phenomenon’ (Patton, 2002, p. 235).

Thus, ideally the recruited modules should not only be different in terms of subject area, but also be different in terms of the potential LD product and process. This includes the level of transformation, the teaching components that are being transformed, the uptake

of underlying LD model, the educator characteristics, and the transformation process. And as modules on the Faculty of Science and Technology at Aarhus University (AU ST) are typically organised with a cohort of educators with diverse teaching obligations, the variation in educator characteristics may also include her/his agency and role on the module. Nevertheless, on the whole some level of opportunism is necessary, given the modules available, and four such modules in the subject areas of astrophysics, mathematics, chemistry, and engineering are recruited together with its educator. Three of the modules include more repetitions and developments over time and, thus, are referred to as four *cases* with one or two iterations. Despite the designation, the cases in this project do not seek to serve as case study exemplars or encourage 'the readers of the case to a new understanding of their own context and processes' (Hamilton & Corbett-Whittier, 2014, p. 6).

### *Step 2: The Learning Design process*

This step focused on the transformation of modules. The primary role of the researcher was to recruit and assist with designing the module by means of the STREAM LD pedagogic model (or simply "STREAM", Figure 15). STREAM is chosen partly due to its historical background, partly due to its practicality of providing an easy-to-use, non-prescriptive (i.e., open-ended), adaptable, and customisable toolkit to the educators with potentially obvious benefits (Conole & Fill, 2005; Weller, 2002). The exact dialogue and design process may vary as well as the role of STREAM. However, all design processes include some level of introduction to STREAM, including its underlying pedagogical ideas of providing online learning materials out-of-class prior to in-class activities, activating the out-of-class activities with relevant activities, using the generated data out-of-class to adjust in-class activities and/or provide online follow-up, and to use this for adjusting the subsequent out-of-class content and activities.

In detail, the model features two feedback loops: (1) a major feedback loop, which illustrates how out-of-class activities provide feedback to in-class and/or online follow-up, which, again, helps adjusting subsequent out-of-class content and activities; and (2) an out-of-class loop where learning materials/curriculum (referred to as *content*) and activities are organised as an interplay in which the activities serve the purpose of activating the curriculum just acquired and generating data about the students' knowledge and progress to the educator for later in-class follow-up (Godsk, 2013). In the context of AU ST the typical duration of the major loop is one teaching week.

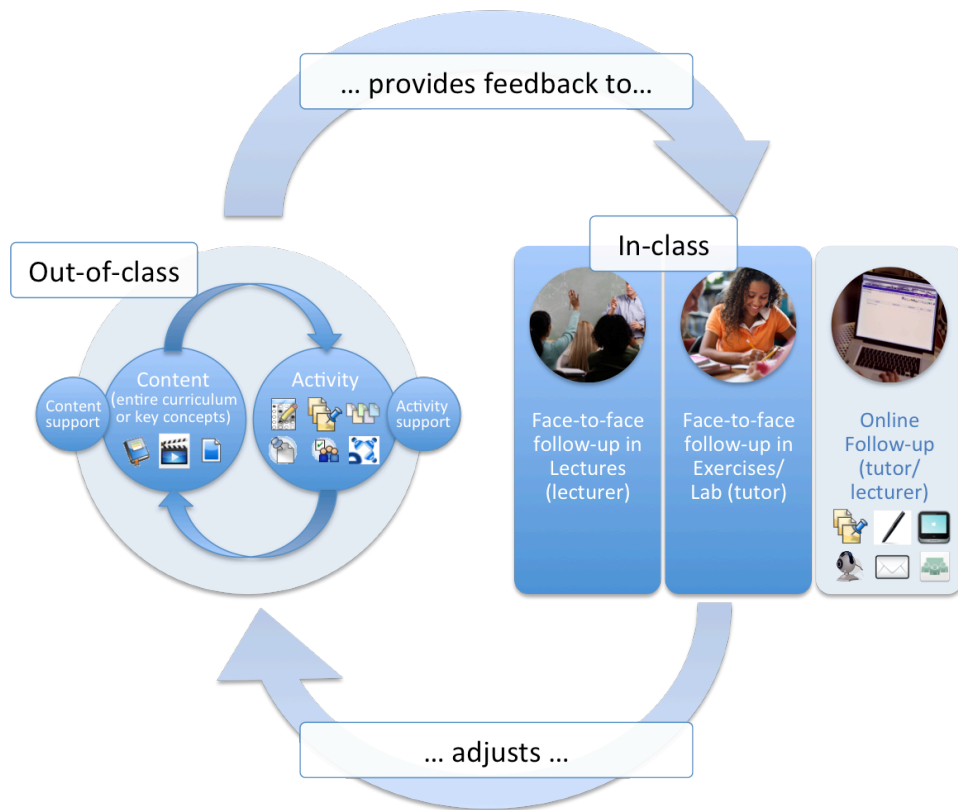


Figure 15. The STREAM model (Godsk, 2013).

STREAM was originally developed in 2013 as a way of providing an ‘easy-to-use, tested, and — most importantly — practical’ model to educators at AU ST for transforming their modules into blended learning with *educational IT* (Godsk, 2013, p. 723). Thus, the acronym STREAM: ‘Science and Technology Rethinking education through Educational IT towards Augmentation and Modification’ (Godsk, 2013, p. 723) with its inherent reference to the faculty, the concept of TEL, and to the two supported transformational levels of *augmentation* and *modification*. The intention was to provide both an open-ended model in the sense that it should not be too abstract nor constraining, while at the same time provide a pedagogical framework built on the well-documented pedagogic strategies and concepts of active learning (Bonwell & Eison, 1991), Just-in-Time Teaching (Novak et al., 1999), Flipped Classroom, and Peer Instruction (Mazur & Hilborn, 1997).

In the context of this project STREAM is similarly used as an open-ended LD framework and supplemented with a LD toolkit for media production support. The toolkit consists of access to a do-it-yourself webcast/video studio, media production assistance, and support to set up learning paths in the institutional LMS (Blackboard Learn). This means that the STREAM model provides a pedagogical framework which functioned as a

guideline to the researcher and his work in supporting the LD process. This support role of the researcher is best described as *observer-participant*. The role is characterised by the researcher not attempting 'to experience the activities and events under observation but [negotiating] permission to make thorough and detailed notes in a fairly detached manner' (Adams, 2010, p. 6). In other words, the researcher is in dialogue with the educators and provides educational support and presents the STREAM model but does not participate in the actual development of materials, their implementation (but the media lab may provide technical support), or carry out the teaching. Details about this dialogue, dates, documents, and time consumption, however, are kept in the research journal.

### *Step 3: Assessing the Learning Design*

At the end of the term, the efforts and impacts on the teaching and learning are assessed according to the research matrix for assessing LD interventions presented in Table 1. A total of seven aspects are analysed: the effort and impact of each of the three main stakeholders and the characteristics of the actualised LD. This is done by means of four methods:

1. An observation of the teaching practice and the actualised LD online. This includes an observation of the materials and activities in the LMS, and an analysis of the actualised LD and its compliance with the underlying LD and the principles of LD in general (i.e., PLADR). Furthermore, it includes examining the module catalogue for information about formalities and a profiling of the module in terms of the balance of content and activities online and offline, out-of-class and in-class.
2. A semi-structured interview of the educator about her/his teaching practice and the effort and impact of the intervention such as time consumption, attitude towards the intervention, and actualised affordances (see Appendix P for the interview guide). This also includes questions, which together with the observations, reveal its LD compliance.
3. A student survey on their use of materials, satisfaction and preferences, perception of the format and satisfaction and other aspects related to the effort and impact of the intervention (see Appendix Q).



4. A review of data such as examination scores, pass-rates, and online activity in the LMS. In addition to this, the diverse data, observations, and information about the interventions recorded in the research journal are reviewed.

#### *Step 4: Reflection and dissemination*

The reflection and dissemination step includes updating the research journal, developing reports on the results for the educators on request, and picking out data and findings that are useful for recruiting new educators. In addition, the results are used for other purposes, such as promoting educational technology in education in workshops and conferences, for demonstrating the effect of educational initiatives through papers and reports, for supporting educators in using technology based on local data, and as documentation in the professional development programme. This also means that potential spill-over effects may relate to this step. Thus, dissemination activities of various kinds are being included in the research journal. Similarly, to Step 1 and 2, no surveys or interviews are carried out during this step.

Furthermore, the aim of Step 4 is to reflect on what should be refined for the subsequent iteration. Obviously, it is not possible to plan this in detail before the first iteration has been completed. In case it is not needed to refine the module and/or the educator refuses, the second iteration may be used to provide more data for the later qualitative and quantitative study. This includes deducting new knowledge about how to assess LD efficiency and inducting this into the research matrix and concept, the AR process, and/or clarifying aspects that turn out to be not sufficiently covered by data in the first iteration, such as the actualised affordances, data about time consumption, and the costs.

#### *Identifying factors for Efficient Learning Design*

Upon completion of the second iteration the actualised designs, identified LD efforts and impacts by means of observations, interviews, and surveys (in Step 3) as well as the collected data is subject to further scrutiny, that is, looking for factors for LD efficiency. Following the maximum variation sampling strategy (Patton, 2002), any kind of pattern such as comparable results, causalities, and double occurrences are of interest. In order to analyse the qualitative data and combine this with the quantitative data and findings, the research matrix (Table 1) is used together with the four guiding questions for comparing all the data, looking for patterns, providing possible explanations, and identifying factors for ELD. Possible explanations are either identified directly in the analysis or by further scrutinising some of the additional available data in-depth such as the educator interviews, module observations, student comments, and statistical data.

## Validity and reliability

The project's methodology is not without drawbacks and a common critique associated with AR research is the reliability of the findings (Amiel & Reeves, 2008) as well as the potential limited transferability of the developed solutions and results to other contexts. What may work in one particular setting may not be pertinent to another, which, furthermore, draws attention to the validity of AR; however, the aim is to provide enough breadth to cover the STEM undergraduate area in the context of AU. Being an active researcher with a personal and professional agenda, potentially having to overtly analyse the performance of colleagues, and, at the same time, being situated in a complex setting may not necessarily be the best position to consider cause and effect, control variables objectively, and handle ethical issues. In addition, AR is notorious for generating a lot of data through a variety of methods and involving several people as co-researchers, which makes the analysis time-consuming and potentially unstructured (Creswell, 2014).

Thus, caution needs to be taken when interpreting the data and a number of measures need to be taken in order to maximise the validity and reliability of the findings. This includes methodological triangulation, data triangulation, and investigator triangulation (also referred to as *intercoder reliability test*, see also Lombard et al., 2010). As illustrated by the research matrix some of the indicators are addressed by more than one method. The aim of this methodological triangulation is partly to provide more precise and thorough results and partly to validate the findings. Table 2 provides an overview of the main potential validity and reliability threats. The complete set of threats and measures is provided in Appendix F.

Table 2  
*Categories of potential threats to validity and reliability*

Methods	Threats to validity and reliability	Measures (Triangulation)
Educator interviews and surveys	The interpretation of qualitative data in interviews and survey comments	The coding of the qualitative data will follow a coding frame, be explicit and the findings will, in most cases, be supplemented with quantitative data. An intercoder reliability test will be carried out on the interviews.
Educator and student surveys	Representativeness of the educators and students in the surveys due to low response rates	A confidence rating will be calculated for the survey. Furthermore, other data that describe the similar aspects are being collected to data triangulate, and thus compensate, for a potentially low response rate. In addition, the representativeness of the sample will be assessed.
Observation	Teaching and STREAM observations may not be accessible or aspects of the STREAM compliance may be overlooked.	As a consequence, the results are double observed and intercoder reliability tested and results presented are subject to reservations.
Management and educator interviews, surveys	Vested interests, Halo, and Hawthorne effects in surveys and interviews	To be addressed by asking different questions about related topics. No intercoder reliability test will be carried out due to the confidentiality associated with the interview and most documents.

Data reviews	Data consistency in surveys	The data provided by the LMS is compared with the data available in the study administrative system. If any (major) inconsistency arises the study administration will be contacted for a clarification.
Across all methods	The validity of the applied LD concepts in both questions and assessment	Developing and assessing the concepts is a part of the project and discussed in the Conclusion.
Across all interventions	The <i>observer-expectancy effect</i> (or <i>experimenter effect</i> ) (Rosenthal, 1966)	Some experimenter effect from the researcher to the educators is probable in AR. Thus, a journal is being kept to document the process and the role of the researcher. Vice versa, an intercoder reliability test has been conducted for the observations to avoid researcher expectancy bias.

## Data collection

Having established in the previous sections a mixed method for scrutinising the perspectives on LD and the LD efficiency over four interventions, this section will describe the data collection and representativeness in further detail.

### Data on the perspectives on Learning Design

A total of four substudies were carried out in order to scrutinise the three main perspectives on LD: One interview of the senior management, two surveys of, respectively, the educators and the students, and one review of documents related to LD and TEL (Table 3). Furthermore, both the educator perspective and student perspective were examined through interventions and the accompanying interviews with the educators, student surveys, and a parallel project assessing the impact of an online professional development programme at AU ST (Godsk, 2018).

Table 3

#### *Overview of substudies and year*

Perspectives	Interviews	Surveys	Review of documents
Institutional perspective	2016	-	2017***
Educator perspective	2015–2016*	2015	-
Student perspective	-	2015–2016**	-

\*This refers to the intervention specific educator interviews. \*\*The main survey was conducted in 2015 but further informed by the intervention specific student surveys.

\*\*\*The review was conducted in 2017 but based on documents dating back to 2010.

For analysing the institutional perspective, a semi-structured interview of the senior management, represented by the PVC, was conducted and a total of 15 identified resources on the topic were scrutinised: seven official news and announcements about TEL, five strategy and policy documents, two working documents on strategy and policy, and one website documenting the effort (see overview, casebook, and other details in Appendix G). The documents were collected in March 2017 and the PVC interview was

carried out on 15 December 2016 and subsequently transcribed and further analysed in NVivo. The PVC interview and the 15 resources were then coded in NVivo according to the research matrix and the aspects of effort and impact as described in the conceptual framework. New codes were added during the coding for any emerging subcategory. In theory, these sources should provide a balanced view on TEL and LD at AU ST. In practice, however, much of the funding for educational development and TEL, the development practice, aims, and the associated pedagogical and media services were decided at faculty level. Furthermore, the area of TEL and the associated strategies and organisation were being revised and may potentially have had hidden agendas. This means that the institutional perspective may include additional stakes in impact and effort associated with LD that were not fully identified.

The educator perspective was examined through an online, anonymous survey in SurveyXact in connection with a faculty-wide evaluation of TEL uptake and TEL basis sent to all module responsible educators (except for engineering educators) ( $N = 397$ ). The survey was carried out online between 18 June 2015 and 2 July 2015. Two reminder emails were sent. 213 completed the survey and 14 partially completed the survey ( $n = 227$ ). All valid question responses were included in the results, which in this context meant that also survey partial responses were included, unless it was an obvious outlier, as each question and response was meaningful in itself. This is equivalent to a response rate of 57% and a margin of error of 4.3% with a confidence level of 95%. All 24 science programmes and all types of science teaching activities, including lectures, group work, lab exercises, fieldwork, examination, and supervision, were represented in the survey (see Appendix H). However, not all educator career stages were represented in the survey (Table 4). This may be explained partly by the structure of ST modules in which primarily senior career educators such as associate professors and full professors were module responsible and partly by the aforementioned exclusion of the engineering educators. The response rates made the survey representative for senior and module responsible science educators, whereas engineering and junior educators were not fully represented. Furthermore, the respondents included educators on graduate modules not necessarily convergent with the undergraduate educators. Thus, these biases and the potential difference in teaching roles were taken into account when analysing the data.

Table 4

*Overview of all academic staff at ST and respondents in survey*

Career stage	Academic staff	Respondents in survey	Response rate
Professor	136	55	40%
Associate professor/senior researcher/senior adviser	433	134	31%
Assistant professor/postdoc (incl. 'researcher')	470	27	6%
PhD students	445	0	0%
Other academic staff (incl. part-time academic staff)	530	11	2%

The student perspective was examined through a web-based questionnaire in SurveyXact combined with the end-of-module evaluation of a compulsory first-year, second quarter module attended by all first-year science students (except engineering students). An email was sent to all the students who were signed-up for the end-of-module examination with a link to the questionnaire. This was done immediately after their examination ( $N = 821$ ). The survey was open for 13 days (17–30 Jan 2015) and closed just prior to the release of the grades to avoid any influence on the responses. During that period, two reminders were sent out. In order to increase the response rate 10 cinema gift vouchers were offered. The response rate was 44% ( $n = 361$ ) of which 4% ( $n = 35$ ) were only partially completed. Again, all valid question responses were included in the results, unless it was an obvious outlier. This is equal to a general margin of error of 3.9% with a confidence level of 95%. In addition, the distribution of the responding students across programmes strongly correlated with the programmes to which the responding educators were associated (Pearson  $r = 0.64$ ) (see Appendix I for the exact distribution of respondents). Nevertheless, at least three potential biases should be taken into account: (1) Engineering students were excluded from participating in the survey. (2) Only first-year, undergraduate students were included in the survey. (3) The survey was carried out in the context of a module evaluation, which potentially may have influenced the perspective on LD and TEL in general.

### Data on Learning Design efficiency

For the second part of the project four methods were used for establishing the transformation process and assessing the actualised LD and its efficiency of each module as described in Methodology. Of a total of 18 modules adopting STREAM, the maximum variation sampling strategy resulted in the recruitment of four educators with diverse backgrounds and teaching roles, and their diverse modules covering the STEM acronym (Table 5). The remaining 14 modules were not included in the research due to their similarity with one of the other sampled modules in terms of subject area (not

covering the STEM acronym and/or too identical), level of transformation, cohort of students, or due to practical reasons (see Appendix T for a list of the remaining candidate modules). The data collection was conducted between 2014–2017 for the modules held in 2014–2016. Two of the modules were repeated and one module, Digital Electronics, was organised as two consecutive modules and, therefore, followed over two years. Due to the limited time frame of the project, it was not possible to cover any of the modules for a longer period of time. Details about the modules and years are provided in Table 5.

Table 5  
*Overview of cases, methods, and years*

<b>Cases</b>	<b>Observations</b>	<b>Interviews*</b>	<b>Surveys</b>	<b>Data reviews*</b>
Case 1: Astrophysics (science)	2014, 2015	2015	2014, 2015	2014, 2015
Case 2: Calculus 2 (mathematics)	2014, 2015	2015	2014, 2015	2014, 2015
Case 3: General Chemistry (science)	2016	2016	2016	2016
Case 4: Digital Electronics (engineering)	2015, 2016	2016	2015, 2016	2015, 2016

\*Some interviews and data collection were carried out the year after the module due to practical reasons.

The module observations of the actualised LDs were carried out by making screenshots of materials, activities, and communication and by saving statistical data and a copy of the module page from the LMS. This also included module catalogue examination and download of information about learning goals, credits, and duration. The collection of data was guided by the research matrix, which meant that the actualised LD, effort and impact factors were particularly in focus. Based on these observations, compliance with the STREAM model and the LD characteristics (identified in the literature review) were assessed and intercoder reliability tested (see Appendix O). The observations were carried out in April–May 2016 and again in January–March 2017. See Appendix K–N for an excerpt of screenshots and the learning goals.

The educator interviews were carried out in 2016. The interviews were semi-structured and guided by an interview guide with information about purpose, informed consent, and based on the research matrix. The interviews were captured using an audio recorder, subsequently transcribed in Word, and coded and scrutinised according to the effort and impact factors listed in the research matrix (Table 1). In addition, the interviews were intercoder reliability tested. The results are available in Appendix P. Appendix C and P provide a list of the applied transcription symbols and the interview guide. Two days prior to the individual interviews a questionnaire of merely one question battery on aspects important for their transformation of the module was sent to the educators (see Table P1 for the questionnaire). Besides learning more about the educators' aims with

transforming their module, the purpose of the survey was also to obtain comparable results with the institutional and student perspectives.

The web-based student surveys were developed and carried out using the SurveyXact web-based survey tool in 2014–2016, except for Astrophysics in 2014 which was carried out on Blackboard. Emails with links to the survey were sent to all students enrolled in the modules directly from SurveyXact immediately after the final examination and up to two email reminders were automatically sent to students who did not respond. Participating in the surveys was anonymous but in Astrophysics points contributed towards the final grade. The surveys were closed prior to the release of grades and the data was subsequently processed in the built-in analysis tool in SurveyXact by combining the surveys; translating the labels and scales; and constructing stacked bar charts based on frequencies split according to the surveys sorted chronologically (except for Astrophysics 2014, which was collected later — see explanation below). Additional module data on grades, activity, and pass-rates was processed in Excel.

Of 2,575 students 1,016 students responded in the seven surveys when outliers were removed. This gives a response rate of 39% and a cross-survey confidence interval of 2.4% as also partial responses meaningful in themselves were included (see Table 6). Unfortunately, the low response rate for Digital Electronics mean that most results from this survey are non-significant and, thus, are combined with other data in the analysis. In addition, the results from Astrophysics 2014 are deficient due to the educator insisting on carrying out the survey himself by means of an insufficient adaption of the generic survey.

Table 6  
*Student survey responses*

	Case 1: Astrophysics		Case 2: Calculus 2		Case 3: General Chemistry	Case 4: Digital Electronics		In total*
Year	2014	2015	2014	2015	2016	2015	2016	
<b><i>N</i></b>	126	147	821	1,096	317	37	31	2,575
<b><i>n</i></b>	93	92	361	352	95	13	10	1,016
<b>Response rate</b>	74%	63%	44%	32%	30%	32%	32%	39%
<b>CI 95%</b>	5%	6%	4%	4%	8%	22%	26%	2.4%

Number of students (*N*), number of responses (*n*), response rates, and margin of errors at 95% confidence interval. \*Duplicates may occur as it was possible to be enrolled in Calculus 2 and Astrophysics or General Chemistry at the same time.

The average age of the respondents was 21.8 years (median = 21), 46% were female, and average distance to the university was 10 km (median = 4 km). All major science and technology areas were covered by the surveys, including the four letters in the STEM acronym (see Figure 16 for the exact distribution). Engineering respondents were not included in this distribution.

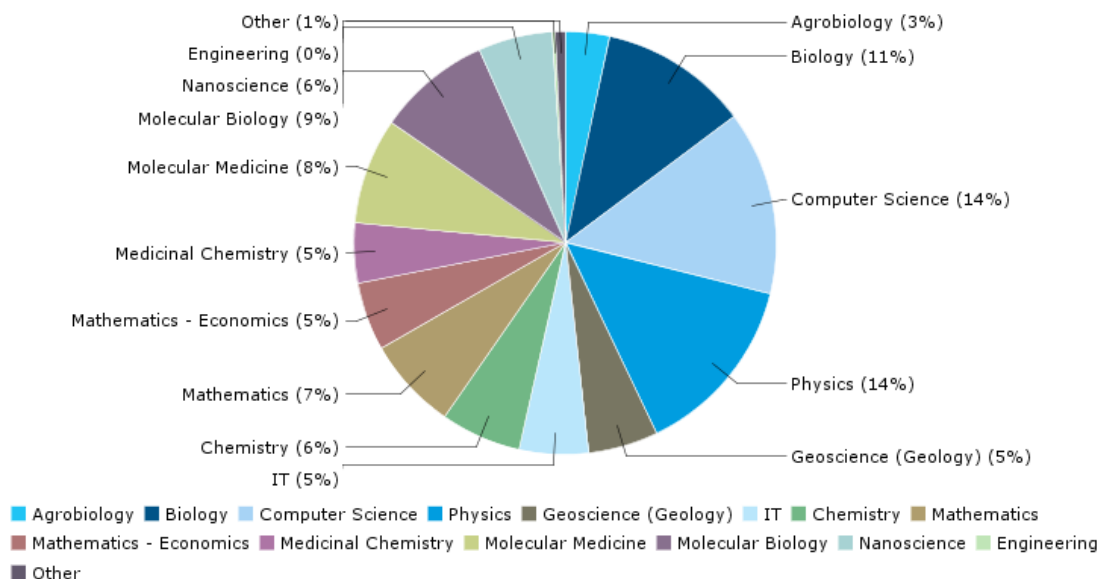


Figure 16. The distribution of students over programmes. 1% equals approximately 10 students.

All the cases were first-year modules which means that the vast majority of the students had limited experience with university teaching and, as such, their perceptions of teaching and learning should be considered in this light.

The collection and review of the data, such as scores, use and LMS statistics were carried out throughout the project. The examination scores and pass-rates were acquired through the study administration and the activity statistics were looked-up in the LMS. In addition to the quantitative data collection, the research journal was updated with details related to the process, efforts, and impacts in terms of information about dialogue with educators, observations, dissemination activities, and thoughts recollecting important details. The journal was initiated on 12 October 2015 and updated throughout the project. Entries prior to this date were recollecting by means of email conversations, documents, and other registered activities.

Across all surveys, Likert scale responses are listed descending according to the responses *to some* or *to a certain* extent in all stacked bar charts if not marked differently. Furthermore, all interviews and surveys were carried out in Danish, except for the



general educator survey, which was carried out in English due to the many international educators. This means that all quotations and comments are translated from Danish if not stemming from this survey or an official document available in English (the original quotations are available in Appendix S). The statistical raw data, including the complete module page copies; sets of screenshots; the PVC and educator interview transcripts; the research journal; strategic documents on the institutional perspective; complete survey data; and additional data on grades, pass-rates, and online activity, is only available upon request due to data protection.

## Ethical issues

The project's ethics proforma was approved on 20 November 2014 (Appendix B) and no major ethical issues were experienced during the project. Nevertheless, the research entailed a number of minor, potential ethical issues including the risk of exposing specific modules, individual educators, cohorts of students, programmes, the management, and departments at the university as being inefficient, uninformed, and/or backward-looking. To the extent possible, all material was anonymised and the educator survey was carried out completely anonymous. However, to protect the research all interviews and surveys were either voluntary and included a clause about informed consent.

Furthermore, the interviewees, that is, the PVC and all the educators participated voluntarily in the interviews and explicitly agreed that the results must be used for the purpose of this project. In addition, they were offered the opportunity to withdraw their answers or the entire interview within a few days after the interview should they regret any statements. None opted out or requested anonymity, but the PVC requested that she would like to review material in which she was quoted prior to publication. As none of the educators requested anonymity, screenshots are not anonymised so they provide a more genuine documentation of the LD. However, as the analyses identified practices and details that could be considered less flattering and unfavourable for some educators, none were mentioned by name.

Likewise, all students remained completely anonymous and only aggregated data is presented. They all participated voluntarily in the surveys and were explicitly informed that the data was for research purposes and that it would be treated anonymously. In addition to this, the Law on Transparency and Openness (Retsinformation, 2005) makes it legitimate to access and use various data, such as grades, for research purposes.

As the findings were made and ready to be disseminated, some minor ethical concerns were present, which related to the double role of the researcher striving towards being objective in his interpretation and dissemination of the results and also being an educational developer loyal to his employer and management. This is a potential issue for AR and in the context of this project this was and will be handled by sending the aggregated results to the educators together with an interpretation, and identified, problematic LDs and practices will be discussed. Results will be shared with the PVC as described prior to actual publication. All interview transcripts, observations, recordings, and other non-aggregated data and appendix material will be kept confidential and stored on AU's servers according to local guidelines and the Danish Privacy Law (Retsinformation, 2000).

Another, and potentially more influential ethical issue, relates to the institutional perspective, the educators, and the researcher himself. Both the institution and educators may have had agendas and aims with educational technology, such as cost reduction, reorganisation, lower time consumption, and particular pedagogical ambitions, which each may not have been interested in sharing with the researcher. Thus, the dilemma of the researcher in this project has been whether he should try to uncover contingent hidden agendas and aims or take their statements at face value in order to avoid cornering individuals. Some statements were accepted at their face value, however, both in the case of the PVC interview and the educator interviews the results were triangulated. The PVC interview was triangulated with the various official documents (see Appendix G) and the educator interviews were triangulated with the faculty-wide, anonymous educator survey and the additional results from each LD intervention.

## Summary: Assessing Learning Design efficiency

As revealed by the initial conceptualisation in Chapter 3, it is tempting to consider LD efficiency as a simple effort-impact ratio. This ratio in itself, however, does not provide any information about which stakes to include in the assessment, their weighting, nor an assessment methodology. As a consequence, a concept of Learning Design in Practice was developed, which in more detail illustrates the dependency of three primary stakeholders and their potential stakes in LD. Based on this set of stakes associated with the various impact and effort aspects, a research matrix of mixed methods for assessing LD interventions and analysing the various perspectives on LD has been developed and presented in this Chapter.

The research matrix is a part of a larger methodology entailing a literature review a perspective analysis on LD supplemented with an AR methodology for trialling a concept of ELD. The data for analysing the LD perspectives and for assessing the LD efficiency is based on four LD interventions on STEM modules. A total of five interviews involving the PVC and four educators, eight surveys involving 227 educators and 1,016 students, seven module observations, and a series of diverse data and documents form the basis for this assessment. Obviously, this is a complex set-up stressing the need for a simplified concept of ELD in which the main interests and perspectives on LD as well as the factors which indeed contribute to improving STEM undergraduate education LD efficiently are incorporated. Further analysis and assessment of the data are provided in the following two Chapters.

## 5. Learning Design perspectives

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The purpose of this section is to analyse the data collected from the three main stakeholders — the institution, the educator, and the students — and their general perspectives on LD for TEL in STEM undergraduate education (cf. RQ1). The perspectives are analysed by means of descriptive within-case analyses guided by the research matrix (Table 1), including the identified indicators for each perspective, and four guiding questions on interests in LD and/or TEL potentially based on LD (see Chapter 4). This is then combined with the case analysis in Chapter 6 to provide a discussion of ELD in Chapter 7.

### The institutional perspective

As described previously, the institutional perspective on LD is indirectly shaped by a series of government level factors such as political announcements and directives on digitisation, funding, intake, and accreditation requirements; an institutional senior management level dealing with strategic matters, budgets, and overall educational agenda; and both are indirectly and directly shaped by a series of decentral actors, which at AU primarily consists of the educational units and media labs. In the context of AU ST, the decentral actors are the local educational unit, ST Learning Lab (STLL) and the media production unit Media Lab (ML) (previously referred to as Science Media Lab or SML), and the two predecessors Centre for Science Education (CSE) and CDIO Development Lab (CDL). These decentral actors define the approach to educational development and media support at faculty level (i.e., AU ST), which since 2013 has included an open-ended approach to LD supported by STREAM (Godsk, 2013; STLL, 2017).

The government and political agenda changed around 2015 along with the Danish general election the same year, which had an impact on the role and ambitions for universities, including AU. Up until 2015, the profile model (The Danish Ministry of Education, 2014a) was dominant with its ambition of increasing intakes. However, a shift in the political agenda with an increased focus on employability of candidates and cost-effectiveness of educational institutions meant that universities from 2016 and onwards were required to save 2% annually due to reduced grants — the so-called reprioritisation contribution (Finansministeriet, 2015). This shift in attitude can be illustrated by a recent

comment by the Minister for Higher Education and Science (2017) concerning the previously prevailing profile model:

‘61 per cent of young people that have completed 9<sup>th</sup> grade are expected to get a higher education. Denmark has a high educational level. Now it is about improving learning and preparing the students for the future job market’.

However, at the same time universities are continuously being evaluated by The Danish Accreditation Council based on a large set of criteria regarding the quality, coherence, and relevance of the provided programmes. Furthermore, digitisation is high on the political agenda and, among others, expressed in the Government’s (2016) *The Digital Strategy 2016–2020*, which states that:

‘In a digital world, IT and digital tools and learning materials should be a natural part of didactic practices and teaching for children and young people. New digital tools and learning materials must challenge the digital generation at day-care facilities, schools and other educational institutions, and support good didactic practices and high-quality teaching’ (The Government et al., 2016, p. 29).

TEL then can be seen to be in a political tailwind supported by The Digital Strategy and the accreditation requirements. However, at the same time the reprioritisation contribution prescribes a cost-reduction, which may influence the institution and its perspective on TEL.

Within AU, a related shift has occurred from focusing primarily on branding and recruiting students in general to focusing on recruiting the best students and on quality in education. This may partly be explained by the aforementioned governmental agenda and limited funding, partly explained by other reasons such as the change of Vice-Chancellor in 2013, a designated Pro-Vice-Chancellor for education in 2014, and a growing awareness of the potential of technology in education — partly supported by The Digital Strategy. Nevertheless, at the time of writing (i.e., October 2017), the official strategy for educational technology at AU (referred to as a *policy for educational IT*) dates back to 2011. The policy has three main focus areas: the technological platform and services for TEL, development of educators’ qualifications and teaching practice, and students’ learning and competency development (Aarhus Universitet, 2011). Regarding the question of its relevance today, the PVC responded in the interview:

‘Since we developed ... the educational IT strategy the world has changed — the education market has changed completely. There has been a massive slowdown in influx [funding] ... in terms of “dimensioning”, neither do we see the previous development of educations — a large focus on improving student completion times has arisen. So, ... we now have a completely different focus on quality in recruitment [and] rethinking education [with technology] ... We are highly focused on recruiting the motivated students with good qualifications — this has been dramatically intensified’ (PVC, 2016).

This shift in focus and the present focus is further substantiated by the official documents regarding TEL, education in general, and local announcements. Coding the interview and documents resulted in three effort subcategories: *digital competencies*, *funding and provisions*, and *strategy*; and three impact subcategories: *business potential*, *educational potential*, and *educational limitations*. In addition to this, two interpretative categories were identified: *governance in practice* and *perception of educational technology and TEL*; and three residual categories. The complete set of categories, subcategories, and count of codings is provided in Appendix G.

A cross-tabulation of the aforementioned 15 resources and the number of references revealed that there was indeed a shift in view on the role of technology in education as suggested by the PVC. It also revealed that this shift happened around 2013, thus, the results were divided into two periods, with each having a column in Appendix G, including a count of codes for each period. Scrutinising the resources and codes for 2010–2012 revealed a focus on using technology to support a series of business aims such as branding, increased intake/recruitment of many students, support a so-called "single market" for programmes, an overall educational aim of providing quality in education, and to modernise education/appear modern. From 2013 and onwards the role of technology was more focused on, in particular, recruiting the best students; quality in education including a more varied focus on job skills, supporting student diversity, improving the study environment, and increasing retention and completion rates. That is to say, a potentially more elitist role that fits well with the statement by the Ministry of Higher Education and Science (2017) about ‘improving learning’, ‘[preparing] the students for the job market’, and the ‘dimensioning’ referred to by the PVC. In regard to affordances of TEL the PVC in particular stressed the aspect of learning to link theory to practice and alignment between the curriculum and examination (Table 7). Flexibility affordances were less important, which could be explained by her view on online education at AU:

‘... I don’t believe in fully online education. I still believe in the meeting between the student and the educator and the curriculum — and I am aware that it can happen in another way too. ... We have an attractive campus and ... study environment... and it is our ambition that this physical and psychological working environment is to support this meeting’ (PVC, 2016).

Table 7

*The PVC’s prioritisation of nine teaching and learning affordances of TEL in respect to AU in general*

	a very high extent	a high extent	a certain extent	a limited extent	a very limited extent	not at all	don't know/not applicable
that the examination reflects the curriculum and skills the students are supposed to have learnt	x						
that the students learn to link theory to practice	x						
that the students find the teaching and learning enjoyable		x					
that the students develop skills for a future job		x					
that the teaching is in complete concordance with the formal requirements (i.e., learning goals and the estimated study time/ECTS)		x					
that feedback is provided to the students' learning process, their assignments, and answers to their questions		x					
that the students can repeat lectures and other teaching activities as they prefer			x				
that the students can study from where they want and do not always have to come to campus			x				
that the teaching supports collaboration and interaction among the students			x				

With regards to the institutional effort, a series of official strategies addressing TEL directly or indirectly were provided, including the university’s development contract with the ministry, the 2013–2020 strategy at AU, the policy for educational IT, and the digitisation strategy. Furthermore, TEL was addressed in working documents and supported through a number of news and announcements (see casebook in Table G2, Appendix G). In addition to this, a university wide LMS was acquired and implemented, decentral units were supported in their work with TEL, and the senior management had adopted an ambitious view on TEL expressing that ‘you’ll see massive investment in [educational IT]. Not as a cost-cutting measure but simply [in order to maintain being] an attractive university’ (PVC, 2016).

Furthermore, the effort associated with providing digital competences among the educators was strengthened from ‘60% of all educators are offered a rethinking of a course — entirely or partly — through educational IT’ (Aarhus Universitet, 2011) to a more proactive position in the Digitisation Strategy:

‘Another important prerequisite for increased use of Educational IT is that teaching staff must possess the necessary digital competencies. For this reason, all teaching staff must be offered competency development and other forms of support in relation to the organisation of their teaching with digital tools. More intensive digital support of teaching often involves rethinking courses and students’ activities and relationships. Teaching staff must be offered support in relation to this process.’ (Aarhus University, 2017a, p. 7)

With regards to LD, however, there were no direct governmental or institutional references to the concept except in a working document at AU from 2017. The term here appears in a diagram with no further explanation except for the phrasing: ‘AU Learning Design — Competency development of educators and students based on a joint pedagogical vision, taxonomy, and model’ and, obviously, in the materials provided by STLL (2017) related to the STREAM initiative and this project. Thus, it is reasonable to assume that, except for the local initiative by STLL, there were no direct expectations associated with the impact and effort of LD on the institutional level at the time of the interventions in this project, thereby leaving the initiative up to STLL and other decentral educational units. Correspondingly, no evidence was found suggesting a direct interest in any of the five LD characteristics identified in the literature review. However, as the institutional perspective on TEL constantly evolved there were increased expectations regarding the professional development of educators (as suggested by the quote above), which may be associated with the LD characteristic of educators as designers. Furthermore, a potentially more direct interest in LD is associated with its characteristics of reusing designs and providing toolkits as it may increase cost-effectiveness due to economies of scale and serve as a quality insurance measure.

In other words, the institutional perspective on LD for TEL and its impact is primarily indirect and associated with its potential for actualising the identified business and educational aims. In particular, initiatives that increase employability of students, cost-effectiveness, and promote digitisation would be of high priority to the government level, whereas the institutional level would also be concerned with its contributing factors such as recruitment of (the best) students, support for student diversity, retention, study environment as well as a series of factors associated with quality in education, students’ learning, meeting students’ digital expectations, and the professional development of educators (see Appendix G for a complete list). Bearing in mind the most recent aims and the response in Table 7, LD can play an important role if it is capable of supporting educational development and TEL, which actualises these aims.



The effort aspect on LD is indirect and associated with the efforts for TEL. At government level these are expressed in the funding provided to institutions and digitisation strategies. At institutional level at AU ST, however, efforts include the provision of an institutional policy on educational IT, a digitisation strategy, strategic grants of various kinds for development projects, professional development programmes for assistant professors and various introductory courses to TEL, the acquisition and support of an institutional LMS, and an organisational structure with four educational units to support the strategy at AU.

## The educator perspective

As suggested by the Inventory of teaching with Learning Design and the research matrix, the educator perspective on TEL potentially based on LD may be shaped by a series of effort and impact aspects such as their attitude towards technology in education, practical barriers, justification for the intervention, and time consumption. Educators may also have a direct interest in LD; however, a survey assessing the familiarity of educators at AU ST with LD in connection with the professional development programme showed that the educators had no prior knowledge of the concept (Godsk, 2018).

Nevertheless, the respondents in the educator survey in 2015 were on average positive towards technology in education. 73% responded that they agreed or strongly agreed that there was a potential for educational technology in science education. Only 3% ( $n = 6$ ) disagreed (Figure 17).

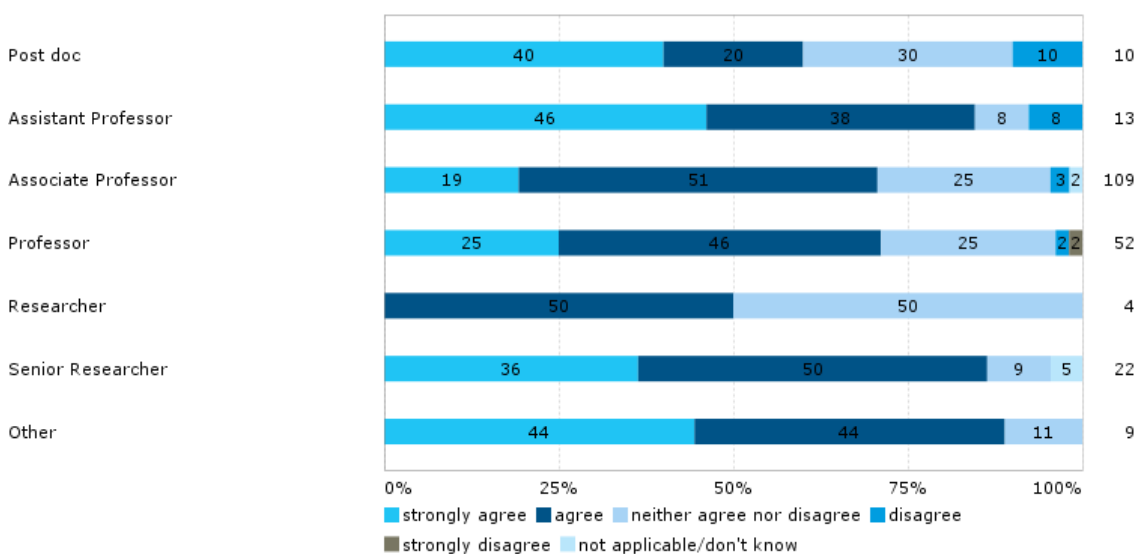
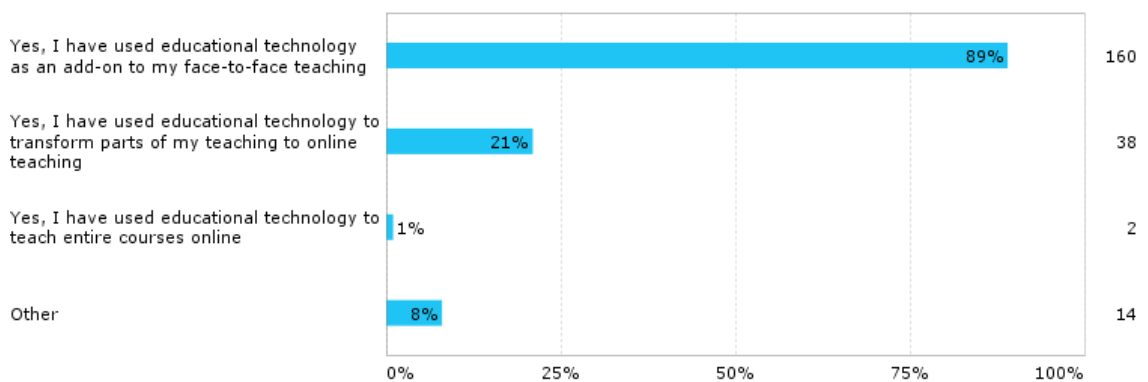


Figure 17. To what extent the educators on different career stages agreed that there was a potential for educational technology in science education ( $n = 219$ ).

In general, among tenure educators the most scepticism was observed among senior staff such as associate and full professors, whereas assistant professors were more positive towards technology in education. Among educators without tenure, the junior positions such as post docs and researchers were most sceptical, whereas the senior researchers were highly positive. Nevertheless, though no formal requirements were stated, technology was widely adopted for different purposes in teaching practices across the faculty. 179 of the educators, equivalent to 82% of the respondents, had prior experience with educational technology as a teacher. 89% (or 73% of all respondents) of these educators had used educational technology as an add-on to their face-to-face teaching. 21% (or 17% of all respondents) had used it for transforming parts of their teaching to online teaching. 1% ( $n = 2$ ) had used technology to teach entire modules online (Figure 18). That is to say, some educators had used educational technology for several purposes.



*Figure 18.* Prior experience with educational technology as a teacher ( $n = 179$ ). NB: The educators may have used educational technology for more purposes and, thus, the percentages do not add up to 100%.

The figures show that some educators were, to some level, able to adopt technology in their teaching practice. This means that some educators saw technology as a means of improving teaching and learning and were willing to spend the effort required to implement it in their teaching practice — if justified. The aspect of justification played an important role and, in particular, whether the technology would improve students' learning.

The educators were asked to prioritise a set of criteria according to the importance for their adoption of educational technology (adopted from Godsk, 2009). The criteria were either predominantly effort or impact-related (Figure 19).

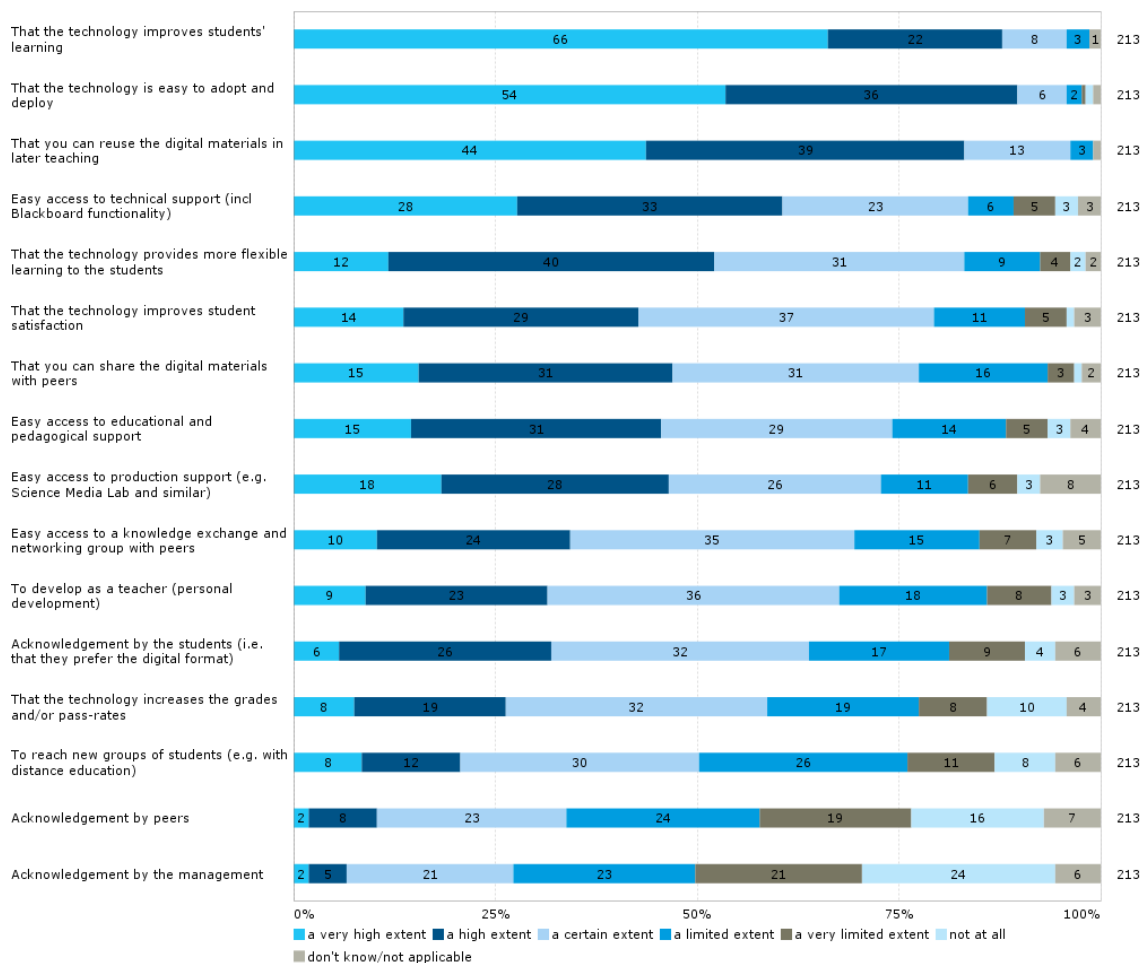


Figure 19. Criteria important for the educators' adoption of technology in education.

In general, the figures show that the most important criterion for the educators' adoption of technology in education was the impact on students' learning. 96% of the educators responded that they to a certain, high, or very high extent found this criterion important for their adoption of educational technology in their teaching practice. In addition, 83% responded that providing flexible learning to the students to a certain, high, or very high extent was important to their adoption of technology in their practice as well as 80% responded that student satisfaction was important. Furthermore, 64% found acknowledgement by the students important whereas merely 33% and 28% found, respectively, acknowledgement by peers and by the management important. This indicated a clear educator priority: that students, their satisfaction, and learning was more important than the management or peers' expectations for the adoption of technology in education. Nevertheless, the educators were less concerned about the potential impact on grades and pass-rates. 37% responded that this criterion was of limited, very limited, or no importance to their adoption suggesting that some educators do not perceive TEL as a means of increasing grades and/or pass-rates.

The general interest in providing quality in education was further substantiated by the educators' prioritisation of aspects important to their teaching in general (Figure 20). Here the educators were here presented with the same Likert battery of nine potential teaching and learning affordances potentially provided by TEL as the PVC (Table 7) and the students (Figure 24) prior to the questions related to technology in education, so that this would not influence their choices. The affordances were not put in the context of LD.

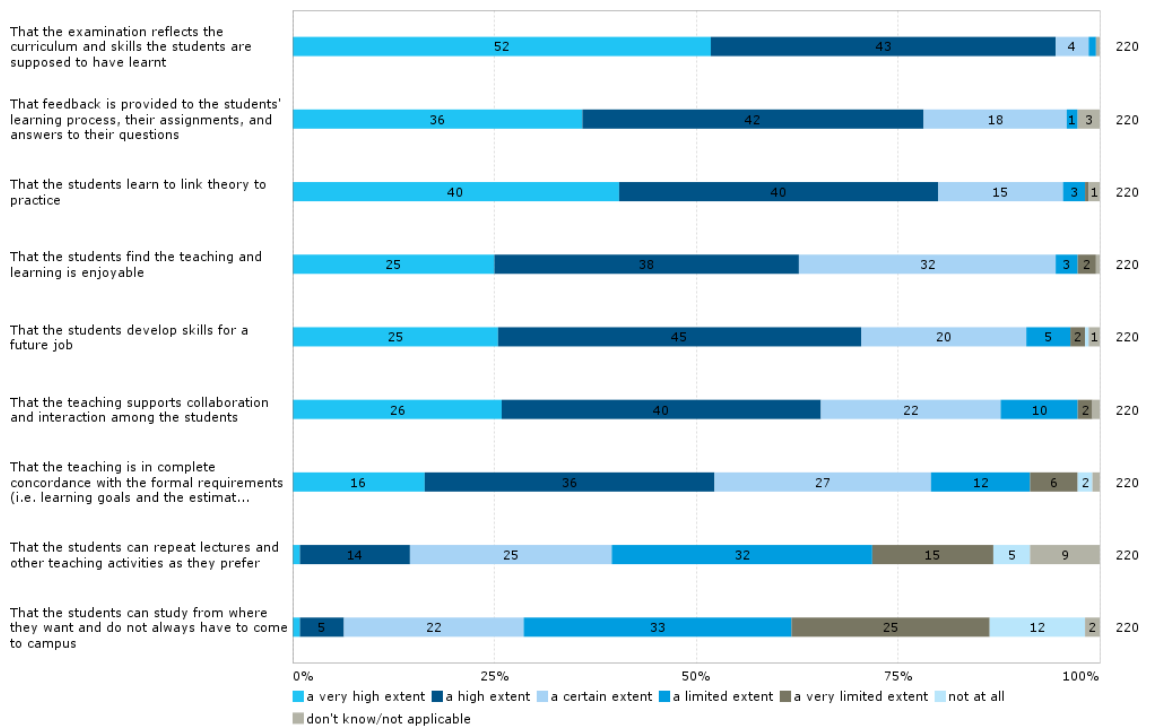


Figure 20. 'To what extent to you find the following aspects important to your teaching in general?'

79%–99% of the educators found to a certain, high, or very high extent seven of the nine affordances important to their teaching. The two affordances of lowest priority were related to flexibility. This is unlike the criteria for the educators' potential adoption of educational technology in their teaching practice, where flexibility was ranked as the fifth most important aspect (see Figure 19). This illustrates that although educators do not find certain aspects important to their teaching practice in general, the same criteria may be important to their adoption of technology and thus potentially also LD. It may also suggest that the educators attributed diverse meanings to some of the criteria in Figure 19, such as to flexibility as not being associated with the time, place, and pace flexibility usually associated with TEL.

However, although other student impact-related criteria were of high priority, educator effort-related criteria were of similar or higher priority and included a desire for easy-to-

adopt technology, reusable materials as well as easy access to technical, pedagogical, and media support (see Figure 19). Additionally, the educator impact-related criterion of sharing digital materials with peers had a high priority. That is to say, there was an awareness of the effort associated with technology in education.

This awareness of effort was further substantiated by the two open-ended questions in the survey in which the educators were asked to provide 'specific wishes for initiatives or services that would help [them] improve [their] teaching practice' and/or 'any other comments'. These questions were not compulsory, but respectively 48 and 21 educators responded. Coding the comments revealed themes similar to, in particular, the effort-related criteria in the Likert questions (see Appendix H). As expected due to the phrasing of the first question, most responses were related to the services and support provided by the institution. Especially the training, technical support, media development support, and access to equipment was highlighted as important. One educator expressed it:

'I would be happy to introduce e-learning in my teaching where applicable — but only if there is a strong technical support and all technical details are being taken care of by relevant technical staff' (Anonymous educator).

In addition, more pedagogically oriented workshops and courses were requested in terms of for instance: 'Short courses with focus on developing content of e-resources [sic], not just the technical side' (Anonymous educator) and '...workshops for teachers that will help us get started using these new opportunities' (Anonymous educator). One educator even requested 'Cutting edge hands on knowledge [sic] to consult concerning tech tools for teaching...'. This interest in professional development was further substantiated by the survey showing that 68% to a certain, high, or very high extent were interested in the personal development associated with adopting technology in education (Figure 21).

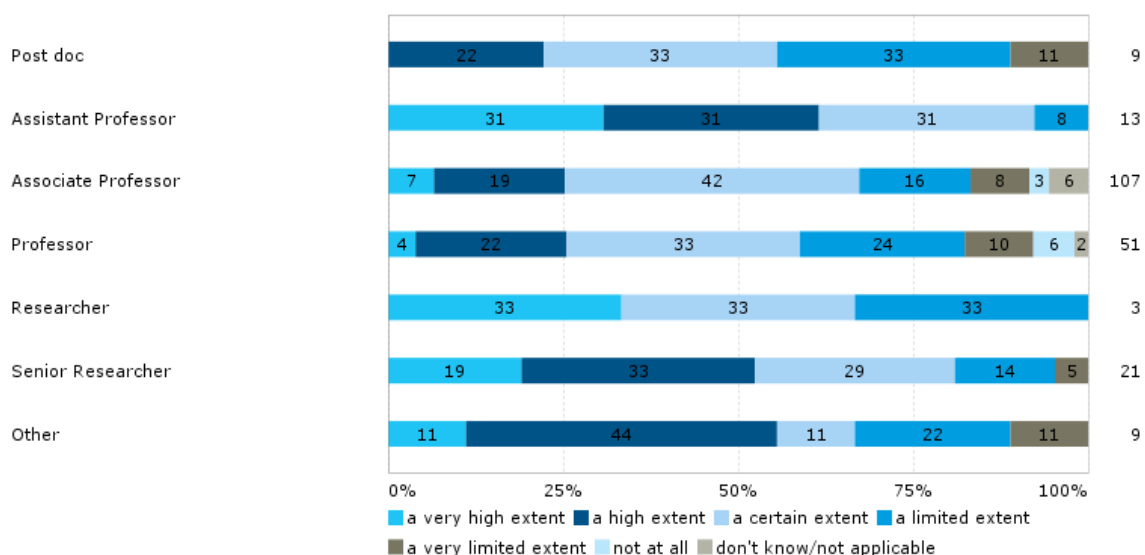


Figure 21. Importance of *developing as a teacher (personal development)* for the adoption of educational technology.

In particular, the assistant professors saw TEL as a criterion for developing as a teacher, whereas the associate and full professors were a little more sceptical (Figure 21). Whether participation in the compulsory professional development programme for assistant professors has had an impact on this interest is unknown. Nevertheless, the data showed a general high interest in professional development, including technology in education, and some even directly requested a pedagogical workshop and/or similar development activities focussing ‘not just the technical side’. Requests, which share similarities with the pedagogy-informed teaching (P) and design-centred (D) characteristics of LD and in particular their emphasis of ‘supporting them in making pedagogically-informed development of their teaching practice’ and letting ‘educators play an active role in the [design] process ... by means of workshops’ (see Chapter 2). In addition, 96% of the educators found to a certain, high, or very high extent reuse of digital materials in later teaching and 77% sharing digital materials with peers important for their adoption (R). This view was further substantiated in two comments suggesting respectively a ‘collection of best practices at the department’ (Anonymous educator) and a ‘P2P platform’ supporting ‘informal ways to contribute’ (Anonymous educator).

Both the survey comments and the figures (Figure 19) indicate an intention for both reusing and sharing materials and experiences. This is somewhat analogous to the ‘desire to explicate teaching practices in order to make them reusable and sharable’ as common to LD practices, except that LD aims at sharing entire practices and not just materials and/or tool-related tips and tricks. That is to say, the educators were highly concerned with practical aspects of technology in education, such as

adoption/deployment, reuse of materials, and support. Aspects, which are in focus in LD and, in particular, the open-ended approaches such as Conole and Fill's (2005) easy-to-use and adapt toolkit concept as well as STREAM (Godsk, 2013).

Overall, the figures and comments document a general high interest in and positive attitude towards educational technology and, therefore, potentially also towards LD and TEL based on LD. Only little conservatism was identified and, if so, it was justified in the educator survey:

'The use of new technology must not spoil the possibilities for other types of teaching. Use of technology can be used to improve the teaching, but it's not all ways [sic] the case. And don't forget there are a lot of others possibilities to improve the teaching' (Anonymous educator).

However, as suggested by the figures regarding the educators' general concern about practical aspects the overarching barrier for the educators was time and missing incentives. This was further clarified in the following comments:

'The most important issue is TIME [sic]. It takes time to develop new teaching materials and habits and this time must be allocated by the university to us as individuals' (Anonymous educator).

'[There] is very little incentives [sic] for me to improve teaching as I am constantly measured on research output and the ability to attract external funding' (Anonymous educator).

However, this may differ for the engineering educators (not included in the survey), who typically have a less research-intensive career and their main task is to teach. Nevertheless, the *attitude, experiences, and perception of TEL* as well as *time spent on teaching and transforming the module* indicators should play an important role in assessing educator effort. Furthermore, as the coding of the comments suggested, the attitude, experiences, and perception indicator was even more varied and should potentially include even further aspects such as educator knowledge and underlying motivation. In addition, the educator survey comments also suggested that much of the educators' attitude and effort was linked to the institution and its provisions as 62% ( $n = 27$ ) of the 43 provided comments were requesting various kinds of additional support, 19% ( $n = 8$ ) were requesting staff development and training initiatives, and 19% ( $n = 8$ )

were requesting strategies and policies, including a clearer strategy on and acknowledgement of teaching initiatives. Furthermore, the comments also indicated a general perception that TEL is always associated with increased effort, as for instance: 'most efforts needed to improve [sic] teaching is associated with increased time consumption...' (Anonymous educator). This potential misperception may explain the high prioritisation of effort-related criteria important for the educators' adoption of technology (Figure 19), such as the potential for reusing the digital materials in later teaching as well as a technology that is easy to adopt and deploy. In respect to LD, this stresses the educators' interest in its potential for reusing entire practices and its inherent efficiency potential.

## The student perspective

As discussed in the context of the Learning Design in Practice concept (Chapter 3) and further concretised in the Inventory of learning with Learning Design (Appendix E) as well as the research matrix, the students would primarily have an indirect interest in LD and, thus, no explicit references to LD were made in the survey. Instead, the students' interest would be constituted by their incentives for studying, teaching type preferences, perception of technological affordances (*attitude*), and preferences regarding workload and learning with technology (if not directly involved in the LD process).

Like the institution, the students at AU ST were pressured by the study progress reform by The Danish Government (2013), which also entailed that the students must reduce the average degree-completion time towards the estimated study time of three years for a bachelor's degree. Nevertheless, the students gave a variety of primary reasons for studying besides merely getting a degree (see Figure 22).

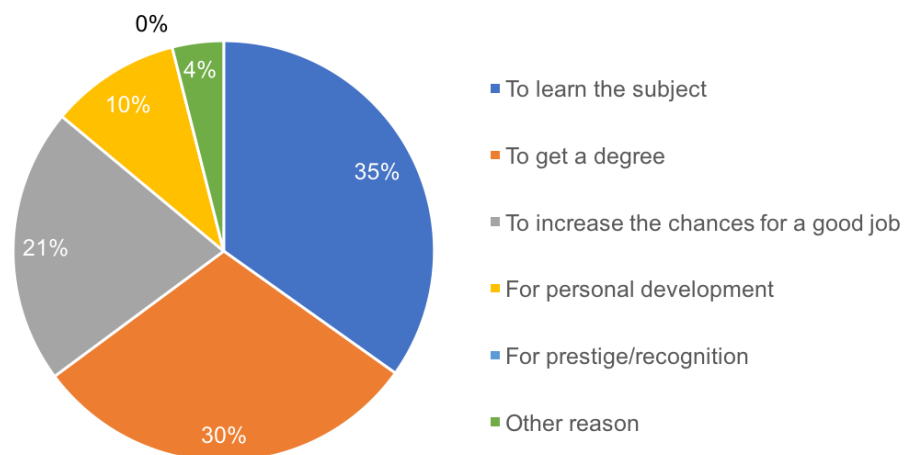


Figure 22. The students' primary reason for studying ( $n = 330$ ).



Approximately half of the students were primarily studying STEM for extrinsic reasons such as a good job or a degree, which are typically associated with a surface learning approach, and the other half were primarily motivated by the subject area and personal development typically associated with deep learning. When asked directly the vast majority, that is, 94% of the students ( $n = 307$ ), responded that they to a certain, high, or very high extent were willing to spend more time on their studies if they felt they learned a lot.

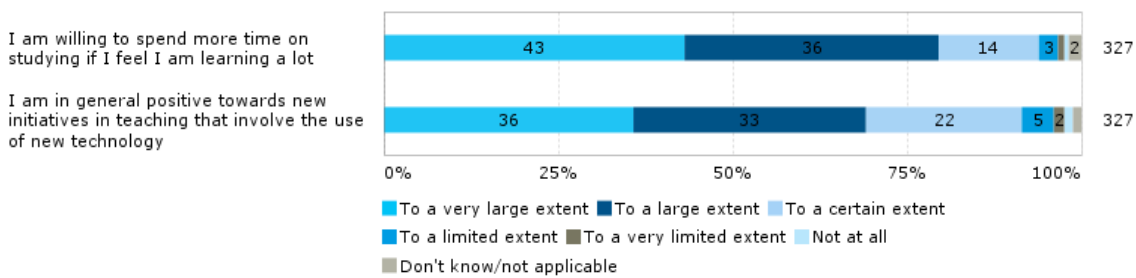


Figure 23. Attitude towards time on studying and new technology in education ( $n = 327$ ).

This attitude was further supported by the ASSIST study of their preferences for the learning environment in general. Here the majority, that is, 66% ( $n = 218$ ), preferred an approach to teaching that supported understanding and a deep learning approach as opposed to 22% ( $n = 72$ ) who preferred teaching characterised by transmission of information (i.e., a surface learning approach). 12% ( $n = 40$ ) were neutral.

Though no direct references were made to LD in the survey, it did reveal that the students were highly interested in most of the nine presented teaching and learning affordances potentially provided by TEL and thus also the potential outcome of a LD practice. In particular, aspects associated with feedback, satisfaction, alignment between the examination and curriculum, linking theory to practice, and skill development were of high interest (Figure 24). Conversely, some affordances were of less interest such as place flexibility, support for collaboration, concordance between learning goals and time estimate, and time and pace flexibility in terms of the opportunity to repeat lectures and other teaching activities whenever they wanted.

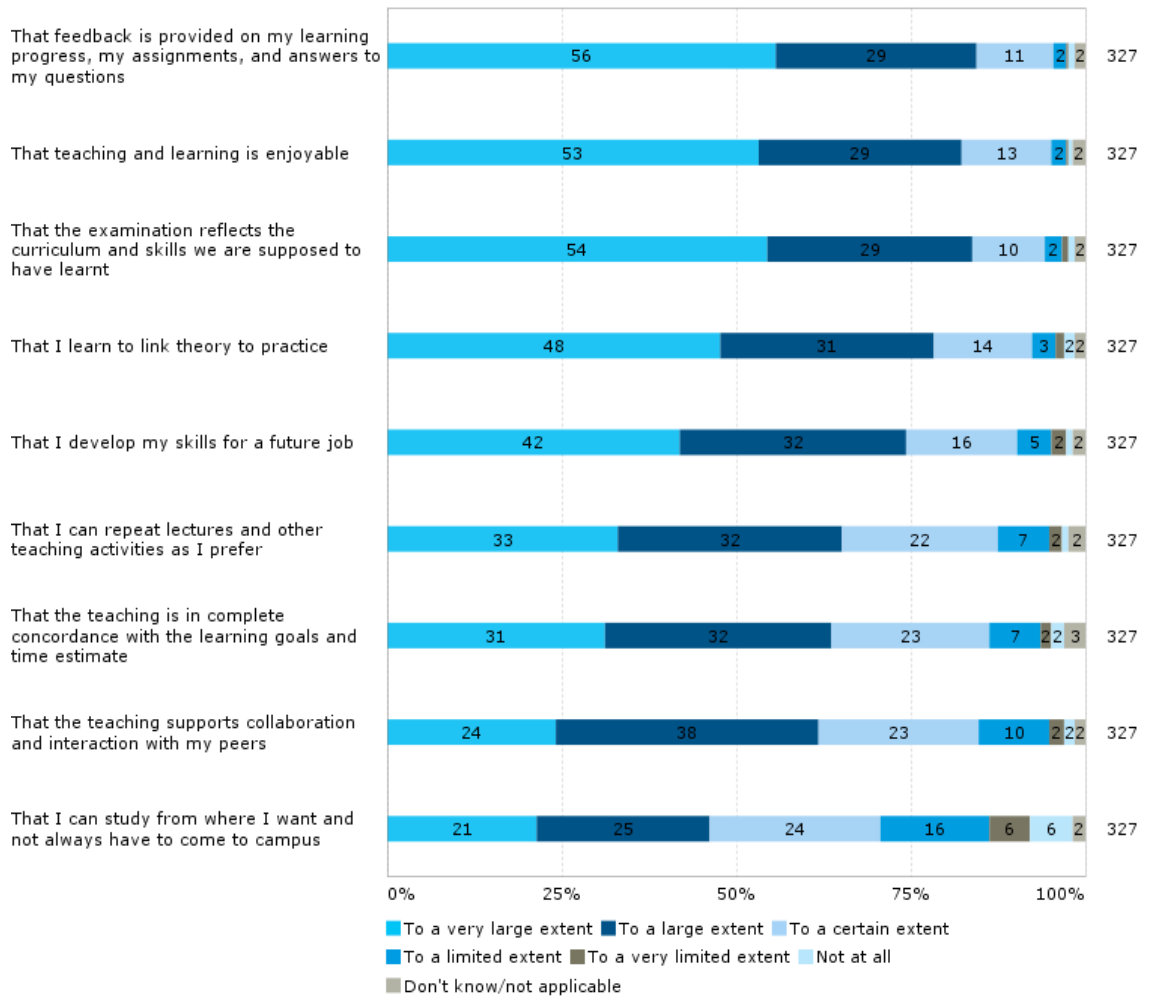


Figure 24. The students' interests in nine teaching and learning affordances of TEL potentially based on LD.

Compared to the educators, the prioritisation in Figure 24 revealed a general high congruity, including a shared interest in feedback and linking theory to practice, but it also highlighted some differences. Firstly, the students were in general more positive towards the nine affordances. This may partly be explained by their less non-committal role to the actual development and implementation compared to the educators. But it may also suggest that the students were generally more positive towards the affordances TEL may actualise for their teaching and learning. Secondly, the students were significantly more interested in flexibility, and in particular the pace flexibility in terms of being able to 'repeat lectures and other teaching activities as I prefer'. Thirdly, the students were less concerned with whether the examination reflected the curriculum as well as whether there was support for collaboration and interaction among the students.

However, comparing the primary reason for studying (Figure 22), that is, whether it was primarily intrinsic (Figure 25), such as *to learn the subject* and *for personal development*,

with extrinsically motivated (Figure 26), such as *to get an education/degree, to improve my chances for a good job, and for prestige and/or social status*, three patterns occurred. Firstly, there was little difference in the individual prioritisations of the affordances between the two groups. Both groups saw feedback and alignment as very important. Secondly, the primarily intrinsically motivated students prioritised *that teaching and learning is enjoyable*, less important was that they *develop ... skills for a future job*. Thirdly, the primarily extrinsically motivated students were less concerned with whether the teaching and learning was enjoyable. Instead, they were more concerned about developing skills for a future job compared to the intrinsically motivated.

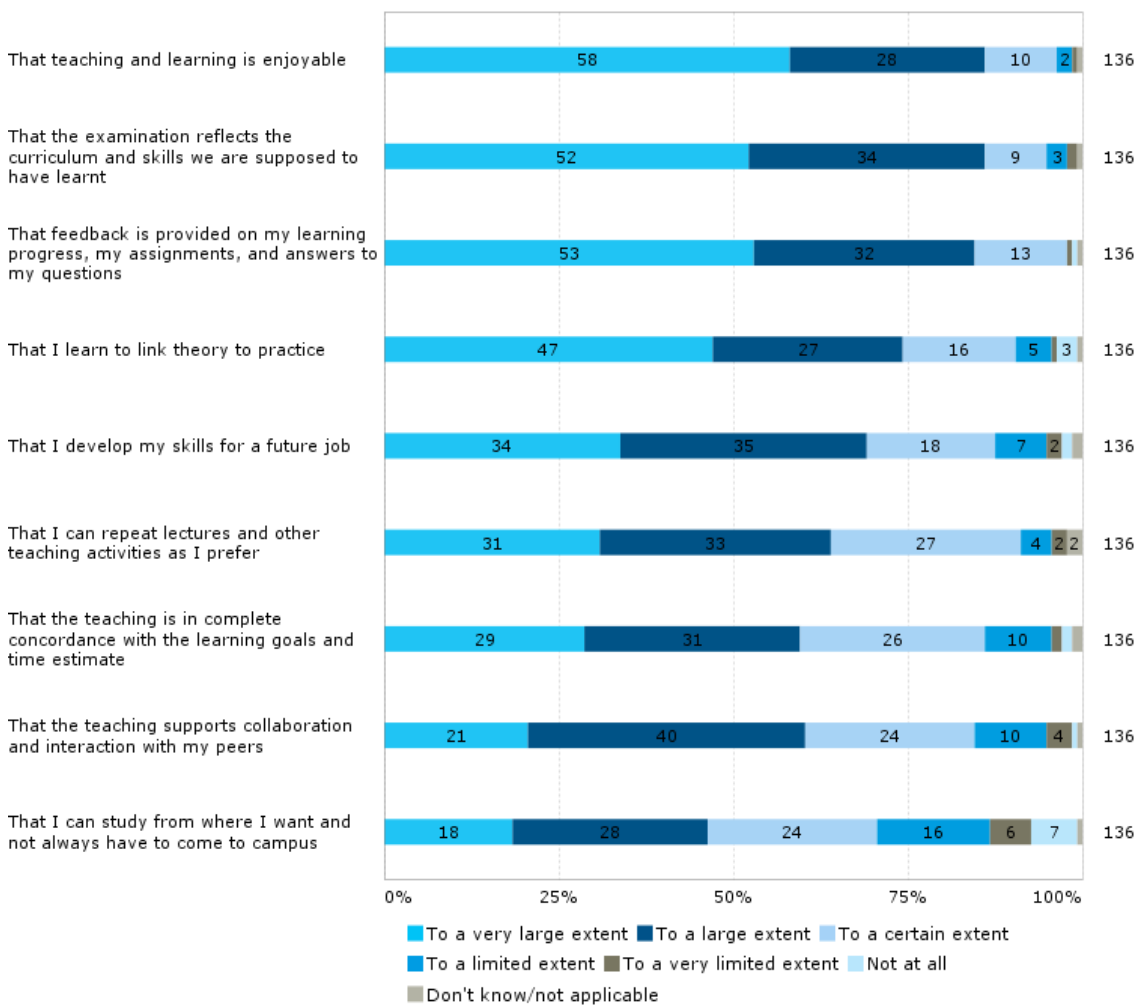


Figure 25. Interests in nine teaching and learning affordances of TEL potentially based on LD among students with a primarily *intrinsic motivation* for studying.

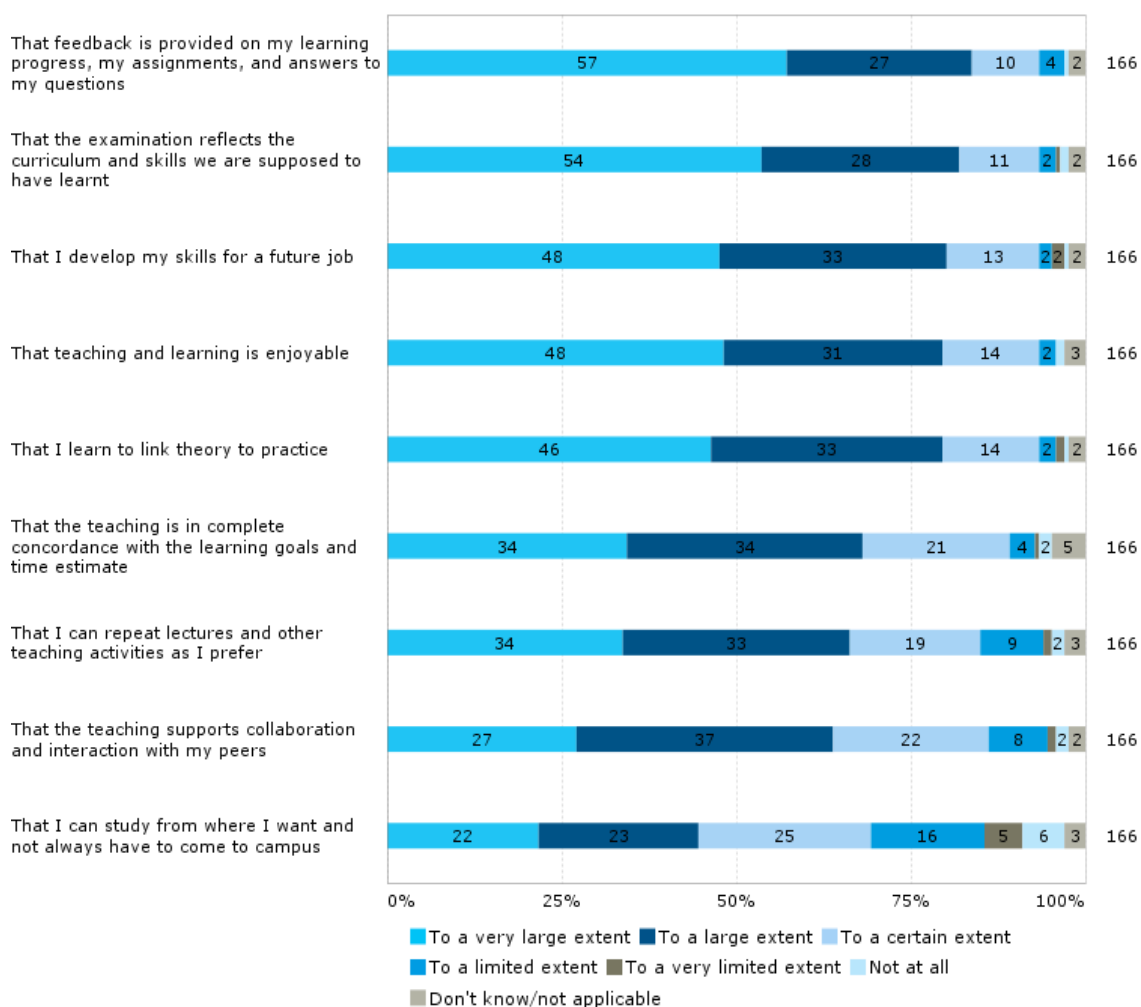


Figure 26. Interests in nine teaching and learning affordances of TEL potentially based on LD among students with a primarily *extrinsic motivation* for studying.

That is to say, there was a general high level of consensus across students' motivation for studying on the affordances potentially provided by TEL based on LD. The five most important were: feedback, alignment, job skills, enjoyable teaching and learning, and linking theory to practice, whereas place flexibility was least important. Nevertheless, the fact that the primarily intrinsically motivated students were significantly more interested in enjoyable teaching and learning and less concerned about job skills, and vice versa for the extrinsically motivated, suggests a different view on the LD product and its role. For instance, a LD supporting deep learning by *providing explanations which go beyond the lectures* (see the ASSIST scoring key, Entwistle et al., 2013, p. 19) (as the case with Astrophysics, see Chapter 6) may target the intrinsically motivated students well, whereas the more extrinsically motivated students may be better targeted by means of materials and activities which provide more obvious (job) skills (as the case of General Chemistry, see Chapter 6). That is, caution should be made as to what extent the introduction of a LD will support both groups of students' perspectives on TEL.

With regard to the required effort, it appeared that there was an unresolved potential for spending more effort on studying and that TEL was welcomed. At least by the majority of the students and in theory as 94% of the students responded were to a certain, high, or very high extent willing to spend more time on studying if they felt they were learning a lot and 91% were positive towards initiatives involving TEL. However, as this perception of TEL may be shaped by previous experiences as well as the context at AU ST, these percentages should be reinterpreted in the context of actual LD cases (as in Chapter 6). For instance, in the context of this research, the four cases revealed that there were diverse preferences regarding the online formats based on the experiences from each module as well as a widespread perception that traditional lectures were motivating.

## Summary: Perspectives on Learning Design

The analyses revealed very limited direct interest in LD at the institutional level in terms of merely one institutional document referring to ‘AU Learning Design’ (potentially due to this project) and no direct interest among educators and students. However, the institution and the educators showed a direct interest in professional development, and the educators were interested in being able to reuse and share learning materials (when surveyed) as well as (to some extent) being active in developing their teaching practice in a pedagogy-informed manner. That is, interests related to the characteristics of LD (see Chapter 2).

The analyses also showed that there was a whole range of indirect stakes in LD associated with the efforts and impacts of LD. By combining the quantitative survey data of the educator and student perspectives with a matrix query of qualitative data, including the sources representing the institutional perspective, the PVC interview, and the educator comments, and subtracting the essence of each perspective according to the research matrix, the in-depth matrix display in Table 8 emerges.

Table 8

*Direct and indirect perspectives on LD based on TEL at AU ST*

Aspect	Indicators	Stakes
Institutional effort	National budgets, political agendas, and directives (government level)	<ul style="list-style-type: none"> <li>• Savings by means of ‘reprioritisation contribution’</li> <li>• Increase employability of students</li> <li>• Cost-effectiveness</li> <li>• Promote digitisation</li> </ul>
	Funding for educational development and technology (strategic level)	<ul style="list-style-type: none"> <li>• Grants of various kinds, including annual strategic grants for development projects</li> </ul>
	Strategies, policies, and aims on TEL (strategic level)	<ul style="list-style-type: none"> <li>• Digitisation strategy [government and institutional level]</li> <li>• The provision of an institutional policy on educational IT and a digitisation</li> </ul>

		strategy
	Pedagogical, media production, and technical development support to interventions	<ul style="list-style-type: none"> <li>Professional development programmes for assistant professors and various introductory courses to TEL</li> <li>An organisational structure to support the strategy, including four educational units, one for each faculty, and two media labs</li> </ul>
	IT and study administrative support to interventions (administrative level)	<ul style="list-style-type: none"> <li>The acquisition and support of an institutional LMS</li> </ul>
Institutional impact	Actualised affordances in accordance with strategies, policies, and aims for TEL	N/A
	Cut costs, increase intakes, and increase completion/pass-rates (retention)	<ul style="list-style-type: none"> <li>Cost-effectiveness of educational institutions</li> <li>Completion rate/retention</li> </ul>
	Other less official or unofficial institutional business and pedagogy aims	<ul style="list-style-type: none"> <li>Recruitment of the best students</li> <li>Study environment</li> <li>Support for student diversity</li> <li>Quality in education aspects: alignment between examination and curriculum, link theory to practice and provide job skills, and motivation</li> <li>Digital competences</li> <li>Digital expectations and provide modern teaching (branding)</li> <li>Student satisfaction</li> <li>Professional development of educators</li> <li>Collaboration/interaction among students</li> <li>Feedback in terms of meetings between students and educators (according to 'the didactic triangle')</li> <li>Increased 'study intensity'</li> <li>Employability of candidates</li> </ul>
Educator effort	Time spent on teaching and transforming the module	<ul style="list-style-type: none"> <li>'The most important issue is TIME. It takes time to develop new teaching materials and habits and this time must be allocated by the university to us as individuals.'</li> </ul>
	Uptake of LD model and defeated barriers	N/A
	Attitude, experiences, and perception of TEL	<p>Attitude</p> <ul style="list-style-type: none"> <li>73% saw a potential for educational technology in science education.</li> <li>'The use of new technology must not spoil the possibilities for other types of teaching. Use of technology can be used to improve the teaching, but it's not all ways the case. And don't forget there are a lot of others possibilities to improve the teaching.'</li> <li>'I think the focus should be on the quality of the teaching and what the students learn, and not on peripheral aspects'</li> </ul> <p>Experience</p> <ul style="list-style-type: none"> <li>93% have used educational technology as a teacher</li> </ul> <p>Strategy and incentives</p> <ul style="list-style-type: none"> <li>'[there] is very little incentives for me to improve teaching as I am constantly measured on research output and the ability to attract external funding'</li> <li>'I don't see my management paying much attention to teaching'</li> </ul> <p>Pedagogic, media, and technical support:</p> <ul style="list-style-type: none"> <li>62% (n = 27) of the 43 provided comments were requesting various kinds of additional support</li> <li>'Support for the teacher to use the new tools is very important. There has been too much 'do it yourself via a webpage''</li> <li>'Provide us with equipment and software for home production of material.'</li> <li>'I would be happy to introduce e-learning in my teaching where applicable — but only if there is a strong technical support and all technical details are being taken care of by relevant technical staff.'</li> <li>'get a better and more intuitive e-learn platform than BB'</li> <li>'Better rooms and facilities'</li> </ul> <p>Professional development and training</p> <ul style="list-style-type: none"> <li>'More exchange of knowledge and experience between teachers.'</li> <li>'...workshops for teachers that will help us get started using these new opportunities.'</li> </ul>
Impact on educator	Flexibility in time, place, and pace	N/A
	Satisfaction and perception of the intervention, including TEL and LD in general	<ul style="list-style-type: none"> <li>Explicit interests related to the LD characteristics of ensuring a pedagogically informed teaching practice (P), having an active role in the resign process (D), and 96% found reusing and 77% sharing materials (R) important for their adoption</li> </ul>
	Other affordances and interests	<ul style="list-style-type: none"> <li>96% found students' learning important for their adoption</li> <li>General interest in professional development</li> <li>General interest in reusing and sharing materials and experiences</li> </ul>

Student effort	Time spent on the module	<ul style="list-style-type: none"> <li>94% of the students were willing to spend more time on studying if they felt they were learning a lot</li> </ul>
	Attitude towards technology in education	<ul style="list-style-type: none"> <li>91% of the students were positive towards initiatives involving TEL</li> <li>Higher expectations among extrinsically motivated students</li> </ul>
Impact on students	Flexibility in time, place, and pace	<ul style="list-style-type: none"> <li>70% of the students found place flexibility important</li> <li>87% of the students found pace flexibility (i.e., support for repetition) important</li> </ul>
	Satisfaction and teaching preferences	<ul style="list-style-type: none"> <li>95% find it important that teaching and learning is enjoyable</li> </ul>
	Improved learning in terms of more higher-order thinking activities, higher grades, and/or higher pass-rates	<ul style="list-style-type: none"> <li>66% preferred a deep learning approach</li> </ul>
	Perceived learning outcome	N/A
	Other affordances cf. the incentives for the intervention	<ul style="list-style-type: none"> <li>Also, feedback, alignment, job skills, and linking theory to practice had a high priority</li> <li>Students were highly interested in most of the nine TEL affordances (see Table 9)</li> </ul>

In addition, all three stakeholders had opinions about the teaching and learning affordances potentially provided by TEL based on LD. The institution was highly concerned about its impact on the overall business and pedagogic aims as prescribed in the strategies, including study environment, quality and costs, and recruitment of students. The educators were concerned about teaching, their own professional development, their students' learning, and whether the technology was easy to adopt, easy to deploy, and materials could be reused. The students were positive towards and generally interested in most of the affordances TEL potentially could provide, including in particular more feedback, alignment, and enjoyable teaching. That is to say, interests were mostly related to each stakeholders' own role, that is, respectively, the business of running a university, the teaching, and the learning. An overview of the three stakeholders' prioritisation and ranking of the nine teaching and learning affordances potentially provided by TEL based on LD is provided in Table 9 ('1' is highest priority).

**Table 9**  
*The median prioritisation of interests in nine teaching and learning affordances potentially provided by TEL based on LD in the surveys*

Priority of TEL affordance and rank	General ranking		
	Institution	Educators	Students
<b>Alignment (examination and curriculum):</b> that the examination reflects the curriculum and skills the students are supposed to have learnt	Very high (1)	Very high (1)	Very high (3)
<b>Feedback:</b> that feedback is provided to the students' learning process, their assignments, and answers to their questions	High (3)	High (2)	Very high (1)
<b>Link theory to practice:</b> that the students learn to link theory to practice	Very high (1)	High (3)	High (4)
<b>Student satisfaction:</b> that the students find the teaching and learning enjoyable	High (3)	High (4)	Very high (2)
<b>Skills for future job:</b> that the students develop skills for a future job	High (3)	High (5)	High (5)

<b>Formal requirements:</b> that the teaching is in complete concordance with the formal requirements (i.e., learning goals and the estimated study time/ECTS)	High (3)	High (7)	High (7)
<b>Collaboration and interaction:</b> that the teaching supports collaboration and interaction among the students	Medium (7)	High (6)	High (8)
<b>Time and pace flexibility:</b> that the students can repeat lectures and other teaching activities as they prefer	Medium (7)	Low (8)	High (6)
<b>Place flexibility:</b> that the students can study from where they want and do not always have to come to campus	Medium (7)	Low (9)	Medium (9)

The educator survey did also reveal strong expectations about institutional efforts such as the strategy of TEL as well as the pedagogical, media, and technical support provided. Furthermore, according to the survey the educators saw the ease of deployment and support of IT systems as the second and fourth most important criteria for their adoption of technology in education. That is to say, although LD efficiency may be described by an effort-impact ratio as expressed in Chapter 3, the actual perspectives on LD in practice is a more complex matter in which the stakeholders have expectations to other stakeholders' efforts associated with TEL and LD as well as its impact on other stakeholders. However, for the purpose of assessing LD efficiency these expectations and interests do not directly express what effort has actually been put into an intervention nor do they measure the actual impact. Instead, they may help to understand the stakeholders' interest in impact and view on effort for LD as well as weighting the different indicators and identifying discrepancies between stakeholders. For example, an impact of interest across all three stakeholders such as supporting students' learning should carry more weight than time and pace flexibility, which mainly is of interest to the students. The expectations and interests may also help identify potential discrepancies between interest in and benefit of LD. For instance, a structured LD approach provided by the institution may be highly beneficial for an educator in her/his teaching development but in practice the educator may expect something completely different and want to do this development ad hoc.

In addition, the perspectives, stakes, and interests identified in Table 8–9 represent the general view within the STEM context at AU ST. However, in the context of actual LD interventions the perspectives may be different and include additional intervention specific stakes related to the aim of the intervention and the involved stakeholders. This is further explored in Chapter 6, which at the same time trials the findings provided in this Chapter 5.





## 6. Learning Design cases

Having set out the perspectives of the different stakeholders, the four detailed LD cases will now be scrutinised by means of the research matrix of mixed methods (Chapter 4). The cases included in this project were the result of the maximum variation sampling strategy (Patton, 2002) and, thus, four diverse modules were recruited each resulting in a range of LD processes and products. However, they were all developed within the context of the overarching LD practice at AU ST based on STREAM.

Table 10  
*Overview of the four cases*

	<b>Case 1: Astrophysics 2014, 2015</b>	<b>Case 2: Calculus 2 2014, 2015</b>	<b>Case 3: General Chemistry 2016</b>	<b>Case 4: Digital Electronics 2015, 2016</b>
<b>Module*</b>				
<b>Credits and level</b>	5 ECTS, undergraduate	5 ECTS, undergraduate	5 ECTS, undergraduate	Each 5 ECTS, undergraduate
<b>Level of transformation</b>	Augmentation, blended/mixed mode	Modification, blended/mixed mode	Augmentation, blended/mixed mode	Augmentation, blended/mixed mode and redefinition/online learning in parallel
<b>STREAM compliance (no. of criteria met)**</b>	6	7	1	6 (2015), 2 (2016)
<b>Aim</b>	Flexibility, collaboration, and feedback	Cost reduction and modernise teaching	Provide self-paced repetition	Recruit students through online learning
<b>Educator</b>				
<b>Designation</b>	Educator 1	Educator 2	Educator 3	Educator 4
<b>Gender and age</b>	Male, mid 30s	Male, early 60s	Male, mid 40s	Male, mid 50s
<b>Career stage</b>	Educational developer (previously postdoc in Astrophysics)	Associate/full professor	Senior researcher	Associate professor and head of programme
<b>Pedagogical training</b>	Teacher training programme in 2011	None	Teacher training programme in 2013	Herning Online course (2.5 weeks) and diverse teacher training
<b>Years of teaching experience in HE</b>	5–10 years	> 10 years	> 10 years	> 10 years
<b>Years on the module</b>	Since 2010	Since 2011	Since 2016	Since 1990 (on similar modules)
<b>Agency</b>	Overall responsible for the module, held the face-to-face lectures and online activities	Overall responsible for the module, held the lectures and online activities. Participated in lab (occasionally) and feedback activities	Responsible for the laboratory teaching.	Head of programme and engaged in planning of all its modules. Two other educators were teaching the modules

\*See Appendix K–N for more details about the modules. \*\*See Appendix O for details.

### Context and Learning Design practice

The context of the LD practice described is AU ST, that is, a research-intensive STEM faculty in which educational development is supported by the educational unit (STLL) and the Media Lab (ML). At AU ST, science modules are organised in quarters of seven

teaching weeks and engineering modules in semesters of 14 teaching weeks. A module typically counts for 5 ECTS and consists of up to five teaching components: *face-to-face lectures* (often large-scale), small-group classroom teaching referred to as *theoretical exercises*, *laboratory work* (sometimes referred to as *practical exercises* or *lab exercises*, which includes experiments), *fieldwork*, and a *final examination*. In large-scale (undergraduate) modules, the lectures are typically held by a senior academic, which is also the module chair, whereas the theoretical exercises, lab work, and fieldwork are typically held by tutors also employed as postdocs, PhD students, or postgraduate students. In small-scale engineering modules, the exercises and lab work are often integrated into the lectures taught by the main educator. Each module has an online module page in the LMS, which is usually maintained by the module secretary or the module chair supported by the tutors.

Though education has a general high priority at AU, research outmatches this at ST due to funding, ranking, and recruitment reasons (Aarhus University, 2017b; 2017c) and there are currently no formal requirements regarding the upkeep of skills, educational innovation, uptake of technology, or LD. Thus, educational development initiatives including LD are typically up to the educators themselves — or initiated by programme managers or STLL. This also partly explains the open-ended LD practice provided by STLL at ST and its underlying idea of STREAM concretising pedagogical ideas and educational strategies into a model, which may serve as a pedagogical framework for the transformation of modules and the dialogue between the educational developer and the educator. The person initiating the LD process varied between the cases. Case 2 and 4 were initiated by the programme managers, Case 1 by the educator and STLL, and Case 3 by STLL. Typically, the educator was introduced to the model and/or its ideas at an initial meeting by the educational developer and based on this meeting and the further dialogue the module was transformed either in collaboration with the educational developer or by the educator himself and, if relevant, supported by ML for the production of materials. It was largely up to the educator himself to consult the educational developer, and the educational developer would primarily contact the educator in order to ensure a focus on students' learning. Thus, it was also up to the educator himself as to what extent the design should be reused and shared. However, to support the process, the module evaluations were shared with the educators.

## Case 1: Astrophysics

Astrophysics (AP) was a compulsory, five ECTS first-year/second quarter undergraduate module for all physics students enrolled in the Physics, Astronomy, or Technical Physics study tracks (Physics, 2016). In addition, AP was available as an optional module for science students, in general, of which typically mathematics students were most commonly enrolled. The main topic of the module was 'the physical mechanisms behind the structure and evolution of the Universe and objects found in the Universe' (Course Catalogue, 2016a), which was further concretised in 10 learning goals (see Appendix K).

Prior to the transformation, the module was taught by means of four face-to-face lectures and three hours of theoretical exercises per week practicing calculations with support from a tutor over a period of seven weeks and culminated with a four-hour open-book, written examination on a set topic. Two educational technologies were used in the teaching practice: the LMS, which was primarily used for announcements and distributing materials, and clickers. The teaching was carried out by one main educator, Educator 1, responsible for the lectures and the module page at the LMS supported by a group of approximately five tutors responsible for the theoretical exercises.

### The Learning Design process

AP was developed over three iterations guided or inspired by STREAM starting with the introduction of a few videos and online activities in 2013 — that is, a year before this project; adding more online activities, continuous assessment, and a so-called "e-instructor" for providing online feedback in 2014; and replacing the paper and pen-examination with a digital version in 2015. The educator was first introduced to STREAM in late 2013 and later he has also been involved in promoting the model to other educators due to his work as an educational developer. During that period of time the main educator was the same person; however, the group of tutors has changed.

The educator has a background as a researcher (PhD and postdoc) in astrophysics and taught the module six times as of 2015. In 2013, the educator joined the Centre for Science Education as an educational developer while still teaching AP but had no prior formal education or experience with educational development, educational technology, or LD, except for the professional development programme in 2011 and first-hand experiences from his own teaching practice. That is to say, since 2013 the educator has had a double role as both educator and educational developer.

According to the educator interview the overall incentives for transforming the module were initially to modernise teaching practice, which he saw as a goal in itself, and to support flexible learning where the students could revise material according to their needs. In 2015, however, his aims had evolved to include a series of other incentives, including supporting collaboration among the students and increasing feedback.

Educator 1 suggested that he did not intend to slavishly follow the STREAM model. Instead, the model was used for inspiration and as a guide to provide answers from 2014 (and onwards).

‘It [STREAM] has ... inspired me to the large transformation in 2014 and to combine the so-called in-class out-of-class activities with each other. For instance, Just-in-Time Teaching, etc.... This is also where I’ve made activities that subsequently test the students. In other words, I’ve taken the STREAM model and tuned it a little bit according to the way I wanted to teach this module’ (Educator 1).

‘It has ... been easy for me to have this model because it has helped me realise what I find appropriate in the module and what I could apply as is, and what I wanted to develop according to [my] mission as an educator and do differently... So, the model provides a lot of answers and you can take what you can use. In addition, I appreciate to have a model to build upon — otherwise you’ll sort of have to reinvent the wheel by yourself’ (Educator 1).

In addition, the educator was conscious about which parts of the model he was using:

‘I haven’t used the little loop [i.e., the out-of-class loop] to a very large extent. The activities I’ve made do not loop, i.e., there isn’t a content activity followed by a test or similar. I do that in another way... the five activities can be completed in random order... So, I am more thinking it as an entirety instead of what feeds what in such a loop’ (Educator 1).

‘... I have also been adjusting the large loop [i.e., ‘the feedback loop’] so it would suit me better. I have changed the aspect of adjusting out-of-class after in-class so that I instead test the students out-of-class after in-class, so it’s another version of the STREAM model...’ (Educator 1).

It appears then that STREAM played a significant role in the initial transformation of the module in 2013 and 2014 but also that its direct role faded in 2015 as the educator started to think outside the box or builds on generated teaching routines. However, compared to the nine STREAM characteristics six out of nine were fulfilled both in 2014 and 2015 (see Appendix O). Compared to the five characteristics of LD all were nearly met as the pedagogy was inductively informed through STREAM as the guiding pedagogical framework. The focus on students' learning was addressed through the dialogue with the educational developer. The educator himself designed the module and the online materials with support from ML. The design of the module was to a large extent reused by the educator. However, no more formal dissemination of the results took place between the two iterations as the educator insisted on carrying out the student survey by himself (see Chapter 4).

### The Learning Design product

The actualised LD in AP 2014 was an augmentation compared to its prior teaching practice, which means that technology was used for 'enhancing activities or transforming components' (Godsk, 2014a, p. 184).

In practice, one out of four weekly face-to-face lectures was replaced with an online learning path designed as single-pages consisting of a sequence of 6–12 items with text items, videos, and various activities out-of-class followed up by in-class feedback (see Appendix K). Figure 27 is a screenshot of the first week of AP in 2015, which was designed as a single-page including an introductory text, two videos, a group sign-up activity, a quiz, a feedback activity, and five optional items of three text/notes items and two videos in the LMS. Most of the online activities gave points towards the final grade and 25% could be earned through the online activities in the LMS.

The screenshot shows the Blackboard LMS interface for Aarhus University. The top navigation bar includes 'MY INSTITUTION', 'COURSES', 'COMMUNITY', 'CONTENT COLLECTION', 'AU LIBRARY - STUDENT', 'AU LIBRARY - INSTRUCTOR', and 'SYSTEM ADMIN'. The course title is 'Uge 1 (29/10-4/11)'. The main content area is titled 'Uge 1 (19 point)' and contains the following text:

Herunder finder I online-aktiviteterne til uge 1. Der er i alt fem aktiviteter samt et spørgsmål, som bliver synligt, når I har gennemført aktivitet 5. Nederst finder I desuden en række ekstramaterialer.

Hvis I gennemgår alle elementer i uge 1 kan I opnå en samlet score på max 19 point. **Deadline for aktiviteterne i uge 1 er torsdag 5/11 kl. 23.59.** Jeg vil anbefale at I starter så tidligt som muligt med at gennemføre ugens online-aktiviteter, da det formentligt ikke er muligt at få teknisk eller anden hjælp kort før deadline.

**Bemærk: Jeres bidrag til aktiviteterne tæller med i den samlede bedømmelse i kurset.**

Pensum til uge 1 er:

- Kapitel 3 (Det hele)
- Kapitel 4 (4.1-4.3)
- Kapitel 5 (5.1-5.3)

Below the text are two video thumbnails:

- Uge 1, Aktivitet 1: Introvideo**: A video titled 'Studio 2 - Hopper - 22 October 2015' showing a man standing next to a screen displaying 'Astrofysik 2015'.
- Uge 1, Aktivitet 2: Video om tidevand**: A video titled 'Optagelse på CSE - 08 October 2014' showing a man holding a globe in front of a whiteboard with diagrams.

A note at the bottom of the page reads: 'NB: I denne video (og alle der kommer senere i kurset) kan I toggle mellem at se skærmen, se mig eller se begge på forskellig måde. Brug ikonet ovenfor med en firkant i en firkant (den bliver synlig når I starter videoen). I kan også maksimere videoen på ikonet ved siden af.'

Figure 27. First week of AP in 2015.

Though most materials and activities were reused to some extent and the number of learning paths, compulsory videos, and activities were almost identical, the teaching practice and LD had evolved between 2014 and 2015. Compared to 2014, an extensive dissemination assignment was added to Week 5 as well as 18 optional extra materials such as videos and texts. Furthermore, more announcements and forum posts were made in 2015 compared to 2014 without this being a specific aim of STREAM.

## Case 2: Calculus 2

Calculus 2 (C2) was a 5 ECTS first-year/second quarter undergraduate module compulsory on all 13 AU ST programmes except engineering. In the mathematics, mathematics–economics, and chemistry programmes the module was referred to as a *compulsory* module, while it was referred to as a *compulsory auxiliary* module on the remaining programmes (Aarhus University, 2016). The aims and objectives of the

module were 'to give the participants knowledge and appreciation of basic methods, concepts and results from (1) calculus in several variables, (2) linear algebra and (3) series' (Course Catalogue, 2016b), which was further expressed in two learning goals (see Appendix L).

Prior to the transformation, individual educators taught the module in four parallel tracks of four hours of lectures each week. In addition, the students were divided into two-hour weekly theoretical exercise classes and had access to three hours *matlab* weekly, where educators and the approximately 50 tutors would provide individual support. Four of the weekly assignments had to be passed in order to be examination eligible and the final examination was a four-hour written, open-book examination (Course Catalogue, 2016c). The educators used the same two textbooks for all four tracks and a common module page in the LMS; however, the tracks were organised individually. Educator 2, who previously taught one of the four tracks — and was used to using clickers during lectures — became sole educator for the entire module in 2014 and 2015.

## The Learning Design process

The transformation of C2 started in 2012 with a pilot replacing one week of lectures with screencasts and online activities initiated by the head of department. The goal was to make the teaching more cost-effective and modern, and in order to pilot this new design one week was replaced (see also Godsk, 2014b). The initial pilot was successful and the head of department together with one of the educators, Educator 2, decided to transform all lectures into learning paths in dialogue with the educational unit. The learning paths were to include videos, online MCQs, reflection exercises, and an e-instructor to provide online feedback on the quizzes and exercises for one of the four tracks (i.e., approximately one quarter of the students) in 2013. In parallel, the STREAM model was developed. It was inspired by the experiences with Calculus, which were then used to communicate the pedagogical rationale and evaluate the transformations.

As the second pilot was also successful the head of department and the educator decided to discontinue the traditional lectures in C2 and solely offer the online format from 2014 and onwards. Over time the incentives evolved and according to the educator interview and survey the incentives for transforming the module were, besides the flexibility in terms of where and how the students can follow the module, that the students develop skills for a future job, that the examination reflects the curriculum and skills the students are supposed to have learnt, and that feedback is provided to the students' learning process. However, the educator claimed in the interview not to recall any talk



about the STREAM model. Instead, he referred to the ideas of the model as something that were introduced by the educational unit (which in this case was also the researcher):

‘... actually, it is you who all along insisted that those reflection exercises where the students were asked to answer what they found easy and interesting and that sort of thing should be included’ (Educator 2).

Or as something he came-up with by himself:

‘I had used clickers and that was also one of the reasons that I, from the beginning, tried to find a way to preserve the good effect of clickers in lectures. And that is what we have done in the learning paths by separating the videos with questions related to what they [the students] had previously seen. So, this element in the learning paths simply came due to my previous experience with clickers’ (Educator 2).

Nevertheless, comparing the actualised LD with the STREAM model, a high degree of compliance was revealed and merely the ongoing adjustment of in-class and/or online activities (no. 5) as well as the thought-provoking aspect of the online activities (no. 9) were not fully met (see Appendix O).

## The Learning Design product

C2 was modified by replacing all the traditional face-to-face lectures with a total of 14 sequential learning paths of approximately 12 steps consisting of videos presenting the curriculum, MCQs for self-assessment, and reflection exercises where the students were asked to indicate what they found difficult and interesting (Figure 28). Each learning path was designed to correspond to the two-hour lecture it replaced, which meant that it should take approximately the same time to complete, include the same curriculum, and be divided into topics (see also Appendix L).

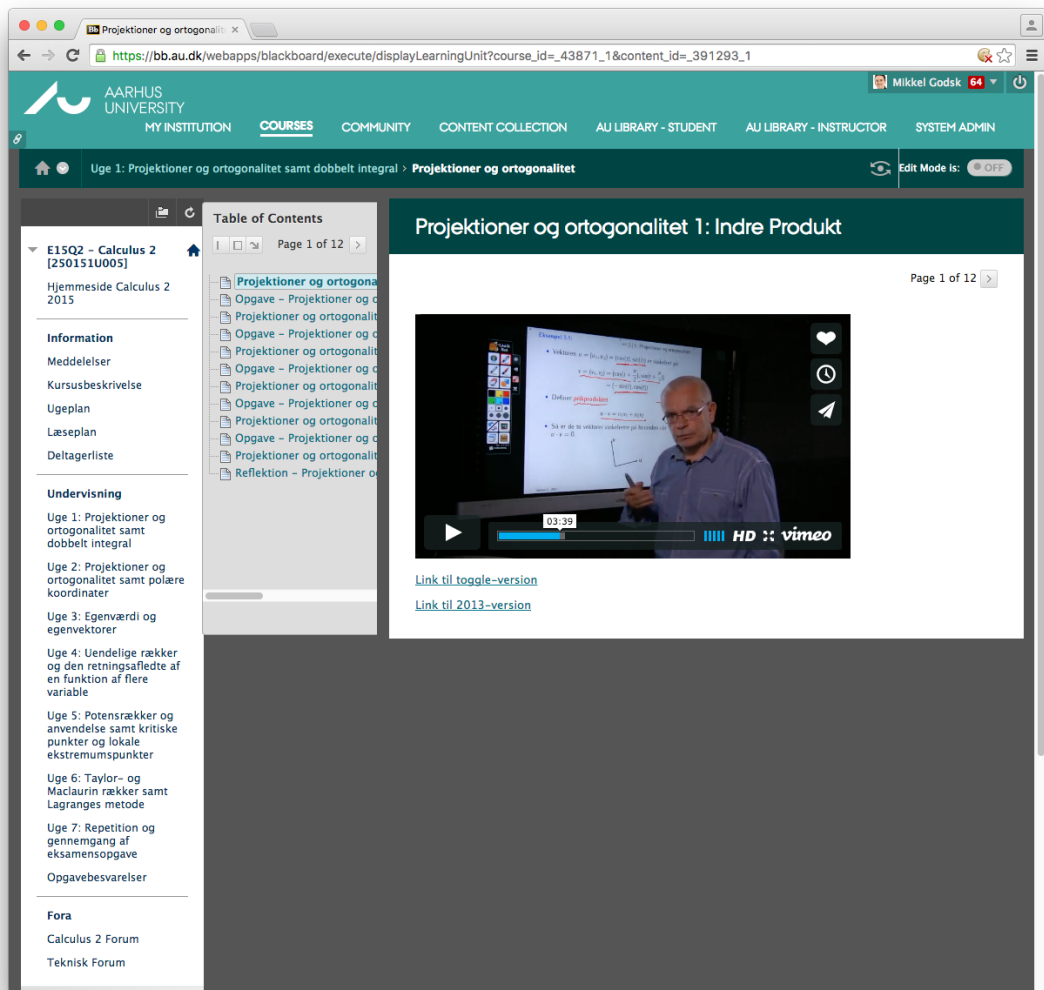


Figure 28. The first week of C2 in 2015.

The transformed C2 was first implemented in the previous institutional LMS, Dokes, but moved to the new LMS, Blackboard, in 2015, which meant that the overall structure of the learning paths was a little different though the content for the videos and activities were identical (see Figure 28 for the Blackboard version). The surrounding set-up, however, had changed as Educator 2 in 2015 decided to discontinue the e-instructor role and provide feedback on the online activities during in-class follow-up lectures. The forums for discussing curriculum and practical issues were no longer in use, and no announcements were sent by the educator via the LMS. The exact reason for this change is unknown but supposedly it had to do with the results of C2 (2014), which were shared with the educator on 18 May 2015 (see Appendix L), a combination of poor pass-rates in 2014 (more details later), the missing recollection of STREAM, and/or a passive e-instructor in Calculus 1 in 2015 as well as a desire to make a quick decision as the evaluation results were delayed three weeks, due to leave.

In addition, and uncoordinated with the educational developer, a new skills training tool, Sci2u (2017), was included on the module as a supplement to the existing assignments. The activities in Sci2u were set up by the developer of the tool, who at the same time used C2 as a showcase. Sci2u included its own learning paths, which were not integrated with the learning paths in the LMS. The exact reason for the introduction of Sci2u is presumably related to the parallel transformation of Calculus 1 in which Sci2u was successfully introduced as a compulsory component counting towards the final grade making 96% of the students participate regularly in these activities in 2015 (just prior to C2 in 2015). The evaluation of this module was shared with Educator 2 on 4 November 2015 per mail, that is, too late to redesign C2 in 2015 substantially. However, he may already have had a sense of these results and did rapidly respond per mail that 'the road ahead is (1) more Sci2u, (2) peer assessment, and (3) more time-consuming assignments' (Educator 2) on 5 November 2015.

### Case 3: General Chemistry

General Chemistry (GC) was a five ECTS, first-year, first quarter compulsory module for all chemistry, medical chemistry, molecular biology, molecular medicine, and nanoscience students. The overarching aim of the module was to provide 'knowledge of elementary chemical concepts as a basis for further studies in chemistry' (Course Catalogue, 2017b), which was further explicated in eight learning goals (see Appendix M).

Both prior to and after the transformation the module was taught by means of two hours of lecturing, four hours of theoretical exercises, and four hours of lab exercises over a period of seven weeks (Course Catalogue, 2017b). The lectures were given by the most senior of the educators, a professor of chemistry, who also served as module chair, whereas the theoretical exercises were taught by a cohort of 8–10 tutors and the lab exercises were facilitated by Educator 3 supported by laboratory technicians. The only difference between the transformed module in 2016 and the previous practice was the extra, optional online learning path with a video and 22 quizzes developed in the context of this project (see Figure 29) and that the homework club was discontinued that year. Besides this learning path, the LMS was only used for announcements, distributing materials, and diverse practical information. In order to pass the module, five assignments and six lab reports had to be passed during the module.

## The Learning Design process

The LD process was initiated and orchestrated by a colleague of the researcher, another educational developer, who was also engaged in the STREAM project. Through a dialogue with the module chair earlier 2016 about the aim of the transformation and common misconceptions of the curriculum, the educator responsible for the laboratory teaching (Educator 3) was involved in the process. The overall aim of the transformation was to support the students' learning on the topic of pH and equilibrium calculations, which, in the educator's experience, was often difficult for the students to understand. They would usually provide wrong answers in their assignments, despite a two-hour lecture on the topic and additional material developed over the years by the tutors. The educator had just been engaged in the module in 2016 but had previous knowledge about it.

The educator was introduced to the idea of students working online supplemented by feedback and in-class activities as outlined in STREAM. The model itself, however, was not shown to the educator or referred to, and neither did the educator recall in the interview being introduced to STREAM at any time during the transformation or earlier. The educator did, however, participate in the professional development programme in 2013, which at that time introduced LD but not STREAM. The educator was engaged in the development and implementation, and a tutor was engaged in the development of the online activities. The actual set-up in the LMS was carried out by ML.

Though the assistance of the educational developer was officially concluded with the 2016 run of the module, it appears in the interview that the educator aims to continue the development:

‘I think I will suggest that some of these things were expanded to also cover other parts of the curriculum’ (Educator 3).

## The Learning Design product

The result was a LD in which the module was taught as previously supplemented with an optional, online component of three interactive self-tests and a video introduction compiled into a learning path. That is, the module in its entirety was (slightly) augmented. The idea was that the component was an extra service to the students for training this particular topic on pH and equilibrium calculations by means of an introductory text, a video with a worked example (14 min.), and three self-tests (referred to as *opgavesæt*)

with a total of 22 problems actualised as three learning paths with MCQs, automatic feedback, and adaptive release of more advanced questions (Figure 29). This also meant that the learning path did not replace any existing activities and, thus, represents an optional addition to student workload. Instead, it was introduced as an extra learning resource on the topic by Educator 3 in a lecture. Nevertheless, according to the survey only 36% of the students ( $n = 115$ ) participated in the activities and several responded that they were not aware of the materials.

The screenshot shows a Blackboard course page for 'Test dig selv i pH- og ligevægtsberegninger'. The page is divided into several sections:

- Velkommen:** A welcome message stating that the page contains a 14-minute video on pH calculations and three multiple-choice assignments. It encourages students to use the 'solve' function and provides instructions on how to use it.
- Video om pH beregninger:** A video player showing a presentation slide titled 'Om pH beregninger' from the Science Media Lab. The slide contains the following text:
 

Opgave: pH i svag syre...

Et velkendt spørgsmål. Det første man (ALTID!) gør er at skrive reaktionen op.

$$HB(aq) \rightleftharpoons H^+(aq) + B^-(aq)$$

Vi opskriver alt vi ved - ligning (1)-(4):

  - $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$
  - $K_w = [H^+][OH^-] = 10^{-14}$
  - $K_a = \frac{[H^+][B^-]}{[HB]}$  Den kender vi
  - $C = [HB] + [B^-]$  Den kender vi
  - $[H^+] = [B^-] + [OH^-]$
- Opgavesæt 1:** Dette opgavesæt indeholder opgaver der omhandler basisviden om pH- og ligevægtsberegninger
- Opgavesæt 2:** Dette opgavesæt indeholder mellemsvære opgaver i pH- og ligevægtsberegninger.
- Opgavesæt 3:** Dette opgavesæt indeholder svære opgaver der omhandler pH- og ligevægtsberegninger, og er en god indikator for din eksamensparathed.

Figure 29. Screenshot of the learning path on pH and equilibrium calculations in GC.

## Case 4: Digital Electronics

Digital Electronics (DE) was actually two successive first year modules of 14 weeks (5 ECTS) each: *Introduction to Digital Electronics* and *Digital Electronics*, and should be seen in the context of the entire bachelor programme in electronics engineering offered in Herning (a mid-sized town located 87 km from Aarhus). The modules were an integrated part of the programme and compulsory for all its students, and their main topics were 'analysis of digital components and their ideal models compared to the analogue world' and an introduction to the 'Very high speed integrated circuit Hardware Description Language' (VHDL) for designing circuits (see Appendix N for the learning goals). The modules were provided in parallel as both augmented/flipped face-to-face teaching and as online/*redefined*, distance learning.

Prior to the transformation the modules were taught by means of two weekly lessons similar to theoretical exercises of two hours each. Each lesson would typically start-out with the educator asking the class whether there were any questions concerning the assignments in the previous session, an introduction to new curriculum followed by individual assignment work. Lab activities as well as student presentations were embedded in the lessons and together with the assignment work estimated to comprise 40% of the lesson time (Aarhus University, 2017e; 2017f). However, according to Educator 4 there was typically a "dead silence" when the educator asked about questions relating to the assignments.

### The Learning Design process

The module has been developed in connection with a large-scale effort to transform the entire engineering programme in Herning to flipped and online learning with the overarching aim of avoiding closure due to low intake (see also Godsk et al., 2017, for further details):

'We had an intake of seven in ... 2014. The year before it was around 12–14. And the year before that a few more.... We had to do something' (Educator 4).

Secondarily, the aim was to provide more dialogical teaching and record the lessons to support online learning materials. As a consequence, an introductory one-day kick-off workshop on flipped classroom was organised by the programme management (including Educator 4) followed by a 2.5 week moderated, exemplary online course (referred to as *Herning Online*, see also Appendix N) and an onsite workshop of six hours

provided by the researcher and CSE. The workshop and the course were held 6–24 March 2015 for the educators teaching the first semester as well as the teachers on the admission courses. That is, the educators on DE participated in an online, introductory course on online teaching and learning (and in particular on Flipped Classroom), including LD and the STREAM model. STREAM was here presented by means of an already published article (Godsk, 2013) and as part of a toolkit of LD models and supporting technologies for transforming the current teaching activities (see Figure N14, Appendix N). One of the outcomes of the course was the development of individual LD ideas and concepts for the different modules, and after the Herning Online course an optional review of the actualised LDs was offered, which no one accepted. Instead, the educators developed their modules individually with technical support by ML and a project manager. Later, additional educators who were involved in the transformed programme were provided with access to the Herning Online course page, but the module was not, however, moderated and no onsite workshop was held.

By the end of the first semester the module evaluations and student survey were carried out and the results were shared with Educator 4 and the project manager on 19 February 2016 together with a list of eight observations regarding student work, satisfaction, and preferences (see Appendix N), but no concrete recommendations were made. That is to say, it was up to Educator 4 to share and/or take action on the results. However, as the second semester started on 1 February 2016 it was too late to take major action on the results and, thus, the results had little influence.

In addition to the introduction of STREAM in the Herning Online course, the model had also served as both a way of explaining the process to prospective students and to others interested in the transformed programme as well as between the educators and programme management:

‘... we have had displayed [the STREAM model] a few times or more... and I do not think that anyone was in doubt about how it worked.... We have shown the model and discussed it... and we have concentrated on what is going on in the model’ (Educator 4).

That is, in the context of the development of DE the researcher did primarily play an indirect role in terms of providing training and the STREAM model to the educators and the programme management. It was then up to the educators to translate this into teaching practice.

## The Learning Design product

The process resulted in a flipped classroom approach guided by STREAM. The online teaching was organised in weeks of typically two learning paths consisting of a mixture of videos, recordings of the in-class sessions, other kinds of learning materials, and a self-test and/or reflection exercise. Figure 30 shows the design of Week 37 in 2015, which included a screencast explaining binary arithmetic operations as the first step in the learning path, an out-of-class MCQ and reflection form, an Adobe Connect recording of the in-class session including follow-up on the out-of-class MCQ, and a picture of the whiteboard from the in-class session (Figure 31).

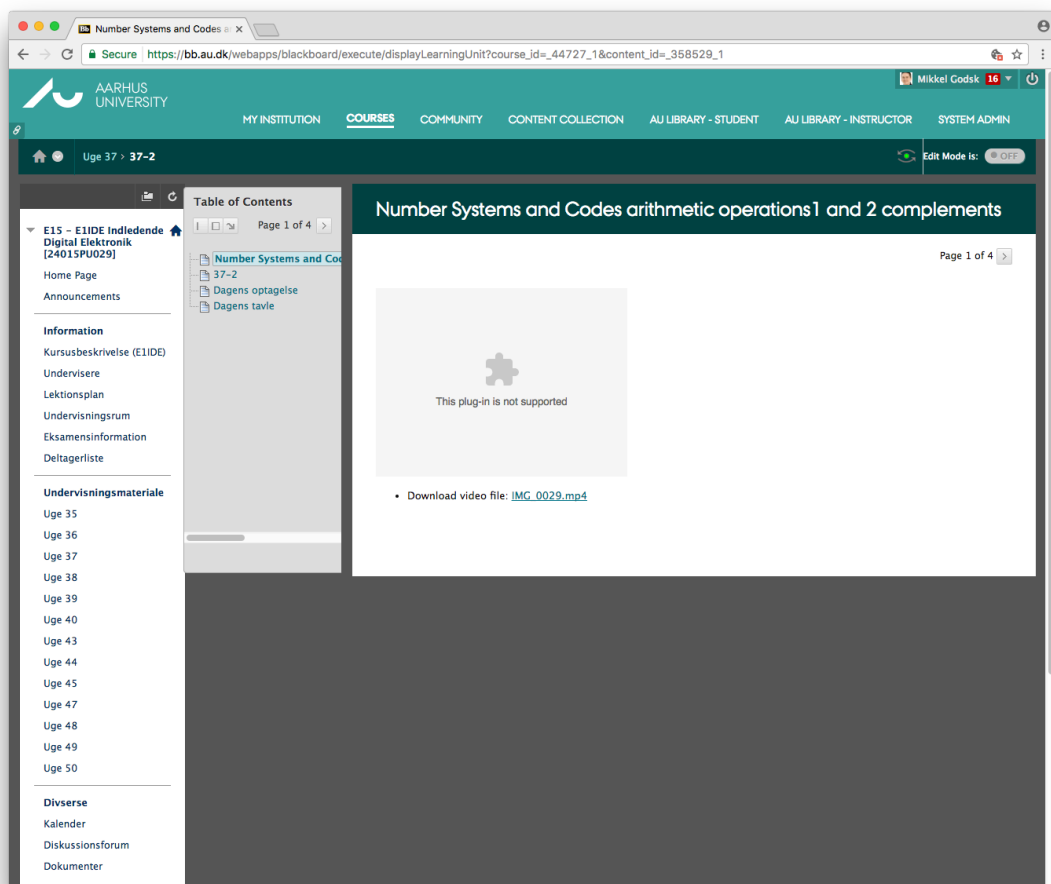
The screenshot shows a web browser window displaying a Blackboard course page. The browser's address bar shows the URL: https://bb.au.dk/webapps/blackboard/execute/displayLearningUnit?course\_id=44727\_1&content\_id=358529\_1. The page header includes the Aarhus University logo and navigation tabs: MY INSTITUTION, COURSES, COMMUNITY, CONTENT COLLECTION, AU LIBRARY - STUDENT, AU LIBRARY - INSTRUCTOR, and SYSTEM ADMIN. The course title is 'Number Systems and Codes arithmetic operations 1 and 2 complements'. On the left, a navigation menu lists 'Uge 35' through 'Uge 50', with 'Uge 37' highlighted. The main content area shows a video player placeholder with the text 'This plug-in is not supported' and a download link for 'IMG\_0029.mp4'. A 'Table of Contents' sidebar is visible, listing 'Number Systems and Codes', '37-2', 'Dagens optagelse', and 'Dagens tavle'.

Figure 30. Screenshot of Week 37 in DE in 2015.



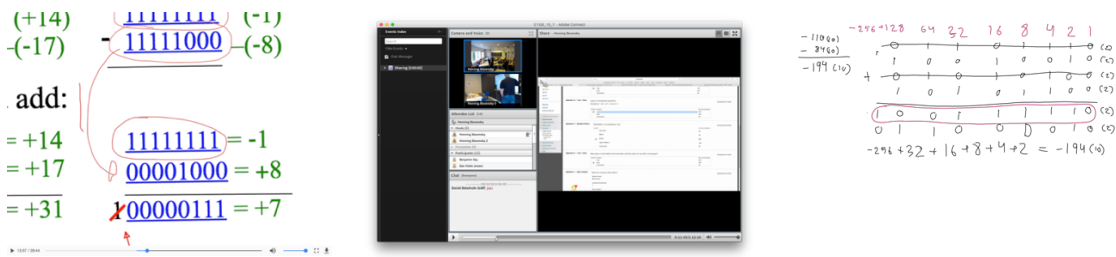


Figure 31. Different kinds of resources available in the learning path of Week 37 in DE in 2015.

Obviously, the contents and activities were different in 2016 due to a more advanced curriculum. However, though the teaching was carried out by the same educators and the overall structure of the modules was the same, they were designed differently. In 2015, the module was in compliance with at least six of the nine STREAM criteria, whereas compliance with only two criteria could be identified in 2016. For instance, the out-of-class activities were no longer designed to provide data to the educator about students' learning and neither were they structured as a cyclical process shifting between content and activity, nor included reflection exercises. That is, the educators were abandoning most of the STREAM model for unknown reasons, including its criteria related to feedback and online activity.

## Efforts and impacts of the four cases

As anticipated by the research matrix, the four LD cases entailed a series of institutional, educator, and student efforts and impacts. These three perspectives of the four cases are unfolded in the following sections and form the basis for the discussion of LD efficiency in Chapter 7.

### The institutional perspective

On the whole, the institutional perspective in the four cases may be summarised according to the first section of the research matrix as shown in Table 11.

Table 11  
*The institutional effort and impact aspects of the four cases*

Aspect	Indicators	Case 1: Astrophysics		Case 2: Calculus 2		Case 3: General Chemistry	Case 4: Digital Electronics	
		2014	2015	2014	2015	2016	2015	2016
<b>Institutional effort</b>	National budgets, political agendas, and directives (government/policy level)	Regular basic funding and completion bonus of, respectively, 1,155 EUR (2014), 1,162 EUR (2015), and 1,128 EUR (2016) per student						

	Funding for educational development and technology (strategic level)	Basic funding		Strategic grants of 6,000 EUR were received in 2013 for the development of the module in addition to the basic funding	Basic funding	Basic funding and strategic funds of 2,000 EUR provided, including 18 tutor hours (approx. 600 EUR)	Basic funding and strategic funds of 200 hours per module equivalent to 8,343 EUR		
	Strategies, policies, and aims on TEL (strategic level)	In compliance with the institutional policy for educational IT and the digitisation strategy							
	Pedagogical, media production, and technical development support for interventions (educational developer level)	Access to webcast facilities and 12 hours of ML support provided equivalent to approx. 403 EUR	N/A	N/A	33.25 hours of ML support provided equivalent to approx. 1,117 EUR	16 hours of ML support provided equivalent to approx. 538 EUR	Herning Online course provided	Herning Online reused	
	IT and study administrative support (administrative level)	N/A	Support to transition to digital examination	N/A	N/A	N/A	Local project management established and limited support from ML		
<b>Institutional impact</b>	Actualised affordances in accordance with strategies, policies, and aims for TEL	Educator upskilled in teaching blended and using STREAM and LD		Educator upskilled in teaching online		Educator introduced to the TEL affordance of pace flexibility	Closure avoided		
	Students influenced by TEL (LD)	126 (630 ECTS)	147 (735 ECTS)	821 (4,105 ECTS)	1,096 (5,480 ECTS)	115 (575 ECTS)*	39 (195 ECTS)**	24 (120 ECTS)**	
	Costs/income	3,465 EUR in extra funding due to pass-rate	6,768 EUR in extra funding due to pass-rate	Savings of approximately 21,400 EUR per repetition of the module, but also a loss of 81,543 EUR in 2014 due to low pass-rates***		N/A	Extra income of 42,992 EUR	Extra income of 34,968 EUR	
	Intakes	N/A	N/A	Module made scalable		N/A	Intake increased from 10 to 37		
	Pass-rates (retention)	80%	82%	74%	75%	98%	57%	62%	
	Other less official or unofficial institutional business and pedagogy aims	N/A		To completely discontinue traditional face-to-face lectures in C2		N/A	N/A		

\*Figure based on number of students participating in the first activity. This means that more may have used the video as 63% responded in the survey that had seen the video (equivalent to 199 students). \*\*Figures based on number of students enrolled on and has accessed the LMS course page. \*\*\*The student survey comments suggest that a difficult examination may explain the low pass-rate.

### *Institutional effort and impact*

In all four cases the transformation was in line with the aim of the university for rethinking teaching with technology expressed in the institutional policy for educational IT (Aarhus Universitet, 2011) and thus strategically supported by the existing initiatives and basic funding to educational development as well as technically and administratively supported by the administration in concordance with the uptake of the newly acquired LMS. Furthermore, the aims of the transformations were in some regards in line with the political agenda expressed in the profile model (The Danish Government, 2013; The Danish Ministry of Education, 2014a; 2014b), which aims to increase intake, cut costs, and/or increase quality (including completion rates).

C2 demonstrated this by reducing the teaching staff from four lecturers to one and also reducing the use of lecture facilities, while still enrolling a similar number of students, whereas DE managed to almost quadruple the intake in 2015 from 10 to 37 (see also Godsk et al., 2017). Based on the average salary of an associate professor (Dansk Magisterforening, 2014), the standard preparation factor and time for giving lectures (Staff Service, 2016), and the rate for renting the auditoria, the total cost savings can be estimated:

On salary:  $(4 \text{ hours of lectures} \times 3.5 \text{ preparation factor}) \times 7 \text{ weeks} \times 3 \text{ educators/tracks} \times (\text{average salary of } 49,747.59 \text{ DKK (incl. pension)} / 160.33 = 310.28 \text{ DKK per hour}) = 91,223 \text{ DKK} = 12,300 \text{ EUR}$

On facilities:  $4 \text{ hours of lectures} \times 7 \text{ weeks} \times 4 \text{ tracks/auditoria} \times \text{rent of } 1,000 \text{ DKK per hour} - (2 \text{ hours follow-up lectures} \times 7 \text{ weeks} \times 1 \text{ auditorium} \times \text{rent}) = 98,000 \text{ DKK} \approx 13,200 \text{ EUR}$

Estimated extra (double time consumption) effort according to the educator interview =  $30,407.68 \text{ DKK} \approx 4,100 \text{ EUR}$

Savings: 158,815.36 DKK  $\approx$  21,400 EUR per repetition of C2

All four modules were funded by the basic funding from the government as well as the so-called 'completion bonus' for undergraduate programmes at universities (UFM, 2015a; 2015b; 2016; 2017). The basic funding was awarded based on the number of passed ECTS and the completion bonus was triggered when a student completed her/his degree within a four-year time frame (i.e., not exceeding the estimated study time by more than one year). As approximately 50% of all admitted students graduated within

that time frame, the total funding per student per each of the four modules in 2015 was (Aarhus University, 2017d):

Basic funding per ECTS (2015):  $94,500 \text{ DKK}/60 = 1,575 \text{ DKK}$   
Completion bonus in average per ECTS (2015):  $(55,400 \text{ DKK} \times 50\%)/180 = 154 \text{ DKK}$   
In average per ECTS =  $1,729 \text{ DKK} \approx 232 \text{ EUR}$   
In average per 5 ECTS (module) = 1,162 EUR

Passed reexaminations were not included in this calculation, which means that the actual funding was slightly higher. Correspondingly, the funding per student was 1,155 EUR in 2014 and 1,128 EUR in 2016.

In the context of DE this meant that the increase in intake and avoided closure resulted in an income of 42,992 EUR (37 students x 1,162 EUR) in 2015 and 34,968 EUR in 2016 (31 students x 1,128 EUR) per module that otherwise would have been zero. As six modules were taught in parallel the income was 257,964 EUR (42,992 EUR x 6 modules) in 2015 and 209,808 EUR (34,968 EUR x 6 modules) in 2016 per semester per cohort across the programme. However, in practice the income was a little lower due to dropout.

With regards to the Danish Government's (2013) study progress reform, which aims at reducing degree-completion time, AP managed to increase its pass-rates and grade point averages (GPA) from 78% and 6.6 in 2013, to 80% and 7.1 in 2014 and 82% and 7.0 in 2015. The exact reason for this is unknown; however, the fact that the online activities started to count 25% towards the final grade and an increased online activity (see Figure 33) may have been contributory. In figures, this equals approximately three students in 2014 and six students in 2015, which is equivalent to, respectively, 15 ECTS or 3,465 EUR in funding in 2014 and 30 ECTS or 6,768 EUR in funding in 2015. However, for C2 the drop in pass-rate from 82% to 74% meant a loss of funding in 2014 of approximately 81,543 EUR. Nevertheless, the student survey comments suggested that the examination was significantly more difficult this year due to low alignment between the presented curriculum and problems during the semester and at the final examination.

In addition, strategic grants of respectively approximately 6,000 EUR and 2,000 EUR were provided by the senior management for supporting the development and online tutoring in C2 in 2013 and GC in 2016. However, no grants were given to C2 after 2014 or to any of the other transformed modules. Instead, they were financed by the basic funding for educational development in terms of the services provided by STLL and ML as well as the educators' teaching obligations and local ventures. For example, for DE,

an additional 200 hours were given to the transformation of each module, which translated to approximately 8,343 EUR per module given the average salary of an associate professor (Dansk Magisterforening, 2014). The basic funding also provided ML support for the video production and the development of learning paths as well as IT and study administrative support. For C2, in particular, the role of STLL/CSE and ML was significant and assistance was provided to set up the learning paths. A total of 33 hours was spent by ML on C2 in 2015 equivalent 880 EUR in variable costs (33 hours x 250 DKK). For AP, the educator developed most of the digital material by himself and made extensive use of the do-it-yourself webcast studio. According to the educator, he spent approximately 1.5 hours recording videos in the studio per week and one hour per day on developing and supporting online activities. DE was supported by facilities established locally in Herning organised by the project manager in collaboration with STLL and ML.

As identified in the perspective analysis a number of general impacts of technology in education were desired and in the context of any of the four modules direct or indirect evidence was found of various institutional impacts. Besides the cost-aspect this included upskilling of educators/professional development, rethinking/development assistance to educators, and support to the educators' teaching development and practice as described in the policy for educational IT (Aarhus Universitet, 2011) achieved through the pedagogical and media support provided by STLL and ML during the transformation process. Furthermore, the fact that the majority of students preferred the transformed format (except for in GC) to traditional teaching together with a positive attitude towards technology in education (see 'The student perspective' below) suggested an increased student satisfaction, which potentially can be seen as a contributing factor for improving the study environment. Other institutional aims identified in the perspective analysis (see Table 8, Chapter 5), such as providing effective tools for feedback; supporting collaboration, interaction, and communication; supporting student diversity and differentiation; supporting active learning and scientific teaching; appearing as a modern university; and motivating the students, were actualised to various extents for the different modules and directly or indirectly documented by the student surveys or the actualised LDs (see the following sections). However, at this point there was no evidence of an increased employability of the candidates, a support for more flexible interdisciplinary study programmes, or recruitment of the best students.

## The educator perspective

In total, the educator perspectives are summarised in Table 12 according to the second section of the research matrix.

Table 12

*The educator effort and impact aspects of the four cases*

Aspect	Indicators	Case 1: Astrophysics		Case 2: Calculus 2		Case 3: General Chemistry	Case 4: Digital Electronics	
		2014	2015	2014	2015	2016	2015	2016
<b>Educator effort</b>	Time spent on teaching and transforming the module	Approximately 50% more time due to special interest in continuously developing the module	Approximately 50% more time due to further development	Approximately double time for the educator (but half the time in total educator resources)		55 hours extra (1 week Educator 3 and 18 tutor hours)	More than 200 hours extra per module	200 hours extra per module
	Uptake of Learning Design model	See Table 10 and Appendix O for details about STREAM uptake						
	Attitude, experiences, and perception of TEL	Educator sees 'development is a goal in itself' and not afraid of experimenting with his module  Introduced to STREAM, medium-high confidence with technology, but limited prior experience with TEL		Very focused on not running what he sees as major risks but in general positive towards introducing technology where he can see a direct benefit  Low confidence with technology and no official pedagogical training and limited prior experience with educational technology. Has been introduced to STREAM		Completed the teacher training programme  Positive towards TEL		Positive towards TEL
<b>Impact on educator</b>	Flexibility in time, place, and pace	N/A	Flexibility in time and place — participated in meetings and conference abroad during the term	Flexibility in terms of time and place and thus more consecutive time for research		Eased pressure on lectures	N/A	N/A
	Satisfaction and perception of the intervention, TEL, and LD in general	'It is fun being the educator on such a module'		'It has been really fun to me...I can feel that I've personally developed through this'		'I think it is a good idea, and that is not difficult — it is easy'		Both frustrated and 'proud of what they have made'
	Other affordances and interests	N/A	N/A	N/A	N/A	N/A		Avoided closure of the programme

### *Educator effort*

In all four modules, the educators reported to have spent more time on developing and teaching their modules than before the transformation, but the total educator hours on C2 was reduced. Educator 1 reported to have spent approximately 50% more time, but in 2015 this was mainly due to a new dissemination assignment he had introduced, which

required a lot more time for feedback than anticipated. In addition, the time consumption was also related to his double role as also being an educational developer in the department:

'I've used more time than a regular educator would because I use it for exemplary use of Blackboard, which is a goal in itself in this module' (Educator 1).

According to the educator, his time consumption had been more or less constant during the years he had transformed the module due to his interest in continuously developing the module but could be minimised:

'if I merely had transformed it once and run the module the same way year after year, I could have done it quite cheap' (Educator 1).

In DE, the programme manager estimated in the interview that during the first transformation of the programme more hours were spent than the 200 additional hours given to each module, which mainly had to do with the development of materials and a desire to develop high-quality videos among the educators before they later realised that:

'actually, it [the quality] does not have to have to be perfect... If you are recording a video and the son or the dog turns up. Well, you will just put the recording on pause, right?' (Educator 4).

According to him, the extra hours now (i.e., in 2016) cover the extra educator effort due to reuse of materials, among others.

In GC, Educator 3 estimated his time consumption on the module to be twice as much as planned. However, this was mainly due to his already minor role as coordinating educator and that all was prepared in advance:

'Because I got [a tutor] involved in the development of the activities ... I have spent approximately one week on the development' (Educator 3).

The tutor reported to have spent 18 hours (equivalent to approximately 600 EUR), which meant that the total educator effort was around 55 hours or 1.5 weeks of work.

In C2, however, the module was restructured in 2013 in parallel with the transformation so that instead of having four parallel tracks with individual educators giving lectures, the current educator became the only educator giving lectures and managing the module.

'If we compare to when I merely had the role as lecturer on one-fourth ... my effort has increased... Now I only have to prepare my single, weekly follow-up lecture. So, the preparation time for the lecture is significantly reduced; however, as I am the sole responsible for the module there has been a damn lot of other work of various kinds associated with Sci2u, video recording, and tutor meetings and such like' (Educator 2).

In the interview, the educator estimated the total effort to be reduced by half:

'I probably use twice as much time now... but bear in mind... that I previously merely covered less than a quarter of the work effort' (Educator 2).

However, he also found it 'more difficult because [he had] less contact with the people [he taught]' and crucial to have access to support:

'I hadn't had a chance doing this without Media Lab.... the service provided has been comprehensive and qualified and an absolute prerequisite in order to make this happen ... I simply couldn't do this by myself' (Educator 2).

Similarly, DE had their difficulties and on a scale from 0–5 with 5 as highly difficult, Educator 4 considered the role as online educator:

'In the beginning, it was absolutely a fiver, but now I think it is decreasing. I am not sure that we are at three yet, but they are getting there.... Because there are still things that act up. Technical things'.

In contrary, both Educator 1 and Educator 3 found it easy teaching with technology:

'It has been easy... That you can delegate parts of the understanding to not only occur during a lecture but that you can refer [to the online material]. They can review a video with almost the same lecture, they can train the different parts by means of the exercises. What this does is good, I think it is a good idea, and that is not difficult — it is easy' (Educator 3).



### *Impact on the educators*

In general, all the educators found transforming and teaching their transformed modules enjoyable:

'It is a pleasure... That is, I like teaching and this is also why I find it highly valuable to be together with the students etcetera. That is great. But ... But it is fun being the educator on such a module, definitely' (Educator 1).

'It has been really fun to me. And I think it has worked well. I can feel that I've personally developed through this. I've learnt some things on the personal level, which I highly appreciate' (Educator 2).

However, according to Educator 4 some educators across the engineering programme were frustrated due to the extra workload, but at the same time proud of their work:

'... when for instance Rambøll [consultancy hired by the government] contacts us and are interested in the work they have done, they [the educators] are proud of what they have made' (Educator 4).

Three of the educators took advantage directly of the flexibility of the transformed teaching has entailed. Educator 1 carried out his teaching asynchronously while attending meetings and a conference abroad, Educator 2 recorded most of his videos during semester breaks to free consecutive time for research (see Godsk, 2014a), and Educator 3 referred to the materials as easing the pressure on lectures.

However, further scrutinising the incentives for the transformations revealed diverse educator attitudes and motivations. In the context of the educator interview on C2, the educator responded:

'You see, the purpose was to, er... (pause for thought). Basically, you will have to ask [the head of Department] about it, because it was him who initiated it and talked about being more efficient' (Educator 2).

Nevertheless, at the same time Educator 2 responded:

'It was important to me to develop a teaching format that was as good as possible and as sustainable as possible and had some potential for the future...'

And to the same question regarding DE, Educator 4 responded:

'The overarching purpose was not to close Herning [sic]'.

That is to say, these two cases had a clear business aim which shaped the educator attitudes and provided an extrinsic motivation. The cases of AP and GC, however, had a more pedagogic aim and intrinsic motivation among the educators. In particular, Educator 1 revealed a highly intrinsic motivation:

'To modernise the teaching a bit, because I think it is also a purpose in itself — that you, sort of, updates yourself' (Educator 1).

Educator 3 provided a more extrinsic pedagogic aim, which, at the same time, revealed his intrinsic motivation in doing well as an educator:

'...many, many students provide wrong answers at their examination and have had many difficulties grasping it... So, this was an attempt to help them because they should become as good to this as the other parts of the curriculum' (Educator 3).

With regards to the educators' expectations of the role of TEL in the transformation, seen aggregated, in particular, the alignment, skills training, pace flexibility, and feedback was highlighted as important (Figure 32).

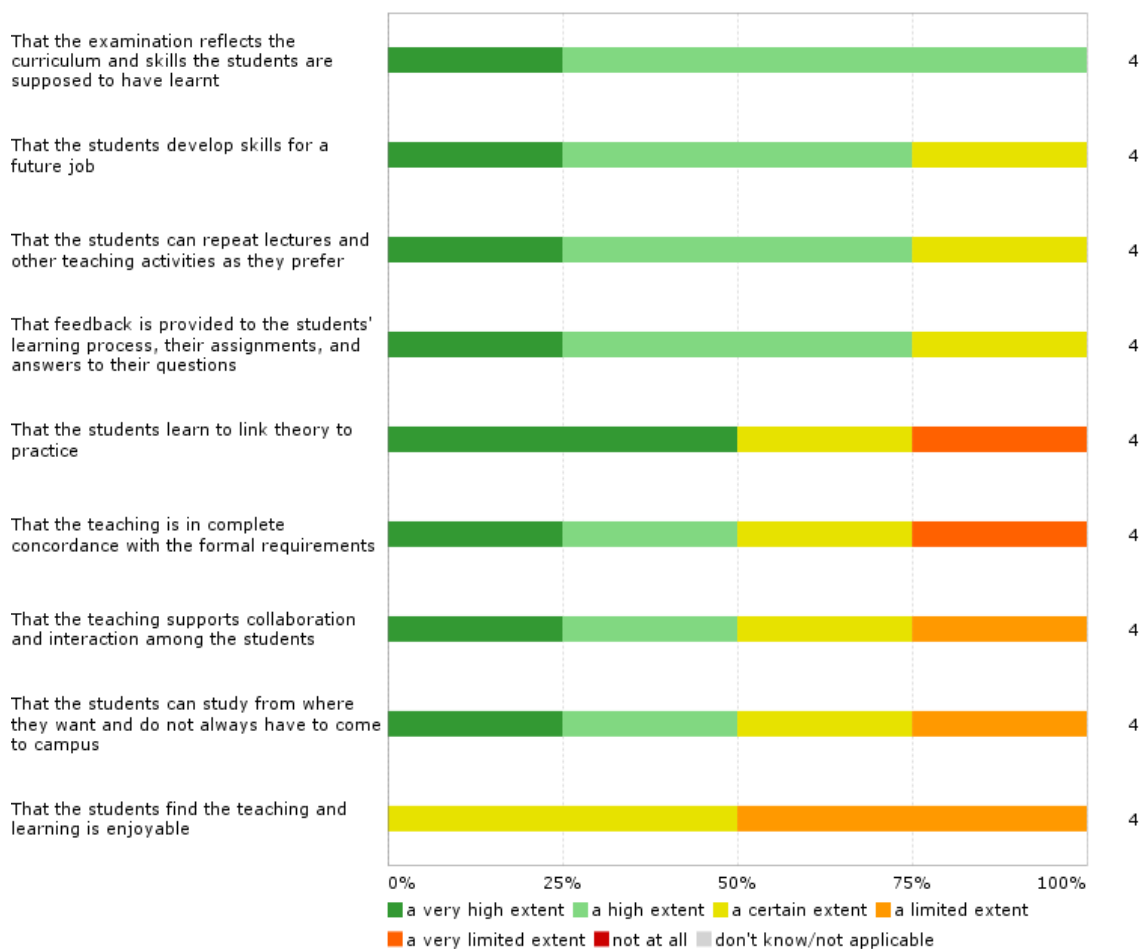


Figure 32. The four educators' prioritisation of TEL affordances according to their importance for the transformation.

However, looking at the prioritisation individually, the responses differed. Educator 1 was concerned with feedback and collaboration; Educator 2 focused on skills training, examination, and place flexibility; Educator 3 was interested in how to link theory to practice; and Educator 4 was concerned with formal requirements and flexibility in general.

### The student perspective

In total, the student perspective is summarised in Table 13 according to the third section of the research matrix.

Table 13  
The student effort and impact aspects of the four cases

Aspect	Indicators	Case 1: Astrophysics		Case 2: Calculus 2		Case 3: General Chemistry	Case 4: Digital Electronics	
		2014	2015	2014	2015	2016	2015	2016
Student effort	Time spent on the module:	9.8 / N/A	11.1	N/A	8.0	13.7	8.1 (12.2**/7.5***)	5.8 (8.8**/5.3***)

	hours per week on average and total online activity on Blackboard	2.5*****	26.8	N/A	16.0	12.0	13.7	38.6
	Attitude towards technology in education (% positive)	****	89%	91%	88%	94%	90%	100%
<b>Impact on students</b>	Time flexibility: participated outside regular lecturing hours	64%	54%	64%	67%	80%	80%	87%
	Place flexibility: participated outside university	55%	53%	73%	79%	82%	100%	100%
	Pace flexibility: participated faster (or slower) than regular lecturing pace*****	59%	66%	43%	71%	66%	80%	100%
	Learning outcome satisfaction	85%	84%	61%	59%	91%	69%	90%
	Preferences: for/against TEL	66%/24%	65%/21%	50%/31%	39%/36%	20%/57%*	50%/30%	50%/25%
	More higher-order thinking activities: use for deep learning	****	89%	74%	65%	68%	80%	87%
	Primary learning approach	****	Deep	Strategic	Surface	Surface	Deep	Surface
	Grades (GPA)	7.1	7.0	5.7	6.4	N/A	N/A	7.6
	Pass-rates	80%	82%	74%	75%	98%	57%	62%
	Perceived learning outcome (learning goals accomplishm.)	****	91%	N/A	79%	96%	76%	73%
	Perceived utility of the online materials for:							
	going over the curriculum	87%	89%	79%	71%	84%	90%	100%
	problem solving	77%	87%	69%	71%	89%	90%	88%
	providing perspective	78%	82%	33%	78%	75%	60%	75%
	repetition	73%	77%	56%	61%	81%	90%	88%
exam preparation	67%	64%	54%	58%	44%	80%	100%	
later use	28%	34%	21%	28%	52%	50%	88%	
Other affordances cf. the incentives for the intervention	Collaboration supported by TEL		N/A	N/A	75–82% felt supported by the materials	N/A	N/A	

\*This includes students who had not participated in and/or were aware of the online activities. \*\*Blended students. \*\*\*Online students. NB: The percentages reported are the aggregated percentages of values related to the indicators responding *to a certain extent* or more. \*\*\*\*Data not available to insufficient adaption of the generic survey (see Data Collection). \*\*\*\*\*Suspected outlier. \*\*\*\*\*Regular lecturing pace is equivalent to either a day or a week depending on the module and its LD (see Appendix K–N for more details).

### Student effort

The survey revealed that on average the students estimated to have spent 9.5 hours per week on the transformed modules, ranging from 5.8 hours per week in DE in 2016 to 13.7 hours per week in GC (Table 14).

Table 14  
Students' estimated average weekly time consumption

	Average	Median	SD
<b>Astrophysics (2014)</b>	9.8	10.0	4.6
<b>Astrophysics (2015)</b>	11.1	11.0	4.2
<b>Calculus 2 (2014)*</b>	-	-	-
<b>Calculus 2 (2015)</b>	8.0	8.0	3.9
<b>General Chemistry (2016)</b>	13.7	14.0	5.0
<b>Digital Electronics (2015)**</b>	8.1	8.0	3.2
<b>Digital Electronics (2016)**</b>	5.8	6.0	3.2
<b>All responses</b>	9.5	9.0	4.7

\*Data not available for C2 (2014). \*\*These are in fact two consecutive modules.

Likewise, the overall online time in the LMS differed between modules, ranging from approximately 12 hours on average per active student in GC to 39 hours on DE (2016) (according to its Grade Center, see Figure 33).

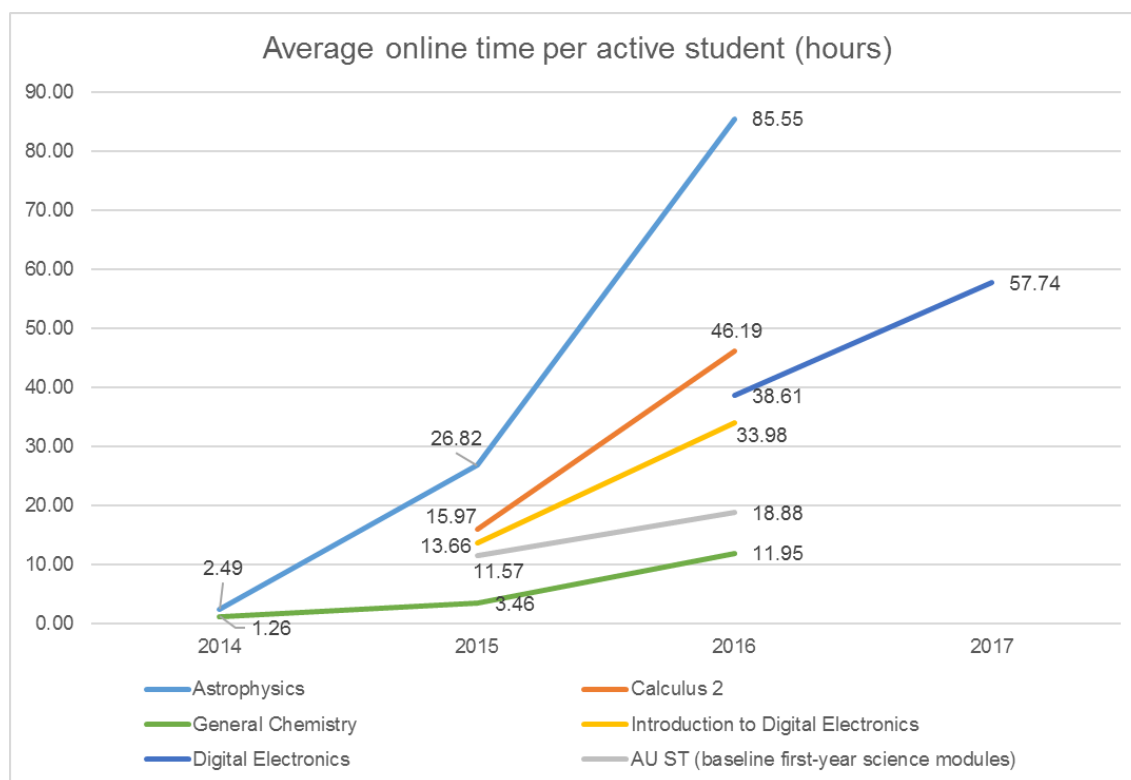
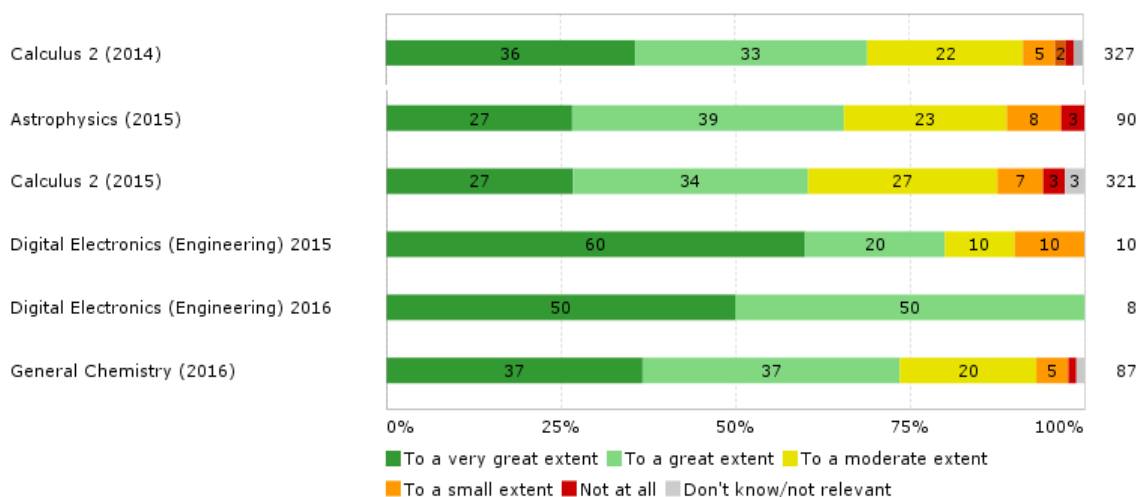


Figure 33. Total online time on the modules incl. historical data. NB: The data from AP (2014) is suspected to be an outlier and thus should be subject to reservations.

In spite of the lack of some historical data due to a shift in LMS, Table 14 and Figure 33 do show a shift in effort. There was not a significant change in the amount of time the students spent on a transformed module in total between the first and the second run, but there was a significant increase in the time spent online compared to modules in general (baseline). This may suggest a shift in teaching practice and uptake of LD, such as the educator had intensified the amount of online activities and/or their usage and introduction, and/or a shift in student approaches to online learning — or a combination.

To put students' activity in further perspective 88%–100% of the students across the transformed modules responded that they to a moderate, a great, or a very great extent were 'positive towards initiatives that involve the use of new technology in education' (compared to 91% across all first-year science students in 2015, see Chapter 5) (Figure 34). That is, the students were in general not required to spend more time on the transformed modules than any other module (except for DE in 2015), which in this context would be estimated to approximately 14 hours weekly per 7-week module and 7 hours weekly per 14-week module of 5 ECTS (UFM, 2015c), and technology was not seen as a burden.



*Figure 34.* The students' attitude towards the introduction of new technology in education. NB: Data from AP (2014) was not available — see Data Collection of further details.

In addition, 87%–100% of the students across the four modules responded that they to a moderate, great, or very great extent were willing to put more effort into studying if they felt they were learning a lot. This suggests an unresolved potential of improving learning even more by means of TEL (and LD) as the students were not seeing technology as a barrier or burden, they were interested in spending more time learning, and more time

was available for studying as the general time consumption was lower than expected. Nevertheless, the continuous, embedded assessment based on online activities introduced in AP in 2014 and continued in 2015 did cause some distress and made some students give low priority over other concurrent modules.

'It adds extra pressure when you know that online activities count towards the final grade, and that time is moved from the other modules' (Anonymous student in AP 2015).

'I think it has been very stressful with the online activities as we didn't have much time working with the course material before the activities were due and no one would help as they were counting towards the grade' (Anonymous student in AP 2015).

However, on average the students responded that the activities should count 23.2% (median 25%) of the grade and thus in concordance with the actual assessment practice. Merely 14% responded in 2015 that none of the activities should count towards the examination. That is, despite the distress there was a high level of backing for the transformed practice among the students but, at the same time, this practice did challenge the student effort on parallel modules.

### *Impact on students*

The surveys also revealed that a high degree of flexibility in both time, pace, and place was actualised with the online activities compared to the traditional teaching format across all modules. With regards to time flexibility 54%–87% responded that they most frequently participated in the online activities outside regular lecturing hours, that is, evenings, during the weekend and other days off, and at night (Figure 35).

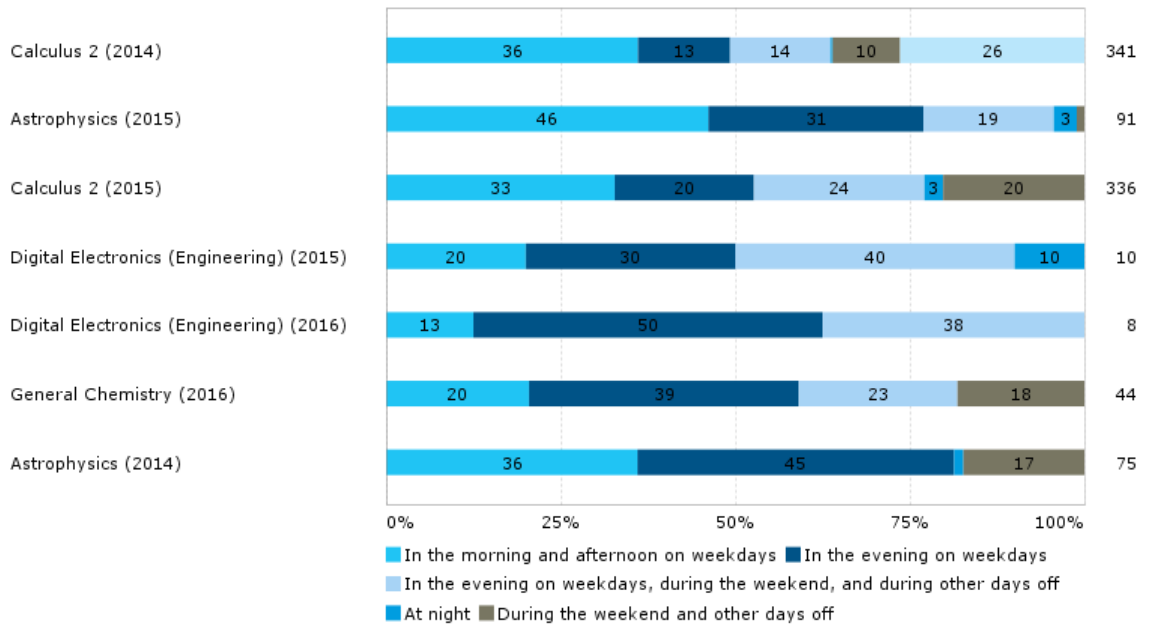


Figure 35. Most frequent time a week for participating in the online activities.

With regards to pace flexibility, 43%–100% responded that they participated in a different speed than the materials were estimated for by, for instance, completing all activities for an entire week in one day. This was in particular distinct in modules with a high level of transformation, such as C2 and DE (see Appendix K–N for details). Also, the actualised place flexibility appeared to be related to the level of transformation, ranging from approximately half the students in AP, who most frequently participated while at the university to, respectively, 73%–79% of the students in C2 and 100% of the students in DE participating from home or elsewhere outside the university (Figure 36). Most students would participate in the activities alone, except for in AP where 52%–53% participated in the activities together with peers, as they were encouraged to by the educator (Figure 37).



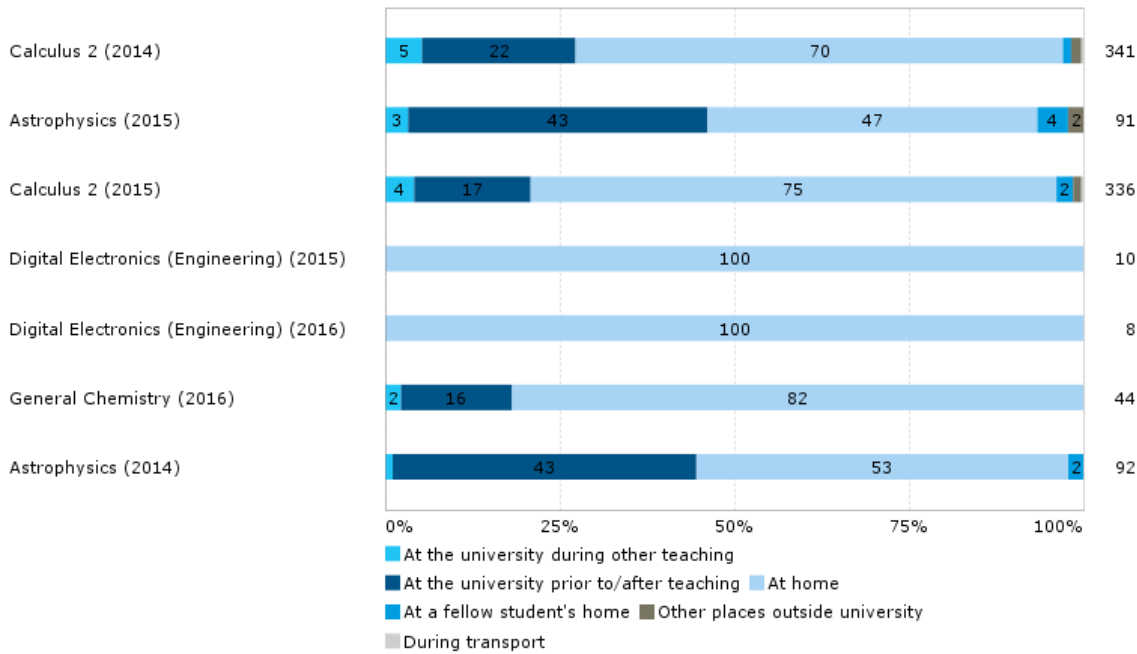


Figure 36. Most frequent location of participation in the online activities.

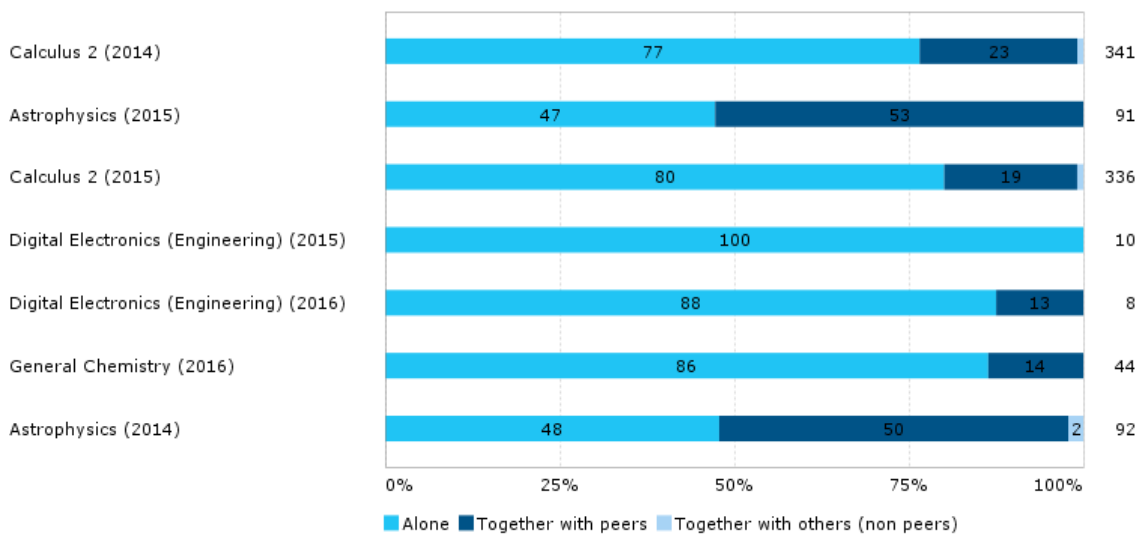


Figure 37. With whom the students most frequently participate in the online activities.

Though the level of flexibility differed between the modules, the results show that students will — almost automatically — make use of the provided flexibility in terms of time, place, and pace. Thus, the institution and the educators can be relatively certain that they will actualise more flexible learning by providing online activities. This suggests that there is an unresolved impact potential for providing much more flexible learning, that is, a high student impact even with a minor level of transformation and a low effort, if promoted to the students together with techniques for making good use of online materials and their flexibility. The results also show that online activities can be designed and/or introduced so that the students participate with peers and others, as for example in AP. Compared to the specific aim of Educator 1 to support collaboration among the

students and increase feedback, the design had encouraged 53% of the students to frequently work together on the activities in 2015 (Figure 37). That is to say, there is a yet unresolved impact potential as 88% of the educators already found collaboration and interaction important for their teaching (see Figure 20, Chapter 5).

The survey also revealed that the students across all four modules were medium to highly satisfied with the learning outcomes, ranging from 59% in C2 (2015) to 85% in AP (2015) (Figure 38). Compared to the specific learning goals, the majority of the students in all four modules perceived the goals to be accomplished. In particular in AP and GC, where on average, respectively, 91% and 96% of the students perceived the learning goals to a moderate, great, or very great extent were accomplished. In C2 and DE, the perceived accomplishment was 79% and 73%–76%, respectively (see Appendix K–N for further details). That is, the students in the modules with a higher level of transformation experienced a lower learning goal accomplishment and learning outcome satisfaction. This impact limits the LD efficiency suggesting that, in contrast to for instance flexibility, student satisfaction and perceived learning goal accomplishment do not occur automatically for high level transformations. In addition, more students felt the learning goals were accomplished than they were satisfied with the learning outcome. This suggests a problem related to students' perceived relevance of and interest in the module. Problems, which may be addressed by means of one or more of the teaching and learning affordances of TEL practice making the module more student-centred (Price & Kirkwood, 2011).

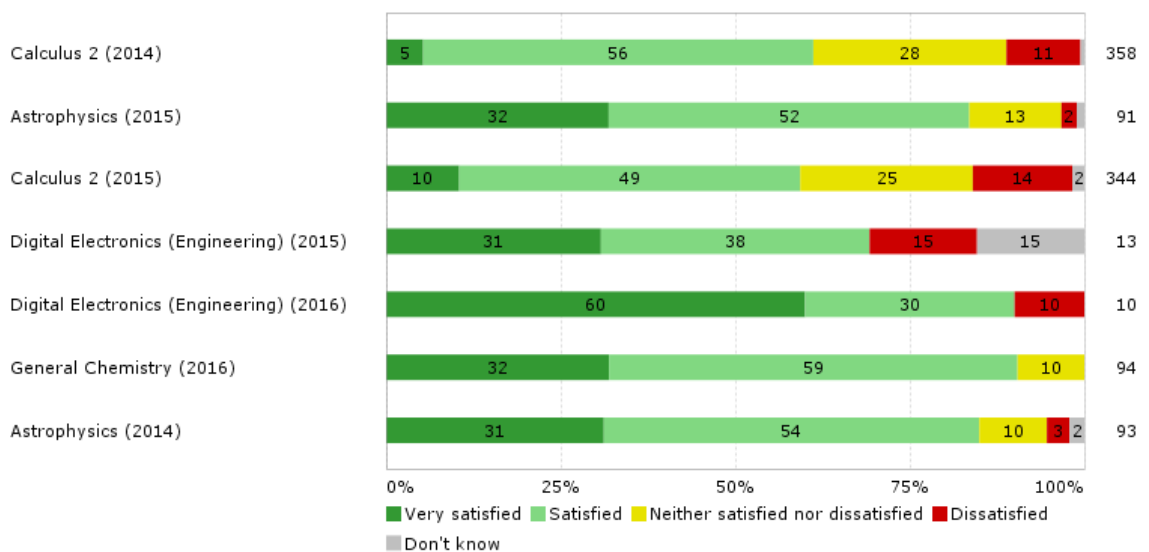


Figure 38. Overall satisfaction with the learning outcome.

Compared to the regular teaching format without online activities, there was a general preference among the students towards the transformed format, except for in GC which may be explained by highly popular face-to-face lectures and/or limited knowledge of the online format (Figure 39). However, there was also significant variations between modules, which, obviously, were linked to the actualised design and teaching practice. More surprisingly, the preference for the online format was fading over time in AP, C2, and DE (i.e., all the modules analysed over time). It is difficult to pinpoint the exact reason for this as students' preferences may also relate to their previous experiences and/or perceptions of traditional teaching and online learning. However, by all appearances this may be linked to a decrease in online activity and a broken feedback loop. In AP and C2 (2015) the e-instructor role was downscaled and limited feedback was provided on the online activities, and in DE (2016) the online *warm-up* activities were discontinued.

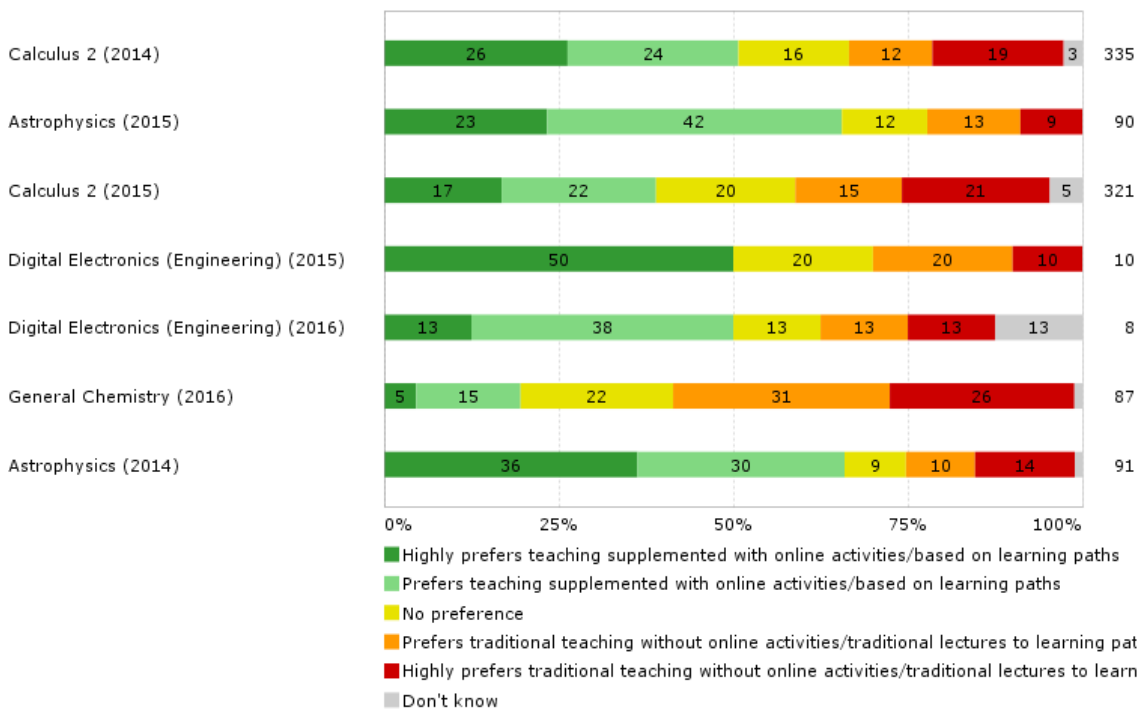


Figure 39. Preference for online teaching as in the respective modules versus a traditional teaching format without online activities or learning paths.

In general, the perceived utility of the online materials was high for most of the provided options and in particular for going over the curriculum, problem solving, and repetition during the semester, whereas most students did not see a later use of the materials, except for in GC and DE (Figure 40–45). However, there were significant differences in the total perceived utility of the modules and in terms of the perceived utility for the different purposes. Some were anticipated due to the aim of the transformation and the materials, for example, that the students on a high level of transformation module such

as DE would consider the materials useful for most of the purposes, that the students using the self-tests in GC would consider these useful for repetition more than most other modules, and that the students found the online materials useful for providing perspective as many optional materials were provided for this purpose. Others were less anticipated, such as that the students in AP found their online materials significantly more useful for repetition, problem solving, and exam preparation than, for instance, the students in C2. In particular, considering the function of the materials in C2 of replacing all lectures and that AP did not have an explicit goal to support these three purposes. Furthermore, the materials in AP were considered more useful for *going over* the curriculum compared to C2 though the materials did not cover the entire curriculum. In total, this showed that having more comprehensive materials did not necessarily yield a higher perceived utility, vice versa, that it was possible to develop a module by means of LD actualising a high level of perceived utility for purposes not initially intended. This brings attention to other aspects of the LD and their potential role, such as the pedagogical integration of the materials, the level of transformation, and the general student satisfaction. It also showed that using LD has the potential to introduce TEL with a high, perceived and/or spin-off utility depending on the LD.

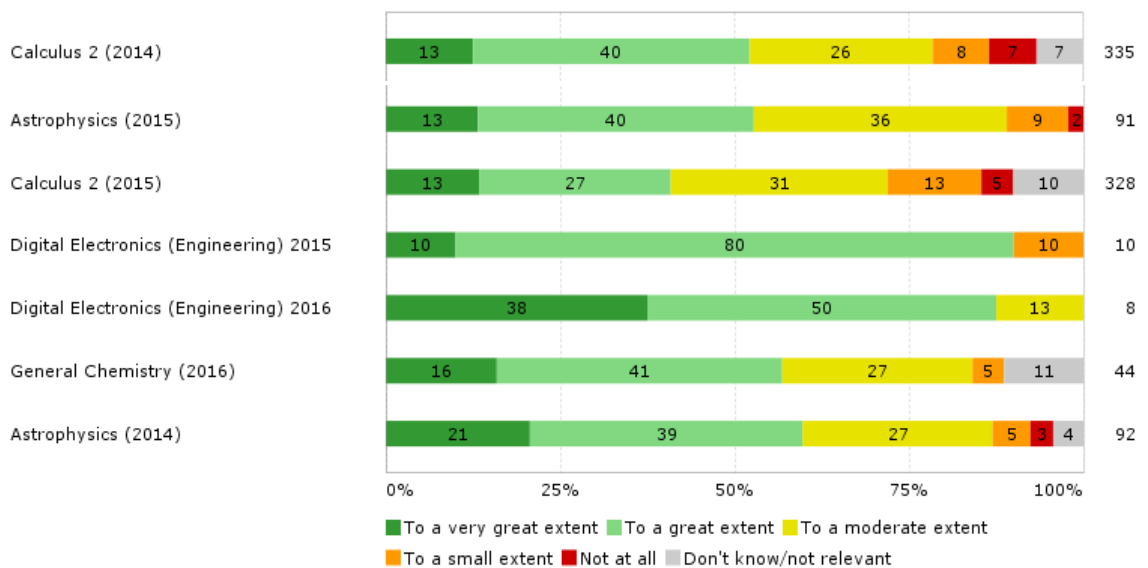


Figure 40. Perceived utility of the online materials for going over the curriculum.

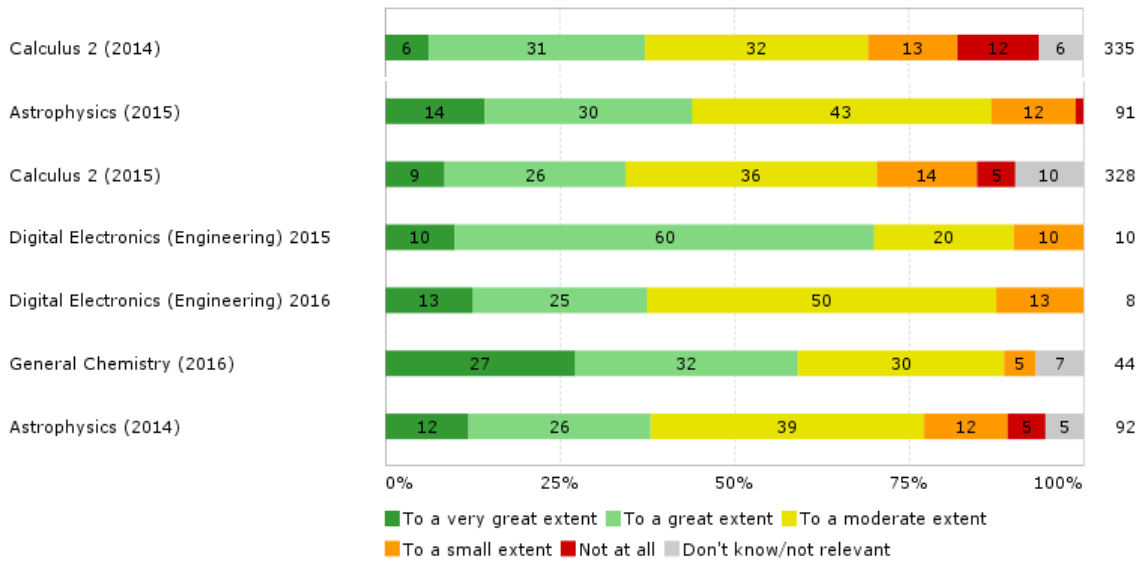


Figure 41. Perceived utility of the online materials for problem solving.

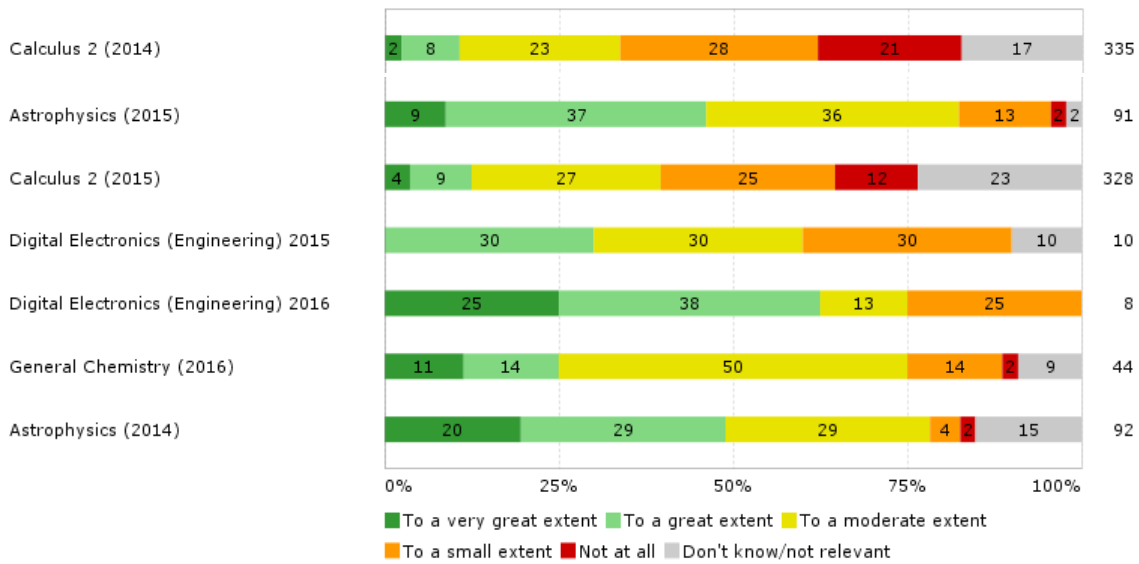


Figure 42. Perceived utility of the online materials for providing perspective.

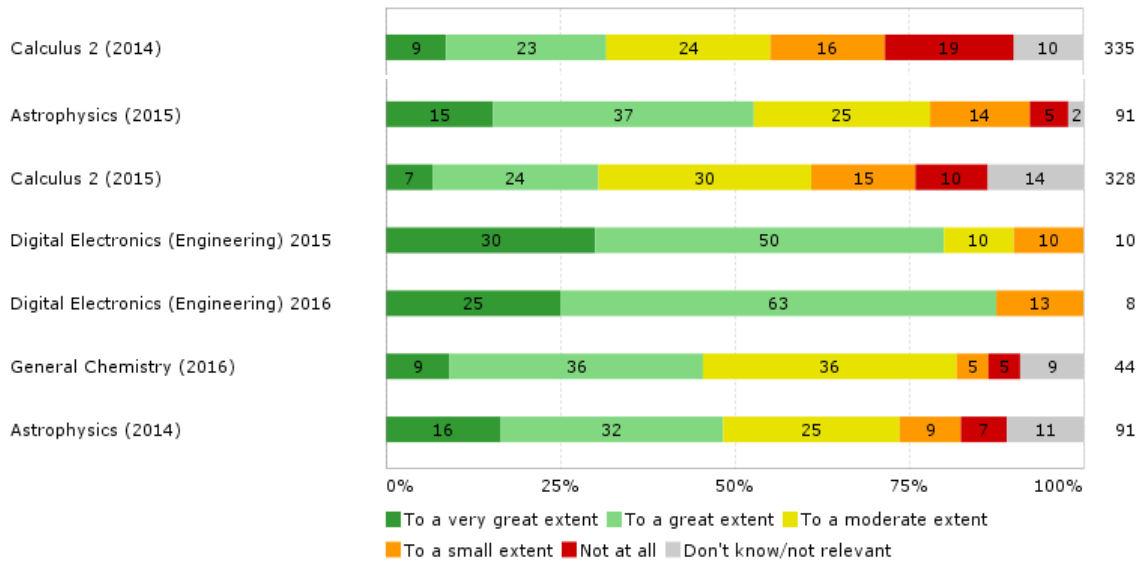


Figure 43. Perceived utility of the online materials for repetition during the semester.

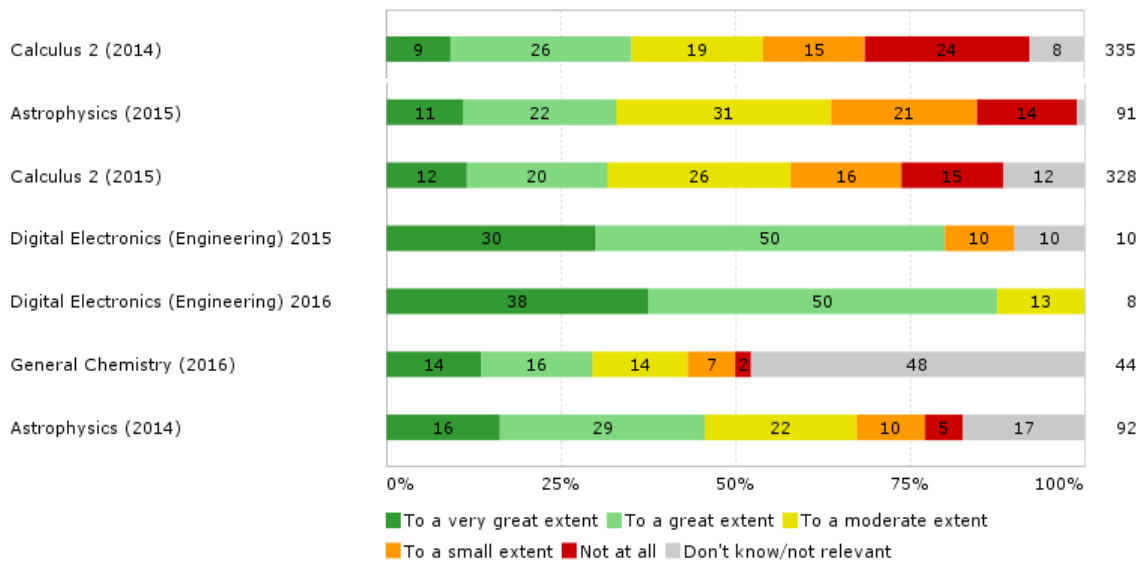


Figure 44. Perceived utility of the online materials for exam preparation.

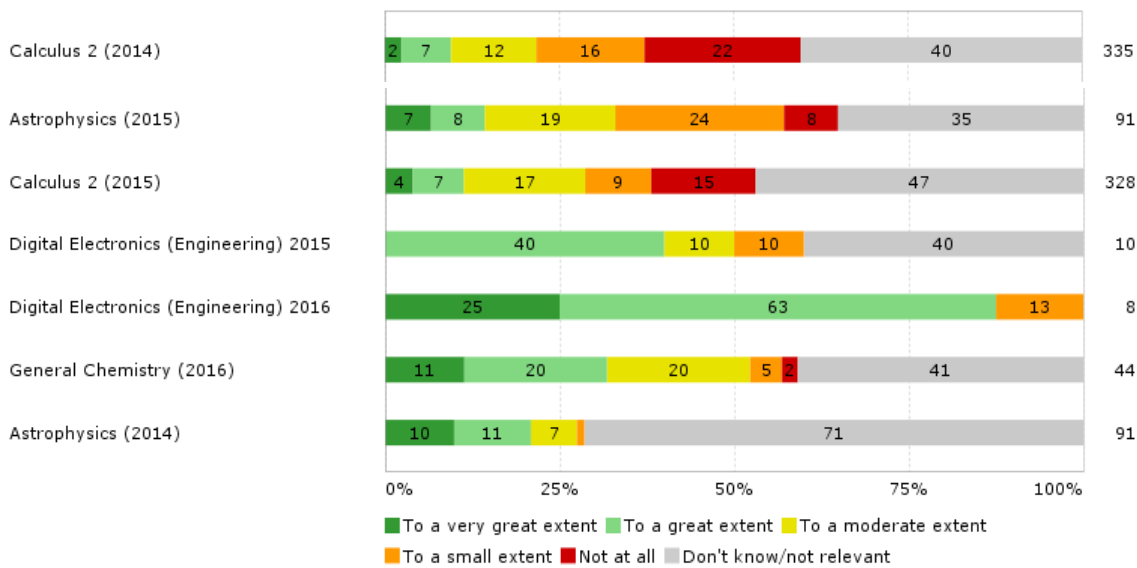


Figure 45. Perceived utility of the online materials for later use.

However, there may also be misconceptions of what TEL in general entails, which potentially contributes negatively to the satisfaction. For instance, as the following student in C2 (2014) implies that face-to-face lectures are more engaging and dialogical than online learning:

'There are no possibilities for asking questions. At the same time it is much more difficult to focus on a screen compared to a real human being spending time giving lectures'.

This also suggests that the role of the materials was — intentionally and unintentionally — different in the modules, which was also reflected in the use of the materials for different learning approaches. In particular with regards to deep learning a large difference was revealed. 100% of the students in DE (2016) and 89% in AP (2015) used the online materials for understanding the topics in-depth, while merely 65% of the C2 (2015) students used the online materials for this purpose (Figure 46). In addition, a development over time was observed in both C2 and DE. From being primarily used for, respectively, strategic and deep learning purposes in C2 in 2014 and DE in 2015, the materials were primarily used for surface learning purposes in 2015 and 2016. That is, a potentially less desirable development and negative impact.

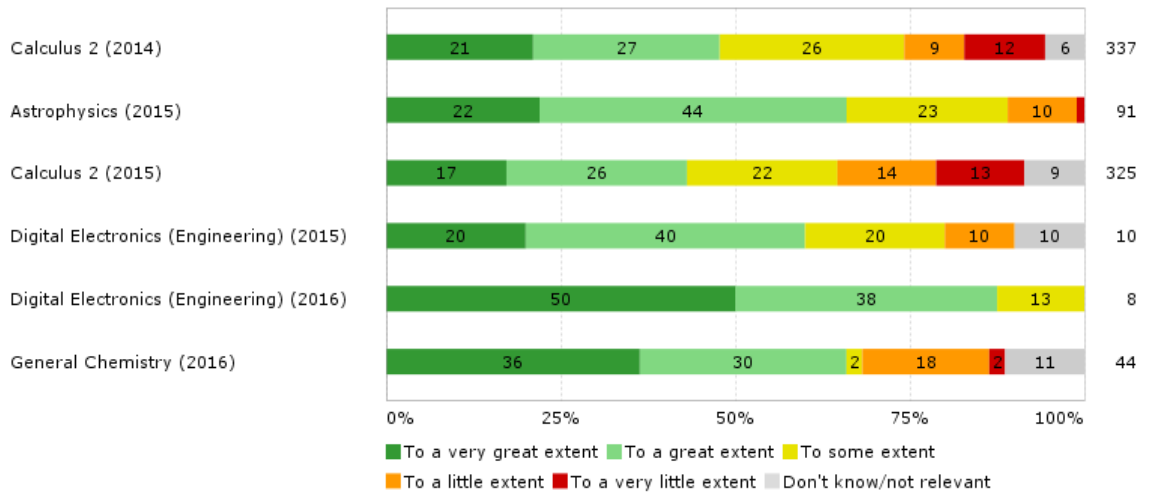


Figure 46. To what extent the students used the materials for understanding the topics in-depth. NB: The results from AP (2014) were not available.

Also for strategic learning purposes, including doing better at the examination, all students in DE (2016) compared to merely 67% in GC used the materials for this purpose (Figure 47). However, for the surface approach of merely 'learning the most necessary curriculum', 84% of the GC students provided this reason (Figure 48).

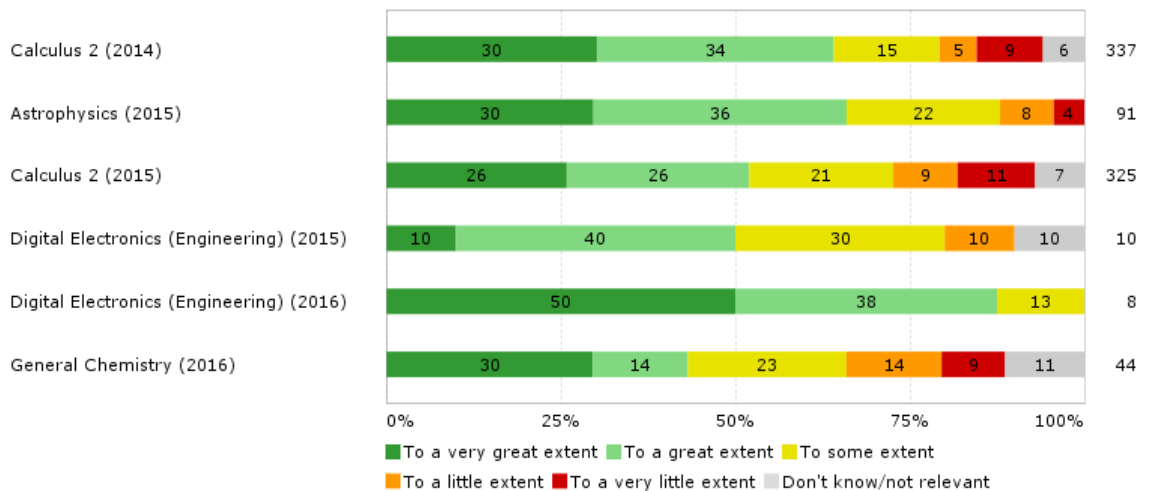


Figure 47. A strategic purpose of doing better at the exam. NB: The results from AP (2014) were not available.



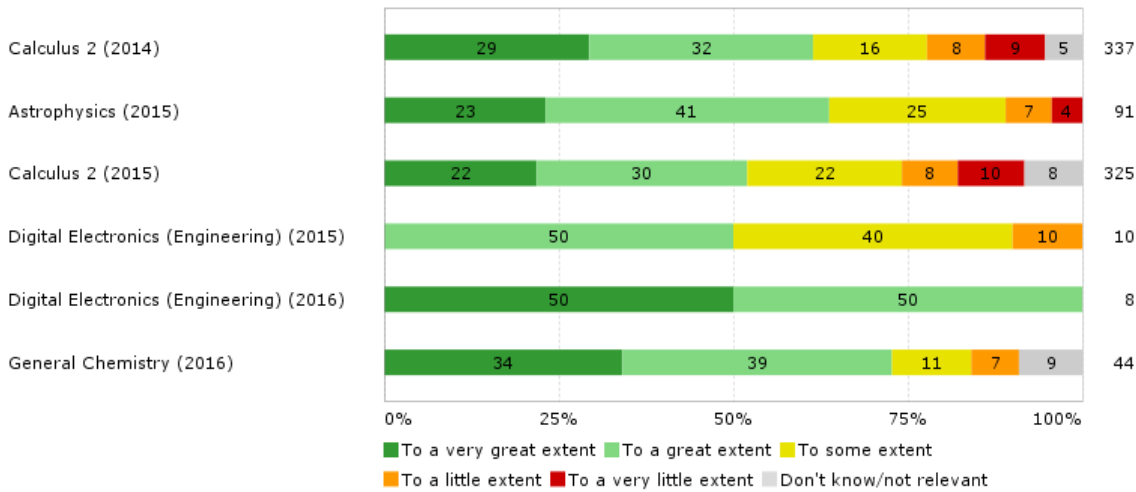


Figure 48. A surface purpose of learning the most necessary curriculum. NB: The results from AP (2014) were not available.

The impact on pass-rates was less obvious. Comparing the pass-rates of the transformed modules with previous and later pass-rates suggests that modules that went through a major transformation, that is to say, C2 in 2014 and DE in 2015, experienced a decrease in pass-rates during the first one or two runs of the transformed module after which the pass-rates increased and even succeeded pre-transformation rates and AU ST baseline (pass-rates across all bachelor modules at AU ST) (Figure 49, see also Appendix R). In contrast, the modules merely being augmented did not experience the same decrease in pass-rates, but rather a slight, yet potentially insignificant, increase.

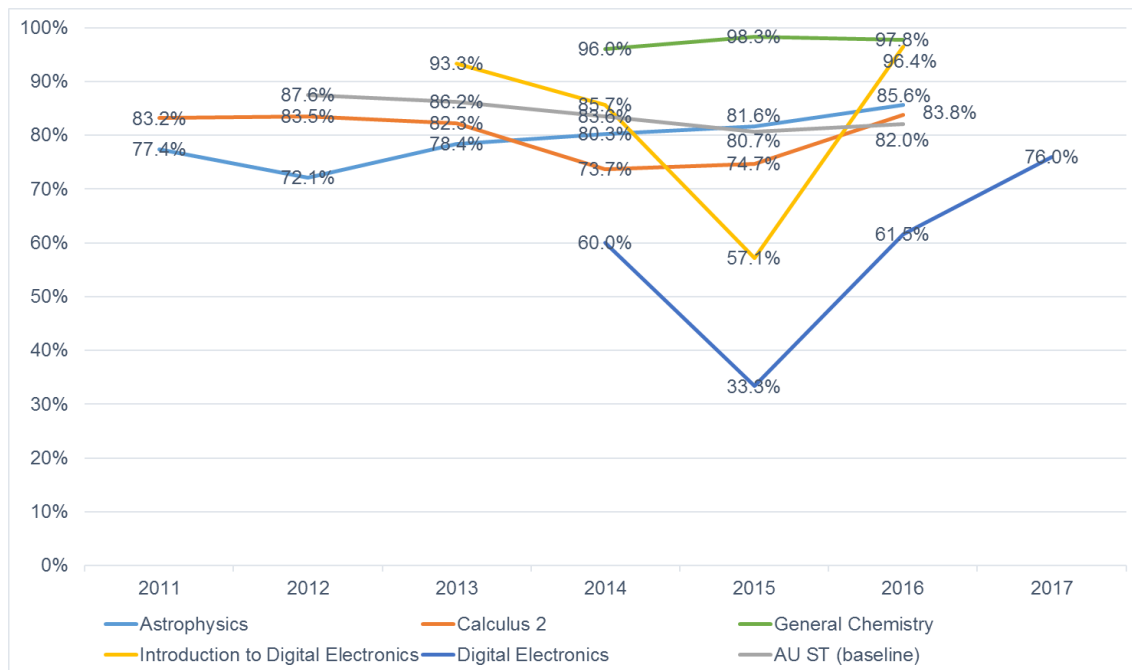


Figure 49. The pass-rates of the four modules, including rates from prior to the transformations. NB: As DE was organised as two modules with individual examinations both results are shown.

A similar pattern was observed among the GPAs, that is, that the grades initially decrease in the modules with the highest level of transformation, whereas the augmented module AP experienced a slight increase, and they subsequently increase and in some cases even succeed pre-transformation grades and AU ST baseline (the grade average across all graded bachelor modules at AU ST) (Figure 50).

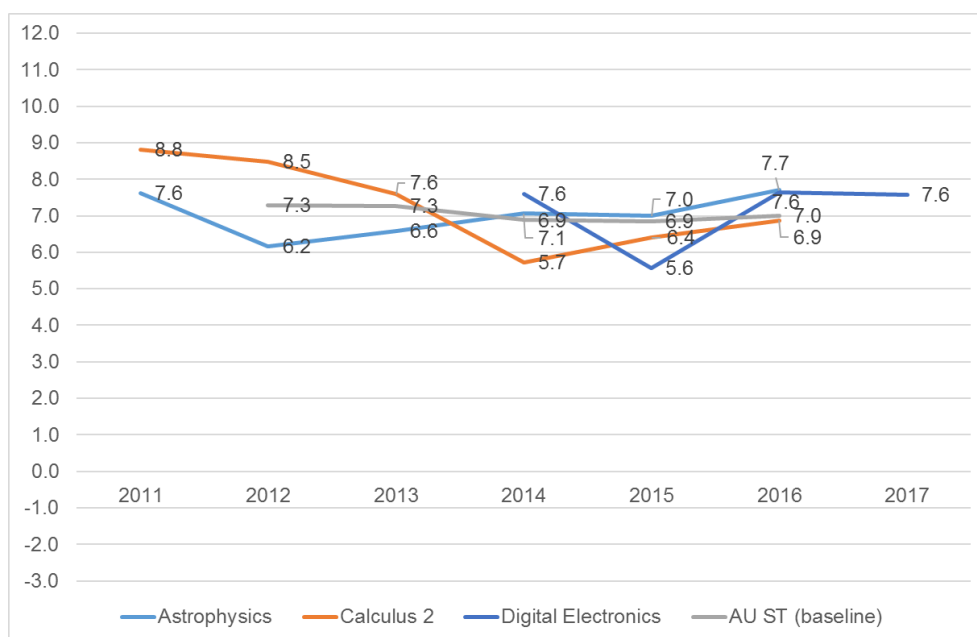


Figure 50. The GPAs. GC and DE (2015) were not included as they were not graded.

In other words, no significant impact on pass-rates and grades was observed, except for a potential decrease during the first one or two years when modules went through a larger transformation as well as a potential minor increase when modules were merely being augmented. This means that TEL based on LD has the potential to deliver at least equally good pass-rates and grades as prior to the introduction of technology but also that the first year(s) of larger transformations are critical and may entail issues related to the LD product, teaching practice, and/or the LD process. Should these potential first-run/year issues be consistent for most large-scale transformations of modules, they identify an important temporal aspect of introducing LD: that impact may not be optimum the first year and that the return of investment typically happens in the second year, if not extra measures are taken. This also raises an ethical-political dilemma of whether the institution should tolerate this negative impact on the concerned student cohorts.

With regards to the special aim of providing materials useful for self-paced repetition on a particular topic on pH and equilibrium calculations in GC, 75% of the students watching

the video and 82% of the students using the self-tests responded that the materials helped their understanding of the curriculum (see Figure 51).

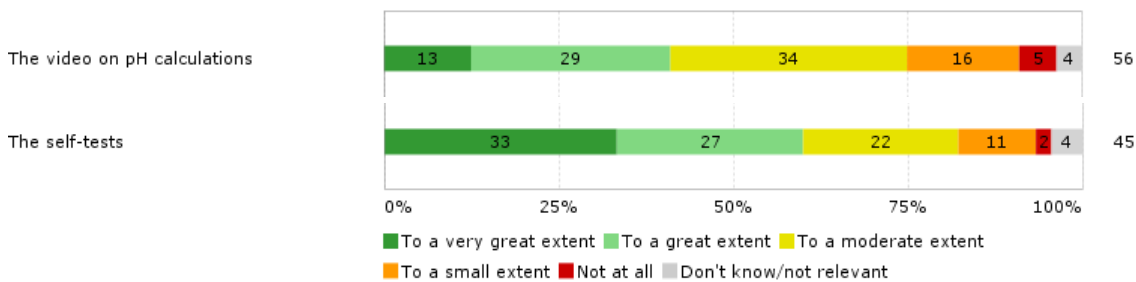


Figure 51. To what extent the materials helped understanding the curriculum in GC.

## Summary: Learning Designs, efforts, and impacts

Four highly diverse LD cases in terms of process, product, subject area, and educators covering the STEM acronym were presented in this Chapter. A total of 12,875 ECTS were impacted by TEL based on LD in the context of this project and improved on most indicators.

The case of AP illustrated how a highly enthusiastic educator, who saw development as a goal in itself by means of a major augmentation of his module improved teaching and learning towards a high level of learning outcome satisfaction, perceived learning goal accomplishment, student satisfaction, and perceived utility of the online materials as well as increased pass-rates and increased grades. In addition, the transformation actualised two main purposes: to provide more flexible teaching and learning, and increase collaboration and feedback. The case also illustrated how the educator initially adopted most of the STREAM characteristics and over time diverged from the model revising the LD according to his own experiences and perceptions as well as spending 50% more time for each run of the module compared to prior to the transformation. Seen from an institutional perspective the transformation was in line with the strategy on TEL and support was provided to the development of materials and educational development. In total, the institution had a *low positive effort* as more effort was put into the transformation/run of the module than prior to the transformation and a *low positive impact* of AP in 2014 and 2015 as the transformed module generally seen had a positive impact compared to the institutional strategic aim for educational IT. The educator spent extra time and had some impact on his own practice, which can be interpreted as a *medium positive effort* and a *low positive impact*. The students, however, invested a *low positive effort* due to the extra time required studying this module and had a *medium positive impact* considering the many provided positive affordances.

C2 and DE, however, illustrated how a LD was used more stringently for unequivocal business goals of cost-cutting and recruitment of students by completely modifying or redefining the modules. In both cases the design was guided by STREAM, which resulted in learning paths with materials, activities, and feedback loops. The impact was in general positive — both institutionally and on the students — outmatching the required effort. However, at the same time it appeared that the design's compliance and thus also the pedagogical ideas of STREAM were fading over time in parallel with the students' decreasing preferences for the online format and their decreasing use of the materials for deep learning purposes. The preferences were fading from, respectively, 50% and 50% in 2014 to 39% and 50% (of which less highly preferred the online format) in 2015, and the use of the online materials were fading from to a great or very great extent being used for deep learning purposes by 48% and 60% to a great or very great extent being used for 52% strategic and 100% surface learning purposes respectively. In both cases, the total educator effort was approximately halved on the second run of the modules proportionally to the number of students enrolled. That is to say, in C2 there was a *medium negative effort* and *high positive impact* seen from the institutional perspective. Seen from the C2 educator's perspective, the transformed module was associated with a *medium positive effort* due to the time consumption and a *low positive impact* due to the provided flexibility and satisfaction. The students in C2 appeared to have spent less time on the module than other modules and thus invested a *low negative effort*, while at the same time experiencing a *medium positive impact* on the learning in terms of more flexibility and a preferred delivery format. This impact, however, decreased in 2015 to a *low positive impact* with less preference for the online format and a primary use of the online materials for surface learning purposes.

In DE, the transformation resulted in a quadrupling of the intake saving the programme resulting in a *high positive impact* on the institution. This required a *low positive extraordinary effort* for the institution in 2015, which was *neutralised* in 2016. The educators, however, were spending a *high positive effort* in 2015 and *low positive effort* in 2016, while at the same time moving from a *medium negative* to a *low positive impact* in 2016 due to an increased satisfaction. The students in DE experienced a *medium positive impact* in 2015 and a *low positive impact* in 2016 at a, respectively, *low positive* and *low negative effort*.

Additionally, the LD of GC, which consisted of a minor component of a difficult topic implemented as a learning path according to STREAM, had a *low positive impact* on the 63% of the students spending a *low positive effort* on online material. However,

developing the component required a *medium positive* institutional effort and whether the educator would actually reuse and pedagogically integrate it in future teaching was uncertain. The educator only invested a *low positive effort* as most of the development was handled by ML.

By aggregating the various stakes in efforts for and impacts on each main stakeholder for each of the four cases (in Table 11, 12, and 13) and weighing them according to Table 8 in Chapter 5 as described above, provides the overview in Table 15.

Table 15  
Overview of efforts for and impacts on each stakeholder in the four cases

Perspectives	Aspect	Case 1: Astrophysics		Case 2: Calculus 2		Case 3: General Chemistry	Case 4: Digital Electronics	
		2014	2015	2014	2015	2016	2015	2016
Institutional	Effort	Low positive	Low positive	Medium negative	Medium negative	Medium positive	Low positive	Neutral
	Impact	Low positive	Low positive	High Positive	High Positive	Low Positive	High Positive	High Positive
Educator	Effort	Medium positive	Medium positive	Medium positive	Medium positive	Low Positive	High Positive	Low positive
	Impact	Low positive	Low positive	Low positive	Low positive	Low positive	Medium negative	Low positive
Student	Effort	Low positive	Low positive	Low negative	Low negative	Low positive	Low positive	Low negative
	Impact	Medium positive	Medium positive	Medium positive	Low positive	Low positive	Medium positive	Low positive

On the whole, the cases in general illustrate that LD processes and products and their impacts and associated efforts may turn out very differently. The cases also illustrate that LD may serve diverse purposes, for example, supporting business goals of cutting costs or recruiting students as well as pedagogic aims such as supporting repetition and students' learning and that, likewise, the educators may have highly diverse views on TEL affordances for their transformation. Either way, this means that assessing the efficiency of LD should also regard the goal of the intervention especially as it appears that the TEL affordances important for the educators' transformation of their modules were different than the general educator perspective. This is identified in Chapter 5 as being highly concerned with pace flexibility and less concerned with student satisfaction. Furthermore, some aims may be crucial to the transformation and, thus, may have to be weighted more than other perspectives.

In addition, LD played highly diverse roles in the process as with the case of STREAM and that educators tend to move away from the model. For instance, all educators were introduced to the model — except for Educator 3, who was introduced to the features of

the model — but still decided to move in other directions. Educator 1 had further developed his practice beyond STREAM, Educator 2 did not recall the model, and Educator 4 and the educators on DE, who were very familiar with STREAM, nonetheless discontinued the out-of-class feedback loop. This suggests that providing and/or introducing STREAM (and maybe LD resources in general) is not enough to ensure a persistent uptake and/or that STREAM may not be providing sufficient guidance to the educators. This temporal aspect challenges the LD efficiency in more open-ended practices similar to STREAM and, thus, it would be relevant to explore this persistence in future research, including how much persistence is required for the LD intervention to be worth the effort as well as whether a higher level of orchestration is required or, for instance, LA may support the uptake.



## 7. Discussion

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Having analysed LD from the three main perspectives, and examined these in detail for the four main cases, the role of LD efficiency can now be explored in detail, in relation to the research questions (Chapter 1). This chapter includes three main sections with a discussion — one for each of the research questions.

### RQ1: The perspectives of the main stakeholders

RQ1: What are the perspectives of the main stakeholders on Learning Design for TEL in STEM undergraduate education?

As the concept of LD was absent in all official policies and not mentioned and/or unknown to the main stakeholders at AU, their perspectives on LD were identified by means of the guiding questions in Chapter 3 on indirect references to LD — that is, the five characteristics identified in the literature review (PLADR), direct references to affordances potentially provided by TEL based on LD, and the associated aspects of effort and impact. The complete set of interests and stakes relating to the perspectives on LD for TEL of the three main stakeholders is provided in Chapter 5.

At the institutional level the general attitude towards TEL potentially based on LD was positive and expressed in a policy on educational IT currently being followed up by a more ambitious strategy. The primary aims were recruitment of the best students, quality in education, supporting student diversity, high completion rates, and ensuring a good study environment as well as the associated professional development of educators and a cost-effectiveness ‘without loss of quality’ (PVC, 2016). Furthermore, the educators were experienced and had a general positive attitude towards TEL despite a limited extrinsic motivation due to fact that AU ST is a campus-based university providing very little online education and that their career is dominated by their research. The educators' main priorities were related to students' learning and other student-oriented affordances but were, at the same time, concerned about the time consumption, required support, and whether materials could be reused. The students had a similar, generally positive attitude towards TEL: 91% were positive towards technology in education prioritising in particular support for feedback, alignment, job skills, student satisfaction, and linking



theory to practice. In addition, 94% responded that they were willing to spend more time on studying if they felt they were learning a lot.

In the context of actual transformations, however, the perspectives on LD were more diverse and dominated by the specific aims of each transformation. In the four cases, the educators had different motivations — intrinsic or extrinsic — for engaging in the transformation and different views on the TEL affordances potentially provided by LD. Three key themes relating to stakeholder perspectives were identified. Firstly, the prioritisation of affordances was different among the case educators compared to the general perspectives (see Chapter 5 and Figure 32). In particular, the case educators were more concerned about pace flexibility and skills training, and less concerned about the teaching being enjoyable. Secondly, the alignment aspect was considered as the most important affordance in both groups. Thirdly, the educators' view on TEL was different between cases suggesting that their aim for LD would be highly case specific. The latter highlights the importance of emphasising this aim when assessing LD efficiency. That is, it does not make sense to merely talk about general perspectives on LD in the context of actual cases. Neither does it make sense to merely talk about intervention specific perspectives as all main stakeholders will have associated efforts and impacts — of which some are likely to be overlooked. It does, however, make sense to weigh in the efforts and impacts according to the general and case specific perspectives.

On the whole, there was a wide, indirect interest in LD due to the affordances it may actualise through TEL. In addition, among educators there was a direct interest in three of the five LD characteristics, that is, in pedagogy-informing their teaching, playing an active role in a development/design process, and reusing and sharing materials. In the context of AU ST the interest highly depended on the pedagogic and business aims of the actual transformation; however, the potential for supporting alignment between examination, curriculum, and the skills the students were supposed to have learnt as well as linking theory to practice were of general and very high priority. Additionally, feedback, student satisfaction, skills for future jobs, and teaching in concordance with formal requirements had common high priorities. The affordances of supporting student collaboration and interaction as well as providing support for various kinds of flexibility such as in time, pace (incl. support for repetition), and place were mostly considered important by the students and to a minor extent by the institution and educators. This is an interesting difference, which suggests a more traditional view on teaching and learning among the educators and the institution. A view that regards teaching and

learning as something that primarily takes place synchronously on campus with limited online and/or flexible components.

Furthermore, the analysis revealed that the institutional perspective not only had business impact aims but also aims for the educators in terms of professional development and for the students in terms of improved learning. Likewise, the educators were not solely focused on what impact TEL and LD would have on them, but also on its impact on the students' learning. The students, however, were primarily interested in their own learning and/or getting the degree. That is, the perspectives on TEL and LD were to some extent overlapping and by combining the interests in TEL and LD identified in Table 8 with the high median interests in TEL potentially based on LD (Table 9) a number of converging and diverging interests were revealed (see Figure 52). Interests located in the intersection suggest that all stakeholders found it of high priority or were explicit about the interest (high convergence), whereas interests located outside the diagram were merely of intermediate interest.

## Institutional perspective

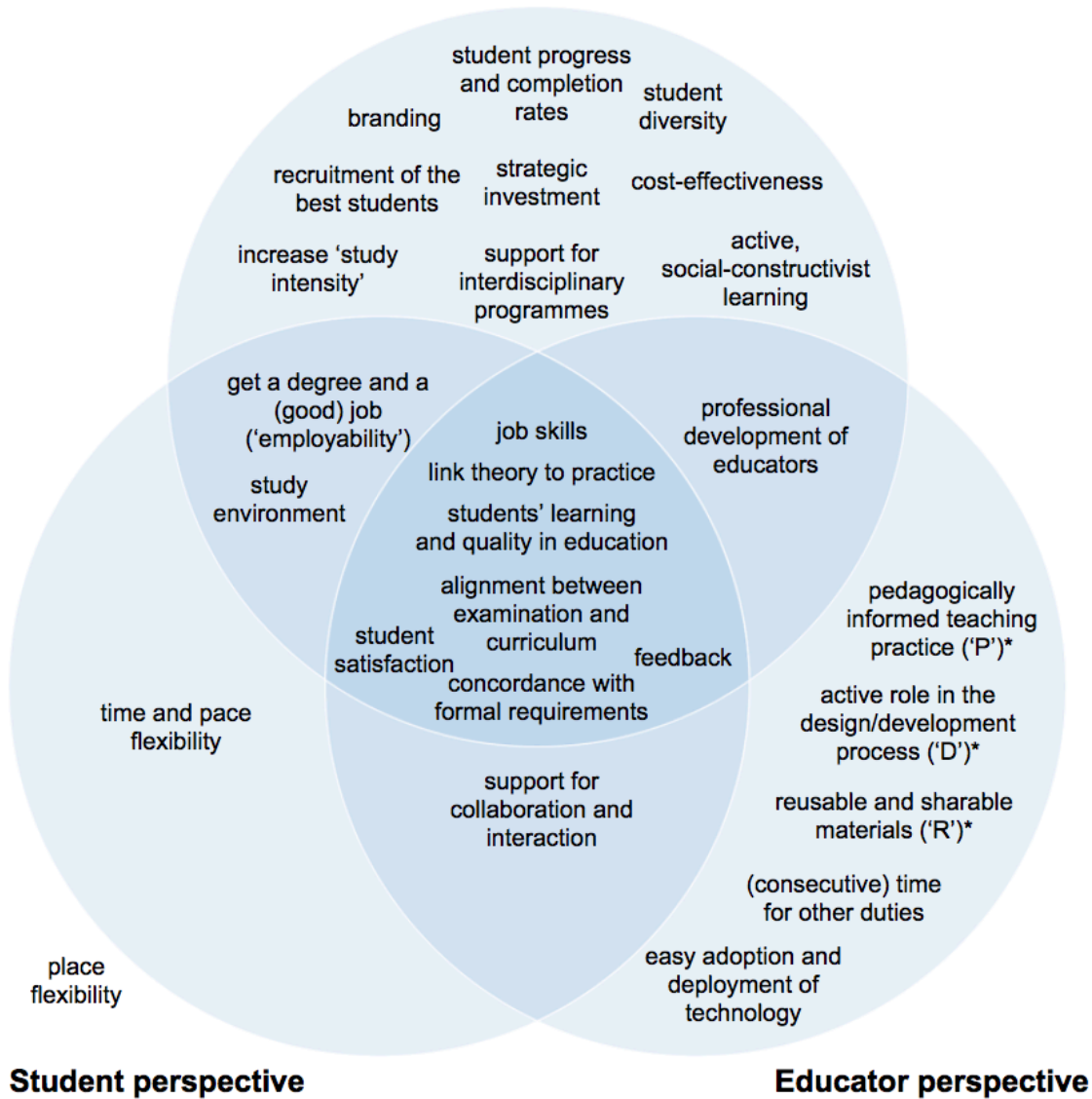


Figure 52. Overview of the three main perspectives on LD for TEL. \*Relates directly to a LD characteristic.

As suggested by Figure 52, in particular the interests associated with quality in teaching and learning were significant at AU ST. This may be partly due to the methodology asking specifically for teaching and learning related aspects, but it also suggests a genuine interest in the affordances potentially provided by TEL based on LD. In the context of providing LD efficiency, Figure 52 also helps the weighting of the different perspectives as, obviously, stakes located in the intersections have high common interest.

## A balanced perspective on Learning Design

The overview of interests in Figure 52 also stresses that a narrow focus on the interests of one or two of the stakeholders may yield an inefficient LD as important aspects may be overlooked. For example, merely focusing on improving learning may fail to address important institutional perspectives such as cost-effectiveness. The overview also reveals that, for instance, an intervention at AU ST that results in high student satisfaction but low place flexibility should be considered more efficient than an intervention with the opposite outcome as the student satisfaction is located in the intersection and thus has a higher positive impact on all three stakeholders.

A part of the balance also relates to the effort perspectives. At AU ST, there was an ambition to improve and modernise teaching by means of TEL, that is, it was not seen as a cost-cutting measure; the educators were highly concerned about the required time and the missing incentives for adopting TEL; and the students were generally positive towards TEL though this attitude may partly be based on misconceptions. This means for instance that LD initiatives at AU ST that require a high amount of educator time without strong incentives and/or high convergence impacts easily run into a low LD efficiency and/or conflict of interests.

On the whole, the overview may help support a more balanced perspective on LD and its role in actualising the affordances potentially provided by TEL. LD that supports the intersections without being too effort-intensive has the potential to be very efficient, whereas LD that primarily supports single interests and/or perspectives may well be less efficient and even in conflict with other perspectives (see also Table 8). Figure 52 may help in identifying fruitful and efficient LD initiatives and focus areas in which LD may play an important role as well as pitfalls with limited interest.

## RQ2: A concept of Efficient Learning Design

RQ2: How can Efficient Learning Design for TEL in STEM undergraduate education be conceptualised and assessed?

As with the concept of LD, the literature review revealed that no common definition or understanding applies to the concept of efficiency. However, the literature review did reveal that efficiency is 'more than addressing institutional needs' and that a one-sided

understanding of LD efficiency may lead to disappointed and unmotivated students and educators, a low learning outcome, and missing sustainability. As a consequence, LD must consider the perspectives of the main stakeholders, that is, the institution, the educators, and the students, and the efficiency as a ratio between the time and effort spent on achieving a certain impact, such as improving learning. The relevance of these stakeholders and their general interest in LD was confirmed by the perspective analysis in Chapter 5.

However, as a concept on a general level ELD can be understood according to the provided description of LD and in the context of the affordances TEL based on LD may provide illustrated in Figure 52. In practice, this means that LD may be efficient in terms of its practice and approach to educational development, its design process, and the actualised product and its actualised affordances. This also means that understanding the interests of the main stakeholders and the actualised affordances are important to assess to what extent the LD has the desired impact, which again relates to the efficiency and ultimately to identifying the factors that deliver ELD. In other words: the more of the interests listed in the Venn diagram and in particular within the intersections that are covered at a low effort, the higher LD efficiency.

The efficiency was initially expressed by means of a simple ratio in which the positive impact on the institution, educators/teaching, and students/learning divided by the effort for the institution, educators, and students would assess the LD efficiency (Chapter 3). ELD would then occur if the positive impact was (much) higher than the effort. However, the perspective analysis (in Chapter 5) revealed that the efforts and impacts (i.e., the denominators and numerators) would be measured by means of different indicators across the stakeholders. Thus, it does not make sense to simply aggregate the values. Instead, it makes more sense to treat each perspective individually and include a weighting ( $w$ ) to each perspective (see the formula below). Like this, cases with strong aims, such as the institutional perspective of avoiding closure in DE, or the student perspective of more collaboration in AP, can accentuate certain perspectives in the assessment.

$$LD\ efficiency = w_I \frac{Institutional\ impact}{Institutional\ effort} + w_E \frac{Impact\ on\ educators}{Educator\ effort} + w_S \frac{Impact\ on\ students}{Student\ effort}$$

As such, the formula may serve as a tool for thinking about ELD, and as a way of highlighting that ELD occur when weighty perspectives have a high impact at a low effort.

## Four Learning Design efficiency scenarios

Ideally, the temporal aspect should also be included in the assessment formula as LD practices and products may be reused saving efforts, aims of the intervention may change, and design may evolve over time as was the case with AP, C2, and DE. Thus, it is meaningful to assess the relative efficiency by comparing the efforts and impacts prior to the LD intervention. This will per definition give four efficiency scenarios of either more or less (or neutral) effort and/or impact as illustrated in the two-dimensional system of coordinates in Figure 53.

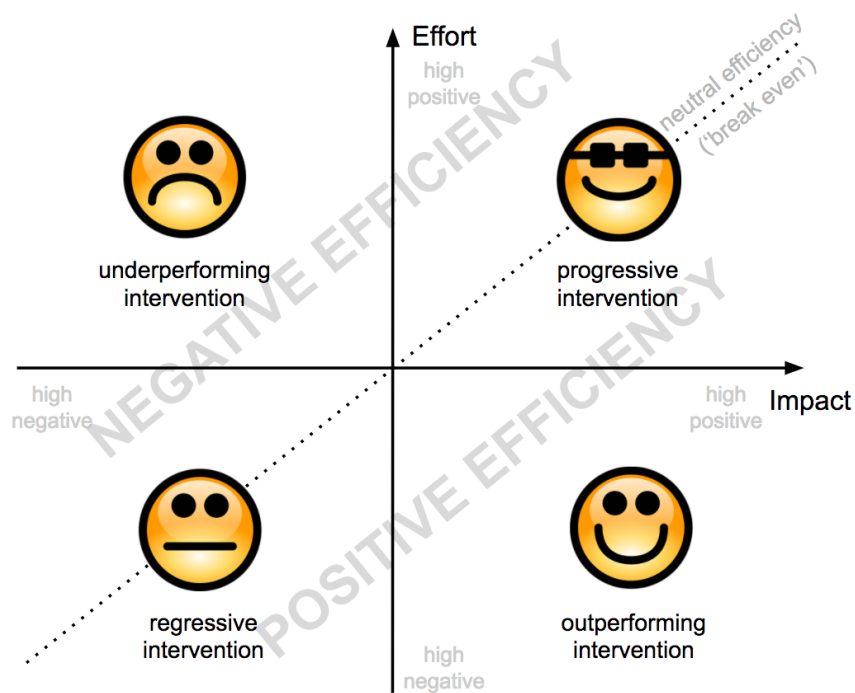


Figure 53. Four efficiency scenarios of LD interventions.

Positive effort values express more effort put into the module than prior to the transformation and vice versa. Positive impact values express an improvement compared to traditional teaching. The diagonal line indicates "break even" LD efficiency, that is, where the positive impact is counterbalanced by a similar increased effort. This also means that interventions to the bottom right of the diagonal line are to be considered as ELD due to their minimum effort and maximum impact, while interventions to the top left are inefficient. The origin (0,0) expresses the effort-impact balance prior to the LD intervention. The emoticons symbolise the efficiency in terms of attitude. The emoticon in the first quadrant symbolises a "high roller" attitude suggesting an investment in impact, while the emoticon with the straight face symbolises a passive attitude.

The scenarios can be assessed according to each stakeholder or as a joint measure as expressed in the formula above presupposing that the weightings are determined and the effort-impact ratios are added. And turning to a business nomenclature these scenarios may be described as either *outperforming*, *underperforming*, *progressive*, or *regressive*.

- Outperforming is characterised by a general positive impact of the LD intervention on most of the stakeholders at general lower effort than previously.
- Underperforming is characterised by a general negative impact on the stakeholders though more effort has been put into the LD intervention and/practice than previously.
- Progressive is characterised by a general positive impact on the stakeholders but also an increased effort in adopting LD.
- Regressive is characterised by a negative impact on the stakeholders but also a lower effort.

While outperforming interventions are to be considered favourable with a positive efficiency and underperforming interventions unfavourable with a negative efficiency, progressive and regressive interventions are subject to strategic considerations and may result in both positive and negative efficiencies. For instance, the institution may consider it legitimate to spend more effort on improving teaching and learning as the case with AP or, vice versa, accept lower quality at a lower effort — in particular if the LD efficiency is positive. Underperforming interventions should only be tolerated if they have the potential to improve over time.

### Assessment of Learning Design efficiency

Assessing LD efficiency may be carried out on an abstract, conceptual level using the four scenarios as a way of thinking about potential outcomes of a LD intervention or more in-depth by measuring the stakes and doing the math. The latter could be carried out by firstly deciding on the precise set of indicators and secondly measuring the efforts for and impacts on each stakeholder by means of appropriate methods such as surveys, observations, interviews, review of documents and data (e.g., as suggested in Table 1). Thirdly, deciding on a weighting based on the aim of the intervention (see the fourth row of the matrix) and the general perspective on LD (see Chapter 5) as well as the required

levels of efficacy — that is, when has the intervention met the aims in full. Deciding on the weighting may be supported by the Venn diagram in Figure 44. In general, the interests in the intersections are particularly important and should be weighted higher when aiming for impact. Fourthly, assessing whether the ratio has improved or not by comparing the variables that express the impact and effort of the intervention.

In addition, the efficiency assessment should not disregard potential ripple and spill-over effects as well as the temporal aspect. For instance, an intervention can be ineffective on an intervention and module level but cause a positive ripple effect that causes peers to think differently and start adopting technology in an effective way and thus should be included in the overall cost-effectiveness considerations. Likewise, materials may be easily updated and/or reused the following year resulting in for example, a progressive intervention becoming outperforming due to the decreased effort as with the cases of C2 and DE.

### The temporal aspect

Though the formula of LD efficiency provided above makes it possible to add the efficiencies of each perspective, the formula does not regard the temporal aspect and therefore makes the assessed values difficult to interpret. Furthermore, the formula operates with absolute values, which means that efforts and impacts will always be positive — negative and zero effort and/or impact values yield nonsense results. Thus, it may be more fruitful to assess the efforts and impacts compared to the run prior to the LD intervention making the assessed values more eloquent. Zero or negative values would then express, respectively, the same or less effort or reduced impact, whereas positive values would express increased effort and/or impact.

As illustrated by the AP, C2, and DE interventions, the first intervention may require a large effort and in the second run of the module the uptake of the underlying LD model may fade and the teaching practice may change. Consequently, the LD efficiency may also fade and should be assessed according to their sustainability — that is, the impact and effort over time.

Figure 53 expresses the LD efficiency (LDE) by comparing the outcome of the LD intervention with the prior situation. By using vectors starting in origin instead of fractions to express the LDE, this development can conceptually be expressed as:



$$\overrightarrow{LDE} = \begin{pmatrix} impact \\ effort \end{pmatrix}$$

Identifying the values of three LDE vectors — one for each stakeholder — and comparing these with the values of a later run of the module will make it possible to establish vectors that express the efficiency development ( $\Delta LDE$ ) of each of the three perspectives by using basic vector operations ( $I$  refers to the institution,  $E$  to the educator, and  $S$  to the students):

$$\begin{aligned} \overrightarrow{\Delta LDE}_{institution} &= \begin{pmatrix} I_{impact,after} - I_{impact,before} \\ I_{effort,after} - I_{effort,before} \end{pmatrix} \\ \overrightarrow{\Delta LDE}_{educator} &= \begin{pmatrix} E_{impact,after} - E_{impact,before} \\ E_{effort,after} - E_{effort,before} \end{pmatrix} \\ \overrightarrow{\Delta LDE}_{students} &= \begin{pmatrix} S_{impact,after} - S_{impact,before} \\ S_{effort,after} - S_{effort,before} \end{pmatrix} \end{aligned}$$

By then adding the three vectors shown above, it is possible to assess the overall LD efficiency of the intervention and its development over time. However, since the prioritisations and the scales used for assessing effort and impact varies from each stakeholder, the aforementioned weightings ( $w$ ) need to be included in the formula to calculate the aggregated LD efficiency development:

$$\begin{aligned} \overrightarrow{\Delta LDE} &= w_I \cdot \begin{pmatrix} I_{impact,after} - I_{impact,before} \\ I_{effort,after} - I_{effort,before} \end{pmatrix} + w_E \cdot \begin{pmatrix} E_{impact,after} - E_{impact,before} \\ E_{effort,after} - E_{effort,before} \end{pmatrix} \\ &\quad + w_S \cdot \begin{pmatrix} S_{impact,after} - S_{impact,before} \\ S_{effort,after} - S_{effort,before} \end{pmatrix} \end{aligned}$$

In the provided formula, it is assumed that the weightings are constant between interventions. If not, three additional weightings need to be included in the formula.

## RQ3: Delivering Efficient Learning Design

RQ3: How to deliver Efficient Learning Design in STEM undergraduate education with STREAM?

The answer to RQ2 gave a varied picture of LD efficiency and showed that three of the four outcome scenarios are potentially desirable depending on the aim of TEL and LD, and that how to deliver ELD depends on the desired scenario. However, Figure 53 showed that the larger impact and the lower effort, the more ELD, and that ELD is

primarily achieved when a LD intervention is outperforming with a high positive impact at a low effort across all three stakeholders. For the progressive scenario, however, ELD is delivered if the positive impact outmatches the increased effort, just as the regressive scenario only delivers ELD if the effort is lower than the lowered impact.

The four cases included in this project each entailed different efforts and impacts (see Table 15, Chapter 6) and based on these it is possible to outline their delivered efficiencies as well as how they evolved over time in Figure 54.

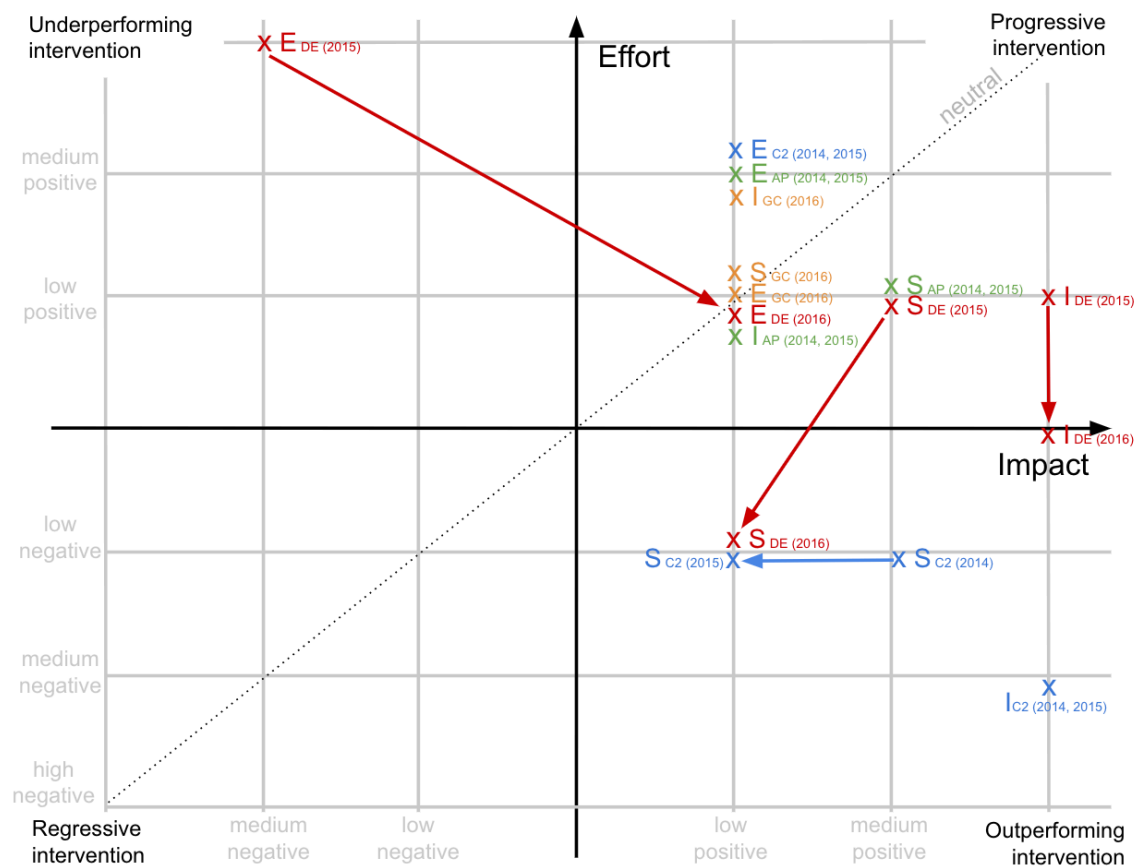


Figure 54. The LD efficiencies of the four cases. I, E, and S refer to, respectively, the institutional, educator, and student perspective.

By adding the vectors of the efforts and impacts using the formula presented above and an equal weighting, it is also possible to estimate the overall LD efficiencies and scenarios (see Table 16). However, should the institution instead of an equal weighting have decided on an alternative weighting of the different perspectives and/or specific efficacy levels (e.g., a level where impact should be considered as 'high positive' or 100%), the efficiencies and outcome scenarios in Figure 54 and Table 16 may have been different.

Table 16

Overview of the LD efficiencies (LDE) and outcome scenarios of the four cases based on an equal weighting of the three perspectives

	Case 1: Astrophysics		Case 2: Calculus 2		Case 3: General Chemistry	Case 4: Digital Electronics	
	2014	2015	2014	2015	2016	2015	2016
LDE	Neutral	Neutral	Positive	Positive	Neutral	Negative	Positive
Scenario	Progressive	Progressive	Outperforming	Outperforming	Progressive	Progressive	Outperforming

An example of how this was calculated for AP (2014) is provided below. Notice that *low*, *medium*, and *high* were translated into the values 1, 2, and 3; that the weightings were considered equal and thus ruled out; and that the before values were zero as this was compared to prior to the LD intervention.

$$\overrightarrow{\Delta LDE_{AP\ 2014}} = w_I \cdot \begin{pmatrix} 1-0 \\ 1-0 \end{pmatrix} + w_E \cdot \begin{pmatrix} 1-0 \\ 2-0 \end{pmatrix} + w_S \cdot \begin{pmatrix} 2-0 \\ 1-0 \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \end{pmatrix} + \begin{pmatrix} 1 \\ 2 \end{pmatrix} + \begin{pmatrix} 2 \\ 1 \end{pmatrix} = \begin{pmatrix} 4 \\ 4 \end{pmatrix}$$

The three vectors illustrate each of the three perspectives: the institutional perspective (orange) should be plotted in (1,1), the educator perspective (blue) in (1,2), and the student perspective (green) in (2,1). The aggregated vector to the right (black) shows that the overall LD efficiency of AP in 2014 is to be considered as *progressive* as both values were positive and with a neutral LDE as the total effort was equal to the impact. In the system of coordinates this would be located on the diagonal line of neutral efficiency.

In theory, all four outcome scenarios in Figure 53 were possible, both on perspective level and overall, just as any kind of temporal movement across the quadrants was possible. In practice, however, it appears that most interventions in this open-ended LD practice start out by being predominantly progressive due to more effort than usual for the educator and institution, and potentially also an improved impact on the students.

Figure 54 and Table 16 illustrate that STREAM delivers various kinds of LD efficiencies, in this case progressive and outperforming, and that efficiency may change over time. In addition, the role of STREAM as well as the interests of the main stakeholders vary and thus may influence the intervention and its efficiency in various ways. In particular, progressive and regressive interventions may be understood according to institutional aims for TEL as the institution may be interested in investing in educational development or might prefer downscaling effort and thus accept quality compromises.

The results also suggest that STREAM may function as a catalyst for introducing LD and potentially also deliver ELD. The process may consist of several iterations and it may get off track as it was the case for the AP, C2, and DE interventions, which either stayed progressive or moved towards regressive. Thus, it is important to look at STREAM and LD impact over time, including the role the model has played in delivering the different kinds of LD efficiencies. This is further explored in the next two sections.

### Progressive STREAM interventions

As revealed by Figure 54 and Table 16, AP and GC are to be considered as progressive. In both cases, the aim of the transformation was defined by the educator and related to improving teaching and learning and based on the educator's own intrinsic motivation for rethinking his module. In both cases, time consumption for the intervention was less important as long as there was an evident, positive impact on their students' learning. Seen from the student perspective, progressive interventions typically involve some extra workload due to the introduction of new technologies and procedures such as the dissemination assignment and continuous assessment in AP or the extra material in GC. Furthermore, they are not necessarily more satisfied with progressive interventions, which may partly be explained by the increased online workload or a reluctance towards new initiatives, active learning, and/or technology in education.

In AP, the educator was highly self-governed both with regards to the design and production of materials, and did not slavishly follow the STREAM model. Instead, he used it for inspiration and as a guide. He was conscious about the concepts of out-of-class and in-class activities and how they should be connected. In 2015, the educator started to diverge from the model as he got more familiar with using technology in education and continuously wanted to refine his module. Over the iterations, the efficiency has been stable neutral in spite of some reuse of materials. This is mainly due to the educator's belief that 'development is a goal in itself' and his ongoing desire to continuously develop the module. As such, AP is an example of a module where design thinking took over which potentially resulted in a less efficient and "everlasting progressive intervention".

However, in the context of the institutional ambitions at AU ST of improving teaching and learning with technology, the intervention may be considered "a good investment" due to a high student satisfaction and high perceived learning outcome, which is consistent with some of the top interests in TEL and LD (Figure 52). Furthermore, it appeared that the online materials were primarily used for deep learning purposes, the module

maintained a high student satisfaction over the iterations, and that the students studied intensely. That is, STREAM played an important role in the beginning as a model informing the design by inspiring the educator ‘...to the large transformation in 2014 and to combine the so-called in-class and out-of-class activities with each other’ (Educator 1).

In GC, the data suggests that increased effort was put into designing and implementing the design with self-tests, especially for the teaching assistant and ML. The majority of the students did not use the materials for various reasons, but those who did responded that the video and self-test materials helped their understanding of the curriculum. For those who did not use the materials, teaching was carried out as usual. In total this means that more effort was spent, but also that the design had a positive impact on the groups of students using the materials. In the context of this module STREAM was not directly presented to the educator — merely its ideas and concepts — which highlights an interesting potential of LD of using models and other aids as a communication tool for educational developers in contexts where an explicit model would be inappropriate (also referred to as *implementation by stealth*). Though pedagogy-informing the design (P), a potential downside relates to the missing articulation of the model (i.e., LD aids, A) as well as the subsequent reuse and sharing of practice (R).

Compared to the concept of ELD, AP and GC did not qualify as ELDs due to a higher effort compared to impact (see Table 16). In order to deliver ELD, they would have needed to either increase the impact without increasing the effort, or lower the efforts while maintaining the impact.

## Outperforming STREAM interventions

As previously described, the first intervention typically starts out as progressive and may subsequently become outperforming. C2 and DE are both to be considered as outperforming according to Figure 54 and Table 16, and it appears that outperforming interventions occur when there is a high degree of awareness about return of investment seen from the institutional perspective and typically associated with business aim and an extrinsic educator motivation.

Though C2's efficiency has changed over time, the intervention was efficient for all years as it had a positive impact on the institution, educator, and students at a lower overall effort, and in particular the institution benefitted from the transformation due to the reduced time consumption and costs for running the module. The general impact on the

students and their preference for the online format was positive but it did gradually decrease over time. In addition, the majority in 2015 was primarily using the online materials for surface learning purposes. The exact reason for this decline is unknown but the answer may rest in the typical STEM education problem of limited integration of the online materials in the remaining teaching and learning activities on the module (see also Chapter 2) as otherwise prescribed by STREAM, less active learning, the limited follow-up on online activity, and the increased use of Sci2u for skills training. Should this trend of gradually fading positive impact continue there is a risk of the module becoming regressive.

Over the years, STREAM has played an indirect but influential role. In spite of the educator claiming not being familiar with STREAM, the model has both been introduced to him and used by the educational developer to guide the transformation. The role of the educational developer and STREAM was gradually reduced as the educator became more self-governed and supported by ML.

DE is an example of a module involving extra effort from both the institutional and educator side due to the complete transformation of the module from being face-to-face to blended and online learning. The intervention was seen as an investment in order to recruit new students and avoid programme closure, which meant that the increased intake should counterbalance the institutional effort making the overall LD efficiency outperforming. Should the transformation have failed in terms of not recruiting enough students, the scenario was instead to be considered as progressive or underperforming depending on its impact on the students. Though quadrupling the intake of students and a general high student satisfaction, the positive impact was fading from 2014 to 2015. Should it continue fade and the institutional impact become neutral due to low intake, the module would become regressive or underperforming.

Both C2 in 2014 and 2015 as well as DE in 2016 qualified as ELD due to the low effort compared to impact (see Table 16). The high institutional and educator effort in 2015 was the main reason for DE not being ELD that year.

### Indirect factors for Efficient Learning Design

As described in the previous sections, delivering ELD was generally about having a large impact at a low/lower effort and relating this to the perspectives on LD and TEL. Thus, the indicators identified in Chapter 3 and Table 1 are direct factors for LD efficiency. However, in addition to these direct indicators, a number of indirect, underlying factors

contributing to the LD efficiencies relating to the practice, process, and/or product were also identified in Chapter 6 and collected below. Thus, the efficiency of the LD can be improved by addressing both the direct factors as well as these indirect factors.

### *Educator motivation and persistence*

The type of educator motivation appeared to play an important role for the efficiency. Extrinsically motivated educators were more concerned with the institutional impact of the intervention and aware of the effort put into the transformation — basically: ‘the impact should be worth the effort’ — compared to intrinsically motivated educators, who were mostly concerned with positive impact on teaching and students’ learning and seem to disregard the effort aspect, resulting in a low institutional and educator LD efficiency. Compared to the four efficiency scenarios it appeared that strong intrinsic educator motivation induced a progressive intervention and strong extrinsic educator motivation induced an outperforming intervention. In particular the senior position educators with a research career, that is, Educator 2–3 and the professors in general (see Chapter 5), were highly concerned about a clear aim of TEL (i.e., the extrinsic motivation) and that the integration was practical, and preferably with support from ML and technical assistance.

In addition, the educators tended to diverge from STREAM over time and either fall back into previous teaching practice or think outside the box as they got more confident with technology and/or were not informed by the impact of the LD. That is, the role of LD and STREAM turned out very differently across the cases mainly due to the educator’s attitude towards educational development and how the LD was accordingly introduced. However, a low confidence with technology was not directly associated with low efficiency, low educator satisfaction, or any major barriers as appropriate support was provided in the context of this project.

### *Students' approach to online learning*

A direct positive side effect was a higher degree of flexibility in both time, pace, and place actualised without additional effort across all four modules. However, the surveys also suggested that there was a diverse approach to TEL and perception of what technology in education actually entails, its utility, and what role it should play, which influenced the student satisfaction both positively and negatively. Some students had a misconception of what online learning and TEL entails and of traditional face-to-face lectures, which was that TEL and online learning is passive self-study based on video or similar materials and that traditional lectures are engaging with plenty of discussion and dialogue. In

particular, the students in modules with a higher level of transformation, such as modification and redefinition, experienced a lower learning goal accomplishment, learning outcome satisfaction, and utility of the materials. In addition, these modules also experienced a dip in pass-rates and grades the initial year after the intervention.

#### *Scale and level of transformation*

The scale in terms of the size of student cohort, the reuse of materials, and the level of transformation, played a major role in cost per capita. In particular, when a module was modified so that educator hours could be minimised as in C2 or redefined to provide distance education as in DE. In addition to this, reusing most of the developed LD as in C2 minimised the costs for repeating the module. That is, there was a significant cost-cutting potential when modifying a module instead of merely augmenting it — in particular for lecture-intensive modules.

#### *Pedagogical integration of online activities*

The pedagogical integration played an important role. For instance, in C2 and DE the STREAM compliance faded over time and in particular the feedback loop and follow-up activities were abandoned correlating with less positive impact on the students in terms of satisfaction, low perceived utility, and surface-oriented learning approach. For instance, in C2 the perceived utility of the — less integrated — online materials for going over the curriculum was significantly lower than, for instance, AP though C2's materials were designed to cover the entire curriculum in contrast to AP.

Also, continuous assessment as in the case of AP had an impact on students' effort and impact. Though the students responded that it was somewhat stressful, it resulted in students being very active online, high pass-rates, and perceived learning outcome.





## 8. Conclusion and recommendations

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This project set out to find an efficient alternative to the unsustainable practices of one-hit wonders and ad hoc approaches that are often found in pedagogic transformation, by means of LD for TEL with the overarching aim of improving STEM undergraduate education with ELD. And ultimately, the intention of the project was to use LD based on TEL overcome the barriers to break the constraints of the iron triangle and thus find a way to provide quality education cost-effectively and support the UN SDG no. 4 of providing 'quality education for all'.

The initial steps of understanding, trialling, and assessing LD interventions for qualifying educational decisions and improving STEM undergraduate education efficiently have now been taken and a series of factors contributing to the efficiency has been identified. This includes characterising LD (PLADR) as well as understanding the main perspectives on LD in the context of AU ST; developing the holistic concept of ELD and an associated mixed methods assessment methodology which pays regards to the perspectives and effort-impact balance of the three main stakeholders; and an identification of direct and indirect factors for ELD based on four open-ended LD interventions of STEM undergraduate modules by means of STREAM. The research illustrates that LD has a potential for delivering TEL efficiently and that ELD is worth pursuing as a concept for the assessment and organisation of LD practices. However, at the same time, the research also illustrates that further work is needed to fully understand and define the concept of LD and that more interventions should be analysed — and ideally over time — to further validate the identified factors for ELD, their reliability across contexts, and the temporal aspects.

A number of common as well as diverse perspectives on LD were identified at AU ST (see Chapter 5). In addition, a number of intervention specific perspectives were identified in the context on the four STEM undergraduate cases, which were either predominantly business or pedagogic aims (see Chapter 6). In general, as there was no knowledge of LD, the perspectives were indirect in terms of the educators' interests in the characteristics of LD relating to informing, designing, and reusing their teaching practice as well as the institution and the students' interest in its potential efforts, impacts, and the affordances it may provide by means of TEL. These interests were relevant for understanding the basis for using LD for implementing TEL and its efficiency as, obviously, actualising the most sought-after affordances would yield a large impact.

Four scenarios were identified for the outcomes of LD interventions: outperforming, underperforming, progressive, and regressive. The outperforming and the progressive scenarios were actualised in the four cases and an important temporal aspect was revealed. Although all cases were informed by LD in terms of STREAM, the uptake of STREAM and the positive impacts of the intervention were in some cases not obtained before the second run of the module and/or faded over time towards underperforming and regressive.

In summary, LD has in this project documented its potential for improving STEM undergraduate education in an efficient way and that transformations can be supported by an open-ended LD approach based on STREAM. In order to maximise impact of the limited effort available and not creating yet a one-hit wonder, it is suggested to follow the concept of ELD and its inherent idea of regarding the stakes of the institution, the educators, and the students. Furthermore, the concept of ELD may also be used to identify and prioritise future interventions, which are more likely to be either outperforming, progressive, or regressive (if that is the aim) and target the modules likely to fade over time. And in particular the fading efficiency is an area of concern though none of the modules are yet delivering negative LD efficiency. The cases demonstrated that important pedagogic features of STREAM such as feedback/follow-up activities, e-tutoring, and integration of online materials in lectures were overlooked over time. The source for this may lie in LD practice, including the level of orchestration, and should be the main topic for future research in order to avoid returning to the one-hit wonder practice.

All in all, despite the fading impact of LD in some of the cases, an overall positive impact has been actualised at a relatively low effort and factors for efficiency have been identified suggesting ELD as a potential way towards more effective e-learning implementation. Thus, future LD research should concentrate on finding the right balance of effort-impact and orchestration in LD practice, according to the PLADR characteristics, in which the educators keep designing (D) pedagogy-informed (P) and learning-centred (L) based on appropriate aids (A), while reusing (R) and sharing fruitful LDs in order to avert the one-hit wonders and ultimately 'revolutionise education through the wider sharing and adoption of effective teaching and learning ideas' as Dalziel (2016, p. xii) put it (more on this in the Recommendations section).

## Contribution to knowledge

As indicated by the introduction and further substantiated by the literature review (Chapter 2), no efficient way of enhancing learning with technology could be identified in the literature and most initiatives were either cost-intensive or one-hit wonders — a problem which is becoming even more critical as the requirements and costs of education are continuously increasing. And, if identified, solutions focused on one aspect only and thus overlooked other perspectives. The LD approach offers methods for making educational development and the introduction of educational technology more systematic and scalable; however, the current practices are often rather complex, costly, and/or time-consuming seen from the institutional and educator perspectives. Thus, there is a need for a broader perspective on LD for TEL and its efficiency, which has been addressed in this thesis through the following original contributions to knowledge.

### Deepened the understanding of Learning Design

Five key characteristics of LD have been identified together with a continuum of LD practices ranging from open-ended LD provision to orchestrated practices. This makes it possible to bring awareness to LD practices, including the effort required to actualise designs, the role of educational developers and educators during the process, the role of pedagogy theory and design aids, and what it takes to make LD sustainable — that is, the temporal aspect. This may also help to highlight less efficient LD due to the high institutional effort potentially associated with highly orchestrated LD practices.

In addition, the main perspectives and common interests in LD have been identified with STEM undergraduate education at AU ST as the case. This has revealed a general interest in a number of affordances of TEL potentially based on LD, which may be present in similar contexts.

### A concept of Efficient Learning Design

A holistic concept of ELD and its related assessment methodology has been introduced for qualifying educational decisions. ELD assesses the efficiency of LD as a result of the effort and impact of the three main stakeholders: the institution, the educators, and the students by means of a mixed methods methodology and a research matrix (Table 1). It includes a wide variety of aspects in the assessment including the compliance with institutional business and pedagogical aims, educator effort and impact on teaching, and student effort and impact on their learning. Furthermore, the methodology provides a way of classifying the outcomes in four scenarios according to the efficiency for each

intervention, for each perspective, and temporally by means of vectors. The identified interests may here serve the purpose of weighting the LD perspectives and revealing potentially compelling as well as inconsiderable factors with regards to the efficiency.

## Factors for Efficient Learning Design

A number of direct and indirect factors which influenced the LD efficiency have been identified. Some of these are related to the LD practice and process, others are related to the LD product. Most significant was the educator factor, including their motivation and persistence towards LD, but also factors related to students' perception of online learning; the aim, scale, and the level of the transformation. Additionally, the pedagogical integration of online activities played an important role and seemed to be linked with the outcome scenario and how this evolved over time. It appears, that most interventions start out progressive; but modules with little motivation and/or educator extrinsic motivation tend to move towards underperforming, while modules with a clear business-related aim tend to move towards outperforming (and later towards regressive). Modules with a primarily educator intrinsic motivation tend to stay progressive as development is seen as a goal in itself. This also means that certain kinds of interventions are at risk of becoming inefficient and/or one-hit wonders without appropriate measures.

## Implications and recommendations for practice

This project proposes a holistic approach to LD with a balanced focus on efficiency by adopting the concept of ELD and thus not overlooking any of the three main stakeholders and their efforts for and impacts of LD interventions. This may be supported by mapping interventions and their movements according to the four outcome scenarios of LD efficiency. The four scenarios, together with the ELD concept in general, may serve as tools for measuring performance, prioritising LD initiatives, and being cautious about the effort being put into the module as well as the impact the intervention has. And for the ultimate aim of this project of identifying the first step in letting LD provide quality education cost-effectively, a good place to start would be to either increase positive impact and/or reduce effort by transforming the modules that have the potential to become outperforming or progressive, or alternatively take a more regressive stand by minimising effort on modules that withstand it and spend the saved effort on impact and outreach elsewhere.

Furthermore, the temporal aspect played an important role in all interventions due to fading LD efficiency, a less efficient first run, a change in LD uptake, and/or enthusiastic

effort from the educator. Thus, it is recommended to assess the LD efficiency temporally and make sure that educators are continuously informed about the LD's impact on their students' learning (by means of evaluations, learning analytics, and other kinds of evidence), so that they do not fall back on old practices and/or or an uninformed redesign of their module (the P characteristic). At the same time, it is worth modifying expectations and thus accept that modules undergoing a large-scale transformation may experience a negative impact on grades and pass-rates in the first year. For interventions where the effort is potentially becoming excessive, it may also be relevant to bring awareness about the effort aspect to the educators, making them consider whether their practice and design is sustainable or not "worth the effort" (relates to the R characteristic).

A scrutiny of the four cases of LD at AU ST revealed a series of underlying factors related to the practice, processes, and products (see Chapter 6–7) of which some, in particular, the business aims, the educators' motivation and persistence towards LD model, and the pedagogical integration as well as the aspects related to student cohort size, reuse of materials, and students' preferences played an important role for the efficiency. These factors, the underlying indicators, and the weightings of the three perspectives may differ between contexts. Therefore, it is recommended to decide on a set of indicators and a weighting according to suitable levels of efficacy in the given context, and subsequently use these to identify local factors and establish a baseline of typical efforts and impacts of LD interventions for a more accurate assessment and interpretation of LD efficiencies.

Though the concept of ELD is not explicitly introduced to the educators at AU ST, its related assessment methodology as well as the identified LD characteristics and underlying factors for ELD are as of 2018 being used to inform both professional and educational development at AU ST. In practice, this is done by structuring the professional development programme for assistant professors according to the PLADR characteristics by introducing the concept of LD; introducing six existing and relevant LD models (including STREAM) based on pedagogy theory; and prompting the educators to use the LDTool for documenting, sharing, and reusing their individual designs. The aim is to make the educators become active designers that share and reuse practices and base their designs on pedagogy theory, and thus avert the one-hit wonder phenomenon. In the context of educational development at AU ST, the concept of ELD will have a more direct role. Recently, the faculty management has recently decided that all of the approximately 200 undergraduate modules needs to be improved within the next five years by means of educational technology. This requires a highly efficient approach as well as evidence of the effort and impact associated with the

transformations for the management; data about the impact on the students for the educators; and data for STLL to assess the outcome scenarios, identify and/or validate underlying factors for ELD, and for the supervision of educators. Consequently, an updated research matrix and surveys are in development based on the concept of ELD, its assessment methodology, and the available data and IT services.

## Limitations of the project

Though most data have been methodological, data, and/or investigator triangulated; modules have been sampled to ensure maximum variation; and literature has been reviewed to put the project in a larger context, the project does entail a number of limitations regarding validity and reliability of the findings, a limited time frame, and a concept of LD build on a slim foundation.

### Validity and reliability

A series of limitations are associated directly with the action research methodology due to the direct influence of the researcher and potential vested interests, the many uncontrollable variables, the context, and the many measures of learning, which are not exact science in the traditional sense. Thus, more research is needed to validate the findings of the project and to make the recommendations transferable to other LD settings; subject areas; programme levels (e.g., postgraduate); STEM teaching components such as laboratory experiments and fieldwork; and institutional contexts in which, for instance, additional stakeholders may play significant roles for LD. In most cases it was possible to validate the results with other data and methods within the project. However, the underlying case of AU ST may in theory be unique making it difficult to directly transfer findings.

Another limitation associated with the pragmatic, expedient approach taken in this project is how the surveys had to be constructed with respect to previous evaluation surveys and/or external demands. In the context of this project this has caused inconsistent and/or unbalanced Likert scales in order to be compatible with previous surveys and provide data for the institution as well as less representative samples in the educator and student perspective surveys due to organisational bounds between the previous Faculty of Science and School of Engineering. However, these limitations are a part of action research, accepting the premise that the research is also oriented towards educational development practice in which the researcher is hired to develop.

Furthermore, though much data has been collected and analysed, it has not been possible to uncover the modules, educators, and the associated learning activities completely as activities happens and content is being presented in-class; students collaborate; the educator is in individual dialogue with students; educators are being inspired by other modules and peers; students are being influenced by others; and due to various other undocumented circumstances. Thus, the designs and efficiencies may have rival causes that are unknown to the researcher.

## The Learning Design concept

The literature review revealed much controversy about the LD concept and to what extent it is a synonym for instructional design, whether it is pedagogically neutral, and its required level of orchestration. Investigating a concept that is ill-defined and carries diverse perceptions, correspondingly, limits the direct application of the findings to contexts with similar LD concepts. To compensate for this slim foundation, the thesis has presented a collected understanding of LD based on five common characteristics identified in the literature and existing practices.

## Recommendations for future research

Besides addressing the aforementioned limitations, the project has also identified a concept of ELD, which would be relevant to further trial and qualify in different contexts. This includes a further scrutiny of the temporal aspect of ELD in other open-ended practices, a development a score sheet to support the efficiency assessment, and a further exploration of direct and indirect factors for ELD. The latter would also include experimenting with diverse weightings of the perspectives as well as diverse sets of effort and impact indicators based on actual, local priorities.

## Further exploration of the factors

The project has identified a number of direct and indirect factors that potentially influence the efficiency of LD interventions as well as a series of stakes in LD. Thus, it would be relevant to further understand why these interests and factors were important and how LD can be optimised so that a high impact at a low effort is actualised. In particular, further scrutiny of the interests located in the intersections of Figure 52 would be a fruitful area to study, and whether supporting these is a way to provide ELD.



## Practical assessment

Likewise, it would be relevant to test the assessment matrix (Table 1) on various occasions in order to simplify it and make it more practical by transforming it into a score sheet in which the three vectors were calculated automatically by means of the weightings provided in Table 8 and the actualised efforts and impacts. As a result, the development of a LD score sheet for assessing future LD interventions at AU ST is in development inspired by the EDUCAUSE 'Learning Space Rating System' initiative (2017) and its related score sheet.

## The temporal aspect in open-ended practices

The temporal aspect of LD turned out to play an important role for the overall efficiency. Firstly, due to the reuse of materials and teaching practice and, secondly, due to educators change in practice. Research on barriers (Ertmer, 1999), educator beliefs (Guskey, 1986), and learning analytics are already providing potential pointers of where to look for explanations and answers suggesting that educators need to see the impact on their students' learning first-hand or through analytics; that there is a need for an entire practice of open-ended, supported, and effort-impact-balanced LD delivery; and that it needs to be related to the underlying LD model. However, it would also be relevant to scrutinise the educators' perception of STREAM and LD in general as well as the second-order barrier of what it takes to accommodate their academic freedom while keeping them persistent in their delivery of ELD over a longer period of time in an open-ended LD practice. For instance, a prolonged study would make it possible to examine whether the educators fall completely into their pre-intervention teaching practices — and we are back at the one (or two)-hit wonder phenomenon — or they realise that they are also going through a learning process and LD support is needed for revitalising their transformed practice.

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# Appendix A: Terminology

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Concepts and terms whose meaning is not evident, are generally explained throughout the text. Nevertheless, a few concepts and terms are pivotal for reading the thesis and may have diverse understandings, and thus explained here:

- *Affordance*: In the context of this thesis, the concept refers to the potential and/or possibilities of TEL based on LD. That is, 'what it can be used for'. Further clarification is provided in the introduction.
- *Augmentation*: Describes a blended learning delivery method in which educational technology (or educational IT) 'is used for enhancing activities or transforming components' (Godsk, 2014a; see also Figure A1).
- *Bachelor*: Equivalent to *undergraduate* when referring to a degree or programme.
- *Components*, sometimes also referred to as *teaching activities*, refers to lectures, group work/theoretical exercises, lab exercises, fieldwork, examination, and supervision.
- *Efficacy*: In the context of this thesis, the concept refers to the ability of a LD intervention to actualise its aims satisfactorily and thus directly relates to the impact aspects.
- *Efficient Learning Design* or *ELD*: A concept developed for this research to describe a positive ratio between effort and impact of LD interventions. The concept is further unfolded in Methodology and in Discussion.
- *Indicator*: In the context of this thesis, the term refers to the measurable variables that are used to describe a LD practice, including the different perspectives, aspects, and stakes in LD.
- *Learning Design* or *LD*: A concept that refers to both a process (as a verb), a product (as a noun), and a practice (as a noun) of educational development. Further clarification is provided in the literature review section.

- *Learning path*: Also known as *learning pathways*. In the context of this thesis, the term refers to a sequence of online items such as texts, video and multimedia material, and activities implemented in a LMS such as Blackboard or Sci2u.
- *Modification*: Describes a blended learning delivery method in which educational technology (or educational IT) 'is used for transforming entire activities' and components, such as replacing lectures with online learning (Godsk, 2014a; see also Figure A1).
- *Redefinition*: Describes a delivery method in which educational technology (or educational IT) completely transforms or reinvents a module into online learning (Godsk, 2014a; see also Figure A1).
- *STEM* is an acronym for the academic area (including programmes) of Science, Technology, Engineering, and Mathematics.
- *TEL*, short for Technology-Enhanced Learning, is an inclusive term, which in the context of this thesis refers to teaching and learning enhanced or transformed by means of web-mediated, educational technology.
- *Undergraduate*: The term refers to the academic levels between admission to university and up to the level of a university bachelor's degree. In the context of the thesis, the term does not cover professional bachelor's degrees, but does include engineering programmes.

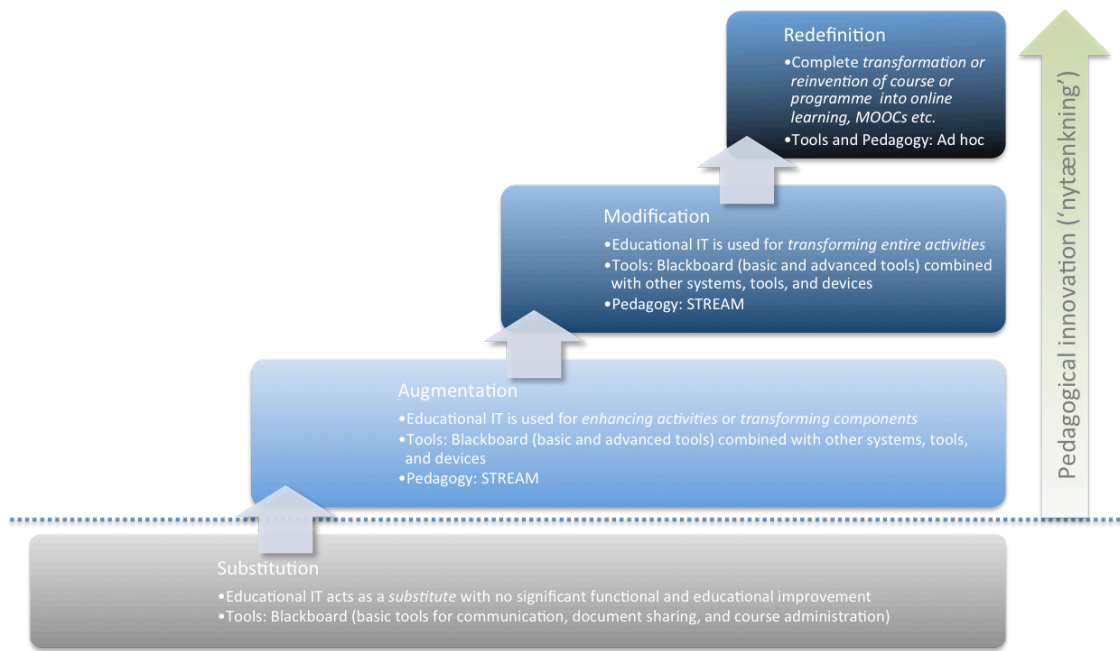


Figure A1. The revised SAMR model (Godsk, 2014a).





# Appendix B: Ethics proforma

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The Open University

From Dr Duncan Banks  
Chair, The Open University Human Research Ethics Committee  
Email duncan.banks@open.ac.uk  
Extension 59198

To Mikkel Godsk, Institute of Educational Technology

Subject *"Improving Learning by Transforming Science Higher Education into Active Blended and Online Learning by Means of Operational and Efficient Learning Design."*

Ref HREC/2014/1769/Godsk/1  
AMS (RED) 107346  
Submitted 18 November 2014  
Date 20 November 2014

## Memorandum

This memorandum is to confirm that the research protocol for the above-named research project, as submitted for ethics review, has been given a **favourable opinion** by the Open University Human Research Ethics Committee. Please note that the OU research ethics review procedures are fully compliant with the majority of grant awarding bodies and their Frameworks for Research Ethics.

Please make sure that any question(s) relating to your application and approval are sent to [Research-REC-Review@open.ac.uk](mailto:Research-REC-Review@open.ac.uk) quoting the HREC reference number above. We will endeavour to respond as quickly as possible so that your research is not delayed in any way.

At the conclusion of your project, by the date that you stated in your application, the Committee would like to receive a summary report on the progress of this project, any ethical issues that have arisen and how they have been dealt with.

Regards,

Dr Duncan Banks  
Chair OU HREC

The Open University is incorporated by Royal Charter (number RC 000391), an exempt charity in England & Wales and a charity registered in Scotland (number SC 038302)

HREC\_2014-1769-Godsk-1-approval

*Figure B1.* The ethics approval of the project 20 November 2014.



# Appendix C: Interview transcription symbols

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The following set of symbols were used for the transcription of the interviews. The set is based on Silverman (2013, p. 442), adapted from Atkinson and Heritage (1984), and adjusted and supplemented with additional colour markings as required.

- (Pause: 0.0s): Timed pause
- “-”: An abrupt cut-off
- “(...)”: Something is being said, but no hearing can be achieved
- (...): Utterance and/or laughter
- \_\_\_: Underlining: something is being stressed by means of pitch and/or amplitude
- \*: A break
- #: Indication of uncertainty of transcription and transcriber comments
- Additional markings:
  - Colour red: no hearing can be achieved but it is potentially audible in other conditions. Sometimes marked with an indication of time.
  - Colour green: Interruptions
  - Colour blue: Action and/or diverse, relevant comments and observations



# Appendix D: Design and learning sciences

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As expressed by Herbert Simon, design 'is concerned with how things ought to be, with devising artifacts to attain goals' (Simon, 1969, p. 114) and as highlighted by Laurillard 'teaching has always been recognized as an art, because it demands creativity and imagination' (Laurillard, 2012, p. 1). Consequently, designing teaching may be considered as an art based on creativity and imagination. However, as stressed by van Aken and Romme (2009) there is a growing pressure on professionals working with design to base their practice on evidence. A response to this challenge is research on teaching and learning as a design science (Laurillard, 2012; Mor & Winters, 2007).

In the context of TEL and LD, design science aims to build design principles and heuristics that support the way that the technology changes the learning process (Laurillard, 2012). An outcome of this work is the aforementioned *design patterns*, which are considered as a 'powerful way of providing structured, teacher-friendly, textual representations of LDs, or of expressing the design rationale underlying learning objects' (Garzotto & Retalis, 2009, p. 133). However, though the concept is tempting and allows a convenient and supportive way of turning theory into practice and to improve quality and potentially lower costs, a number of potential drawbacks have also been identified, which includes the difficulty of adapting and reusing patterns, and the current lack of empirical evidence of its actual effect on learning (Garzotto & Retalis, 2009).

This lack of evidence, however, is highly in focus in the related approach *scientific teaching* (Handelsman et al., 2004), which is currently gaining footing in the context of science and STEM education. Scientific teaching includes a focus on active learning, assessment tools, student-centred learning, and is characterised by '...teaching methods that have been systematically tested and shown to reach diverse students' (Handelsman et al., 2004, p. 521; Handelsman et al., 2007). Though scientific teaching does not promote design patterns, it shares the same belief as design science that teaching practices and their methods should be based on evidence. Ideally, scientific teaching should strive to bring 'the rigor of the research lab to [the educators'] classrooms' and the practice should be based on controlled experiments comparing teaching strategies with student achievement according to Handelsman et al. (2004, p. 522)

*The Learning Sciences* overlap with design science in terms of deploying a scientific approach to testing how interventions impact practice (Sawyer, 2006). The learning sciences, however, reject the experimental and quasi-experimental methodologies to evaluate students' learning and, instead, adopt a design-based approach. According to Sawyer, learning sciences combines several different approaches to studying learning, which includes cognitive science, constructivism, educational technology, sociocultural studies, and 'the nature of knowledge work' (Sawyer, 2006). With regards to educational technology, the learning sciences hold the belief that the reason for unsuccessful applications of technology is often due to instructionist-oriented designs. As a contrast 'learning sciences suggests that the computer should take on a more facilitating role, helping learners have the kind of experiences that lead to deep learning — for example, helping them to collaborate, or to reflect on their developing knowledge' (Sawyer, 2006, p. 8).

## Design thinking

Like design as a science, design thinking dates back to Simon and the later book *Design Thinking* by Rowe (1987). Design thinking is also related to design science in terms of focusing on the design process; however, aside from this there is limited literature and research on what this concept actually entails. Critics such as former Berkeley professor Protzen even argues that 'it appears that D-T [sic] is just a new catchphrase, which, at best, is confusing and at worst, plain meaningless' (2010, p. 1). Nevertheless, Koh et al. (2015, p. 535) stresses that though design thinking is an ambiguous concept it usually refers to 'the act of creating new products, services, or experiences'. In addition, like design-based research, design thinking sees the design process as iterative. That is, the designer will learn through the process and as a consequence potentially redefine initial ideas and solutions (Wikipedia, 2014). This is, incidentally, the essence in the approach to educational development proposed by Tsai and Chai (2012) in Chapter 1: that the educators must acquire this thinking in order to overcome all three levels of barriers. Design thinking is in contrast to design patterns, which assume that designs can be reused in equivalent settings.

## Design-based research

The idea of design-based research dates back to the early 1990s when the method was introduced by, among others, Brown (1992, p. 141) to address the complexity in developing 'innovative educational environments and simultaneously conduct experimental studies of those innovations'. LD is often associated with this methodology

or the associated idea of learning sciences (Conole, 2013; Laurillard, 2012; Mor & Winters, 2007; Sawyer, 2006) due to their ability to provide and capture a more holistic image of technology in the educational practice as opposed to experimental and correlational research designs (Amiel & Reeves, 2008). Like AR, design-based research entails a potentially extensive, iterative process and aims at authentic settings. Design-based research has a strong focus on controlling variables and minimising the influence of the researcher on the findings, and thus, to a minor degree supports the active role of the researcher in an evolving practice as emphasised in AR (The Design-Based Research Collective, 2003; Gravemeijer & Cobb, 2006; Herrington, 2012; Majgaard et al., 2011). Its ability to minimise the influence of the researcher, however, has been questioned by Lorentzen (2016) who through a discourse analysis of literature on teacher training ascertains 'that the researcher holds the power, and that the teacher is viewed as a passive object' (2016, p. 54).





# Appendix E: Learning Design inventories

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Two inventories of teaching and learning with LD respectively were deduced (see also Chapter 3).

## **Section A: Educators' knowledge of and experience with technology, TEL, and Learning Design**

- experiences with TEL as an educator
- knowledge of and/or experiences with Learning Design

## **Section B: Educators' perception of (including attitude toward) technology, TEL, and Learning Design**

- perception of the potential for educational technology in STEM education
- perception of the potential for Learning Design in STEM education
- perception of the amount of effort associated with Learning Design
- (future plans for Learning Design)

## **Section C: Effort and impact factors important for their adoption of Learning Design**

- That the technology is easy to adopt and deploy
- That you can reuse the digital materials in later teaching
- That you can share the digital materials with peers
- That the technology improves students' learning
- That the technology increases the grades and/or pass-rates
- That the technology provides more flexible learning to the students
- That the technology improves student satisfaction
- To develop as a teacher (personal development)
- To reach new groups of students (e.g., with distance education)
- Acknowledgement by the management
- Acknowledgement by peers
- Acknowledgement by the students (i.e., that they prefer the digital format)
- Easy access to educational and pedagogical support
- Easy access to production support (e.g., Science Media Lab and similar)
- Easy access to a knowledge exchange and networking group with peers
- Easy access to technical support (incl. Blackboard functionality) (see also Godsk, 2009)

Inventory of teaching with Learning Design.

The deduced *Inventory of teaching with Learning Design* is provided above and the *Inventory of learning with Learning Design* is provided below. The characteristics (also referred to as *scales* or *items*) are phrased as statements and the notes in brackets refer to their underlying categories. The Section B categories originate from Section C in the ASSIST inventory (Entwistle et al., 2013, p. 19). In Section C and D, the categories originate from the CEQ scales (Graduate Careers Australia, 2010; 2013) and Price and Kirkwood's (2011) affordances. In practice, this means that the items have been phrased

to cover the 11 TEL affordances identified by Price and Kirkwood (2011, p. 3) as well as the three compulsory and the relevant optional scales in the CEQ inventory (see Graduate Careers Australia, 2013, pp. 1–2).

#### **Section A: Students' incentives for studying**

- to get an education/degree [extrinsic motivation]
- to learn the subject [intrinsic motivation]
- for personal development [intrinsic motivation]
- for prestige and/or social status [extrinsic motivation]
- to improve my chances for a good job [extrinsic motivation]
- other...

#### **Section B: Students' teaching type preferences**

- 'lecturers who tell us exactly what to put down in our notes' [surface approach]
- 'lecturers who encourage us to think for ourselves and show us how they themselves think' [deep approach]
- 'exams which allow me to show that I've thought about the course material for myself' [deep approach]
- 'exams or tests which need only the material provided in our lecture notes' [surface approach]
- 'courses in which it's made very clear just which books we have to read' [surface approach]
- 'courses where we're encouraged to read around the subject a lot for ourselves' [deep approach]
- 'books and other learning materials which challenge you and provide explanations which go beyond the lectures' [deep approach]
- 'books and other learning materials which give you definite facts and information which can easily be learned' [surface approach] (Entwistle et al., 2013, p. 19)

#### **Section C: Students' perception of the technological affordances**

- that I can study from where I want and not always have to come to campus [flexibility and Learning Resources]
- that I can repeat lectures and other teaching activities as I prefer [students' revision and reinforcement, flexibility and Learning Resources]
- that feedback is provided on my learning progress, my assignments, and answers to my questions [feedback and Good Teaching]
- that I learn to link theory to practice [link theory and practice and Graduate Qualities and Generic Skills]
- that I develop my skills for a future job [prepare for life beyond university and personal development and Graduate Qualities and Generic Skills]
- that the teaching supports collaboration and interaction with my peers [Learning Community]
- that teaching and learning is enjoyable [Good Teaching, Intellectual Motivation, student satisfaction]
- that the examination reflects the curriculum and skills we are supposed to have learnt [support appropriate assessment, Appropriate Assessment]
- that the teaching is in complete concordance with the formal requirements (i.e., learning goals and the time it takes to complete a module [Appropriate Workload]

#### **Section D: Students' preferences regarding workload and learning with technology**

- I am willing to spend more time on studying if I feel learn a lot [Appropriate Workload]
- I am in general positive towards new initiatives in teaching that involve the use of new technology
- (I prefer spending more time studying at home than attending teaching on campus)

Inventory of learning with Learning Design.

# Appendix F: Threats to validity

Overview of identified threats to validity and reliability and the associated measures in terms of methodological, data, and/or investigator triangulation is provided in Table F1.

Table F1

*Overview of identified threats to validity and reliability and the associated measures*

<b>Methods and threats to validity and reliability</b>	<b>Measures (Triangulation)</b>
The senior management interview and review of documents includes a potential political agenda as well as the problem of confidentiality and loyalty. The management may not be interested in full openness about their perception and attitude towards technology in education. Furthermore, as the researcher is being professionally affected by their decisions, the interview entails a problematic dual role.	Several sources are used to directly or indirectly reveal the stakes of the management. Furthermore, the interview is analysed in the light of the role of the interviewer.
The interpretation of qualitative data in interviews (comments) and observations.	The coding of the qualitative data will be explicit and the findings will in most cases be supplemented with quantitative data.
Low response rate in surveys.	A confidence rating will be calculated for the survey. Furthermore, other data that describes the similar aspects is being collected to triangulate data, and thus compensate, for a potentially low response rate.
Representativeness of educators in the survey.	Only educator responsible for science modules were directly included in the survey, which nevertheless cover most of the educators except for junior educators and educators on the engineering programmes. This limitation is addressed in the interpretation of the results in Chapter 5–7. However, in practice educators would have double roles, which means that also engineering educators are represented (see Appendix H).
Representativeness of the students in the survey.	Only first-year science students have participated in the survey. No direct measures are taken, but the full data about dates and semester are provided as a frame of reference for the interpretation.
The observed STREAM compliance	Aspects of the compliance may be overlooked or misunderstood. As a consequence, the results are intercoder reliability tested.
The educator may have a vested interest in expressing a particular effort and/or impact related to the learning design intervention in the interviews.	Will be addressed by asking different questions about related topics in the educator interviews (see Appendix P for more details).
The categories and content of the interviews.	The educator interviews may be interpreted differently. To address this an intercoder reliability test will be carried out (see Appendix P).
The educators' and students' awareness of the intervention may influence their responses positively (the Hawthorne effect) or negatively in the interviews and surveys.	Some studies suggest that the Hawthorne effect is insignificant and a natural outcome of transforming learning (Brown, 1992); however, to address this, results from students' participation in more than one transformed module are being scrutinised.
Each transformation is being assessed partly based on a student survey with a varying response rate.	A confidence rating will be calculated for each survey. Furthermore, other data that describes similar aspects is collected to triangulate data, and thus compensate for a potentially low response rate.
The students may have good or bad previous experiences with educational technology and a picture-perfect perception of face-to-face lectures. These perceptions may bias their view on the technology interventions expressed in the surveys.	The students are asked to comment on and elaborate their answer about preferred teaching format, which may help identifying misconceptions and picture perfects. In cases with a pronounced misconception their comments are scrutinised.

<p>Low consistency of data. The data about student enrolment and activity in the LMS is not necessarily completely consistent with the actual level of activity and cohort.</p>	<p>The data provided by the LMS is compared with the data available in the study administrative system. If any (major) inconsistencies arise the study administration will be contacted for a clarification.</p>
<p>Outliers, low ratio of respondents to variables, and low sample size may pose a threat to the validity of the correlations and other statistical findings.</p>	<p>Survey responses that are clearly not valid (outliers) are excluded and margins of error are calculated with a confidence interval of 95%.</p>
<p>The validity of the concepts 'efficiency' and 'learning design' and thus also the validity of the assessment results.</p>	<p>Descriptions and definitions of the concepts are included in the thesis to provide a frame of reference for the research. However, in both cases this is fundamentally an epistemological discussion of how to know LD is efficient with the ontological position that it is possible to design (for) learning. However, to qualify the discussion the identified general stakes in LD are used to weight the findings of the interventions and the assessment of efficiency. In addition, different interpretations of the efficiency score will be provided according to the institutional, educator, and student stakes in learning design.</p>

# Appendix G: The institutional perspective

The institutional perspective was analysed by means of an interview with the PVC for education carried out on 15 December 2016 (see the interview guide in Table G1) and through a review of documents such as strategies, working papers, announcements, and websites.

Table G1

*The PVC interview guide (translated from Danish)*

0	<ul style="list-style-type: none"> <li>The purpose of the interview is to get the institutional perspectives on what effective teaching with educational IT is. It is part of my PhD on the learning design approach and its potential for improving teaching efficiency using educational IT.</li> <li>I have read what I could find on strategies and news that elucidates the attitude of AU, but to get a deeper understanding I would really like to interview you about this, including what other expectations and intentions you have of educational IT on AU.</li> <li>All answers are treated confidentially and is for this research purposes only, but I would of course like to use the results later if they were to show something worthy of scrutiny.</li> <li>Therefore, if there is something you think is problematic, sensitive information, or wish not to answer, please let me know.</li> <li>Ask if I can record the interview for my own sake (not shared with others).</li> </ul>	Disclaimer
1	<p>By way of introduction: Overall: What do you regard as the primary role(s) of educational IT at Aarhus University?</p> <ul style="list-style-type: none"> <li>Why especially &lt;roles&gt;?</li> <li>Something you think is not the role of educational IT?</li> <li>And in the long term? What do you regard as the role of educational IT in the future? (Larger/smaller, Special roles?)</li> </ul>	Outlook and vision
2	<p>Looking at the 2011 policy of educational IT (Den Faglige Udviklingsproces, pp. 64–65) lists a number of intentions with/roles for educational IT with different characteristics:</p> <p>Some are inward (based on the 50 % objective and its inherent challenges):</p> <ul style="list-style-type: none"> <li>Supporting the <b>competence development of the students</b></li> <li>Developing of the IT skills of [the students]</li> <li>Students are becoming more skilled and more engaged through the use of modern and relevant technological solutions</li> <li>Personalization of user interfaces and personal learning environments is part of educational IT, thus supporting the teaching and its activities as well as the learning processes of the students.</li> <li>Interaction between students as well as between students and educators.</li> <li>Effective opportunities for ongoing feedback, knowledge sharing, and collaboration</li> <li>Solid <b>teaching and study environments</b></li> <li>Flexible <b>implementation of the internal education market</b></li> <li><b>Give 60% of all educators an offer of a transformation</b> of a course of study (by 2015). The Development Contract for 2015–2017 has a section 1.3 about "modern courses of study and proceedings" (85%)</li> </ul> <p>Some are directed outwards:</p>	<p>Business capacity,</p> <p>improve students' learning, engagement, and skills; improve the study environment, provide effective tools for feedback, collaboration, interaction, and communication, support teaching differentiation through digital media, upskill the educators, provide 'rethinking'/development assistance to 60% of all educators by 2015, support the educators' teaching development and practice, provide technical support for more flexible, interdisciplinary study programmes, -- introduce modern technology in teaching practice and</p>

<ul style="list-style-type: none"> <li>• to be known as a <b>modern university</b>, which sets the international standards for teaching</li> <li>• <b>Recruitment of the best students</b></li> <li>• that Aarhus University can continuously <b>provide attractive bachelor's, master's, and PhD students</b> to the public and private labour market</li> </ul>	<p><b>appear as a modern university,</b></p> <p><b>increase candidates' popularity,</b></p> <p><b>recruit the best students,</b></p>
<p>To what extent are these still relevant?</p>	
<p>Has new arrived since then? <del>Is anybody missing (do you see others)?</del> (eg distance learning)</p>	
<p><b>3</b> As you know, the university is challenged by a number of external requirements, policies, and framework conditions, including:</p> <ul style="list-style-type: none"> <li>• The profile model (reduce costs, increase intake, and completion rate),</li> <li>• The Study Progress Reform,</li> <li>• the reallocation contribution</li> <li>• the institutional accreditation</li> <li>• continuous political reports</li> </ul>	<p>Fulfilment of the profile model (The Danish Ministry of Education, 2014b) - i.e., cut costs, increase intakes, and increase completion rates.</p>
<p>Does educational IT play a role in this context? (Directly or indirectly – in relation to one or more of these?) If so, which and to what extent?</p>	
<p><b>4</b> Are there other financial or commercial intentions or objectives with educational IT at AU?</p>	<p>For example, savings or increased earnings and/or retaining students?</p>
<p><b>5</b> Are there any plans for new initiatives (in the broadest sense) to support the use of educational IT at AU? And if so, which?</p>	<p>Conferences, IT systems, Something that addresses barriers</p>
<p><b>6</b> Yesterday, I sent you a survey about what is important for the teaching at AU of which you highlighted:</p> <ul style="list-style-type: none"> <li>• that the students learn to link theory to practice ('at de studerende skal lære at linke teori til praksis')</li> <li>• that the examination reflects the curriculum and skills the students are supposed to have learnt ('at eksamen reflekterer det pensum og færdigheder, som de studerende forventes at have lært')</li> </ul>	
<p>as important. Why are these particularly important?</p>	
<p>Likewise, you have marked:</p>	
<ul style="list-style-type: none"> <li>• that the students can repeat lectures and other teaching activities as they prefer</li> <li>• that the students can study from where they want and do not always have to come to campus</li> <li>• that the teaching supports collaboration and interaction among the students</li> </ul>	
<p>as less important. Why exactly these?</p>	
<p><b>7</b> Finally I would just like to ask: On a scale from strongly agree to strongly disagree, to what extent do you think there is potential for educational IT in teaching at AU</p> <ul style="list-style-type: none"> <li>• strongly agree</li> <li>• agree</li> <li>• neither agree nor disagree</li> <li>• disagree</li> <li>• strongly disagree</li> <li>• not applicable/don't know</li> </ul>	
<p><b>8</b> To keep the record straight, I would like to know if you have any other comments regarding the subject?</p>	<p>Other documents that could be relevant for me to look at in relation to the intentions/attitudes towards educational IT at AU?</p>

The official strategy and policy documents were found on the university’s website; the working documents were shared by the PVC or other senior staff; and the announcements and website were found through a Google search on the institutional website. This search also served as a way of ensuring that no common, public documents would be overlooked. The search was carried out on 23 March 2017 using the search string “educational IT” site:au.dk’ in *incognito mode*, and the top 50 results were subsequently filtered so that only resources representing the institutional perspective or the ST perspective were scrutinised. Excluded results were local news from other faculties; published articles including 'educational it' in the title, information about courses in the LMS or similar educational IT related topics; and double occurrences due to various language versions. This left 15 documents, which are listed in the casebook in Table G2.

Table G2

*The casebook of the institutional resources used for the analysis*

Resource	Resource type	Year	Period
Educational_IT_paa_AU	Strategy or policy	2010	2010–2012
Nye it-systemer	Announcement	2011	2010–2012
Policy for educational IT 2011	Strategy or policy	2011	2010–2012
News - Et moderne universitet er for de mange	Announcement	2011	2010–2012
Studerende får nyt fælles it-system	Announcement	2012	2010–2012
Strategy2020_text-only_160513	Strategy or policy	2013	2013–2017
Video teaching replaces traditional university lectures	Announcement	2014	2013–2017
News - Godt studiemiljø kan stadig forbedres	Announcement	2014	2013–2017
Aarhus University's development contract 2015 – 2017	Strategy or policy	2014	2013–2017
Seminar on Educational IT 8 October - changes to programme and venue	Announcement	2015	2013–2017
News - Successful internal seminar on educational IT	Announcement	2015	2013–2017
Digitisation_strategy_okt2016	Strategy or policy	2016	2013–2017
Notat fra studieture med UFU 2016	Working document	2016	2013–2017
Media Lab	Website	2017	2013–2017
Visio-EDU_IT_v2	Working document	2017	2013–2017

The documents and PVC interview were then coded according to the research matrix (Table 1). The count of codings, categories, and subcategories are provided in Table G3, and a condensed overview of the institutional and governmental aims potentially associated with TEL based on LD is available in Table G4. See also Appendix J for a cross-case query with the complete set of categories, subcategories, and count of codings of both the institutional and the general educator perspective as represented in the survey comments.



Table G3

*The complete set of categories, subcategories, and count of codings*

Name of category and codes	Sources	2010– 2012	2013– 2017	PVC 2016*	References
Descriptive	14	34	25	13	120
Effort	10	9	7	4	20
Digital competencies	1	0	1	0	1
Funding and provisions	5	3	3	0	6
Strategy	6	6	3	4	13
Impact	11	25	22	12	100
Business potential	8	14	8	7	36
Branding	1	3	0	0	3
Competitive parameter	1	0	0	1	1
Completion	1	0	0	1	1
Cost-effectiveness	3	1	1	3	5
Digitisation	1	0	0	1	1
Educator preparation	1	1	0	0	1
Educator satisfaction	2	0	2	0	2
Increased intake	2	2	0	0	2
Organisational development	1	0	0	1	1
Professional development of educators	4	3	3	0	6
Programme flexibility	2	2	0	0	2
Recruitment of students	4	3	1	5	9
Retention	0	0	0	0	0
Scholarship of teaching and learning	1	1	0	0	1
Time efficiency	1	0	1	0	1
Educational limitations	1	0	0	4	4
Educational potential	11	16	19	5	60
Accommodate student diversity and support pace flexibility	4	2	5	0	7
Alignment	1	0	0	1	1
Communication and collaboration	2	4	1	0	5
Digital competences	2	1	0	2	3
Digital expectations	2	0	1	2	3
Employability of candidates	3	1	1	1	3
Feedback	2	1	1	0	2
Flexibility in time and place	1	0	1	0	1
Grades and pass-rates	1	0	1	0	1
Modern teaching	3	2	2	0	4
Multimedia-supported learning	1	1	0	0	1
Personalised learning	2	1	1	0	2
Quality in education	9	5	7	2	14
Skills development and competencies	3	0	3	1	4
Student satisfaction and engagement	3	0	3	0	3
Student-centeredness	0	0	0	0	0
Study environment	4	2	2	1	5
Study intensity	1	0	1	0	1
Interpretive	5	0	4	8	12
Governance in practice	4	0	3	2	5
Perception of educational technology and TEL	2	0	1	6	7

Residual	0	0	0	0	0
Den didaktiske trekant	1	1	0	0	1
Educator requirements	1	1	0	0	1
Overall strategic goals	2	0	4	0	4

\*This refers to the PVC interview conducted in 2016.

Table G4

*The identified government and institutional aims potentially associated with TEL*

Aims for TEL
<ul style="list-style-type: none"> <li>• Employability of candidates</li> <li>• Cost-effectiveness of educational institutions [business potential]</li> <li>• Digitisation strategy [business potential]</li> <li>• Recruitment of the best students [business potential]</li> <li>• Quality in education aspects: [educational potential] <ul style="list-style-type: none"> <li>○ alignment between examination and curriculum</li> <li>○ link theory to practice and provide job skills,</li> <li>○ motivation</li> </ul> </li> <li>• Student diversity [business potential]</li> <li>• Completion rate/retention [business potential]</li> <li>• Study environment [educational potential]</li> <li>• Digital competences [educational potential]</li> <li>• Digital expectations and provide modern teaching (branding) [business potential]</li> <li>• Student satisfaction [educational potential]</li> <li>• Professional development of educators [business potential]</li> <li>• Collaboration/interaction among students [educational potential]</li> <li>• Feedback in terms of meetings between students and educators (according to 'the didactic triangle') [educational potential]</li> </ul>

The labels in brackets refer to type of potential (i.e., *educational* or *business*).



# Appendix H: The educator perspective survey

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## Questionnaire

The questionnaire for the online educator survey is provided in Figure H1. Besides background data, the questions are based on the Inventory of teaching with Learning Design and Section C in the Inventory of learning with Learning Design (Appendix E). Notice the description of the concept of educational technology, which was included to ensure that the educators would actually know what the concept refers to.

## 'UndervisningsPuls' Survey

*English version below*

ST er ved at kortlægge den nuværende undervisningspraksis ved fakultetet samt afklare, hvad der skal til for at skabe såkaldt "tidssvarende undervisningsforløb" (jf. punkt 1.3 i AU's udviklingskontrakt).

For at fakultetet kan handle på så oplyst et grundlag som muligt, vil vi derfor gerne have dine (dvs. alle kursusansvarlige ved fakultetets) svar på de følgende 8 spørgsmål. Spørgsmålene er formuleret på engelsk af hensyn til vores ikke-dansktalende kolleger. Vi håber ikke, det måtte forvolde forståelsesmæssige problemer.

Spørgeskemaet tager i alt godt 10 minutter at gennemføre og besvarelsen er anonym. Skulle du have spørgsmål til undersøgelsen, er du velkommen til at kontakte Mikkel Godsk, Center for Scienceuddannelse: godsk@cse.au.dk

Vi sætter stor pris på din deltagelse.

Venlig hilsen, Center for Scienceuddannelse

### **In English:**

ST is analysing the current teaching practice at the faculty and identifying necessary initiatives to modernise this practice according to the institutional strategy.

In order to qualify the analysis and initiatives we would like your opinion on the following 8 questions.

The survey is estimated to approx. 10 minutes and your response is anonymous. Should you have any questions please do not hesitate to contact Mikkel Godsk, Centre for Science Education, godsk@cse.au.dk

Your participation is highly appreciated

Best wishes, Centre for Science Education

### **Background Information**

What is your position?

- PhD Student
- Post doc
- Assistant Professor
- Associate Professor
- Professor
- Researcher
- Senior Researcher
- Other

To which programme(s) are your course(s) associated? Tick any that applies.

- Agro-Environmental Management
- Agrobiology
- Astronomy
- Bioinformatics
- Biology
- Chemistry

- Computer Science
- Engineering (all engineering programmes)
- Geoscience (Geology)
- Geophysics
- IT
- IT Product Development
- Mathematics
- Mathematics - Economics
- Medicinal Chemistry
- Molecular Biology
- Molecular Medicine
- Molecular Nutrition and Food Technology
- Nanoscience
- Nanoscience and Neuroimaging
- Physics
- Science Studies
- Statistics
- Sustainable Animal Nutrition and Feeding
- Other

What kind of teaching activities are you undertaking (tick any that applies)?

- Lectures
- Group work/theoretical exercises (TØ)
- Lab exercises (LØ/PØ)
- Fieldwork
- Examination
- Supervision
- Other

### Your Teaching Approach

To what extent do you find the following aspects important to your teaching in general?

	a very high extent	a high extent	a certain extent	a limited extent	a very limited extent	not at all	don't know/not applicable
that the students can study from where they want and do not always have to come to campus	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
that the students find the teaching and learning is enjoyable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
that the students develop skills for a future job	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
that the examination reflects the curriculum and skills the students are supposed to have learnt	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
that the students learn to link theory to practice	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
that feedback is provided to the students' learning process, their assignments, and answers to their questions	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
that the teaching supports collaboration and interaction among the students	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
that the teaching is in complete concordance with the formal requirements (i.e. learning goals and the estimated study time/ECTS)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
that the students can repeat lectures and other teaching activities as they prefer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

## Your View on Educational Technology (including 'Educational IT')

'Educational Technology' is a wide concept, which encompasses educational IT, e-learning, technology-enhanced learning, etc. and usually refers to digital technologies that are used for teaching and/or learning such as clickers, tablets, smartpens, video, video conference, weblogs, and e-learning platforms such as Blackboard, AULA, CampusNet, and CourseAdmin.

Do you have any prior experience with educational technology as a teacher? Tick any that applies.

- Yes, I have used educational technology as an add-on to my face-to-face teaching
- Yes, I have used educational technology to transform parts of my teaching to online teaching
- Yes, I have used educational technology to teach entire courses online
- Other \_\_\_\_\_

I see a potential for educational technology in science education

- strongly agree
- agree
- neither agree nor disagree
- disagree
- strongly disagree
- not applicable/don't know

If you were to adopt educational technology in your teaching, to what extent are the following criteria important to you:

	a very high extent	a high extent	a certain extent	a limited extent	a very limited extent	not at all	don't know/not applicable
That the technology is easy to adopt and deploy	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
That you can reuse the digital materials in later teaching	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
That you can share the digital materials with peers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
That the technology improves students' learning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
That the technology increases the grades and/or pass-rates	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
That the technology provides more flexible learning to the students	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
That the technology improves student satisfaction	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
To develop as a teacher (personal development)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
To reach new groups of students (e.g. with distance education)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Acknowledgement by the management	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Acknowledgement by peers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Acknowledgement by the students (i.e. that they prefer the digital format)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Easy access to educational and pedagogical support	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Easy access to production support (e.g. Science Media Lab and similar)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Easy access to a knowledge exchange and networking group with peers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Easy access to technical support (incl Blackboard functionality)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

This is the last step in the survey. Should you have any specific wishes for initiatives or comments, please do not hesitate to fill in the text boxes below.

Do you have any specific wishes for initiatives or services that would help you improve your teaching practice?

Any other comments?

Thank you for your participation. It is highly appreciated.

*Figure H1. Educator survey questionnaire.*

## Responses

Besides the direct results of the survey (in Chapter 5), the following additional data about the distribution of respondents across programmes (Figure H2), their teaching activities (Figure H3), and their comments to/wishes for services improving their teaching practice are available (Table H1). The latter is based on a coding of the comments displayed by means of an in-depth matrix.



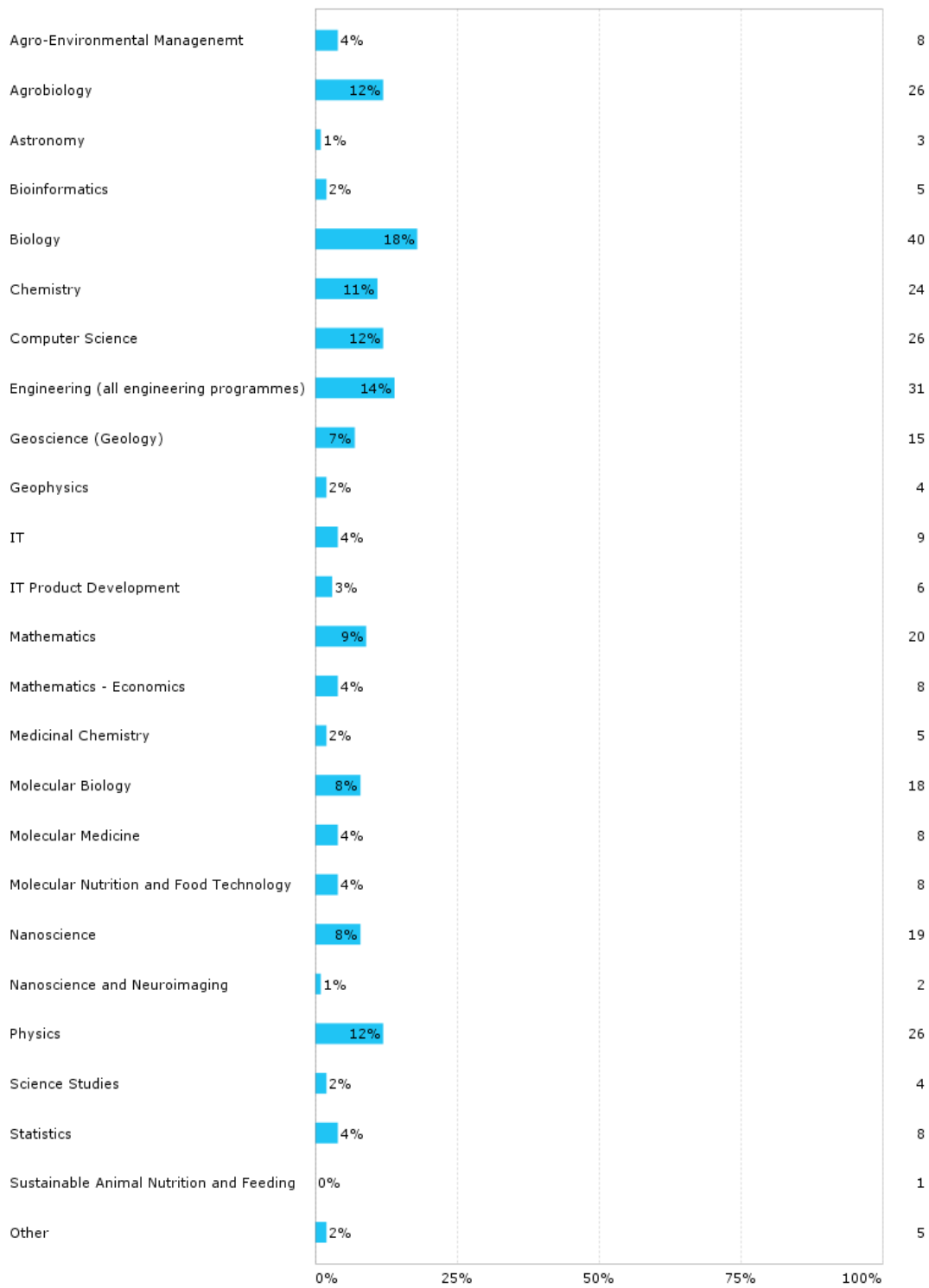


Figure H2. Distribution of the educator respondents according to their modules' programme association.

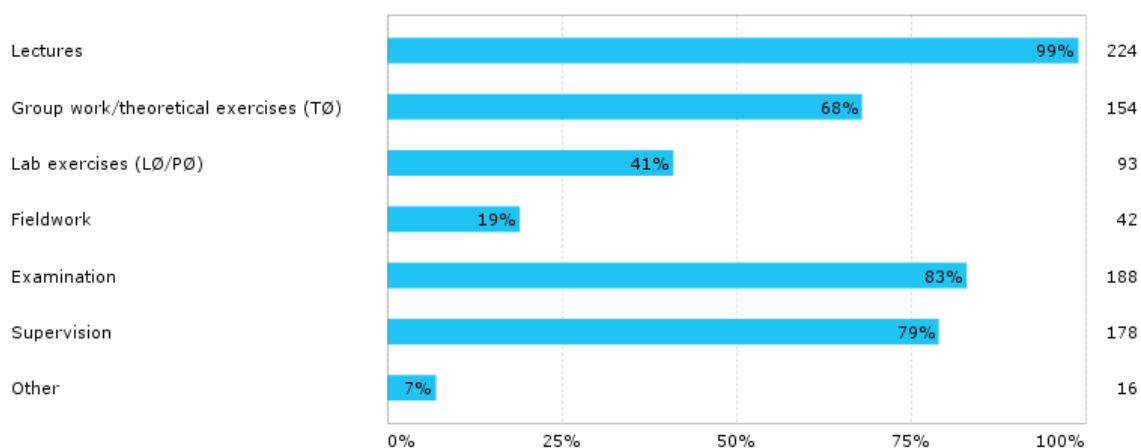


Figure H3. Types of teaching activities undertaken by the educators.

Table H1

*In-depth matrix display of the educator comments*

Descriptive and interpretive	66	
Institutional effort	41	
Strategies and policies	8	<ul style="list-style-type: none"> <li>• Clear strategy for digital exams in the future</li> <li>• If the faculty wants to improve teaching there should be an overall decision to restructure teaching (e.g. flipped classes). There is also a need to develop systems for grading during teaching periods, not only after.</li> <li>• Preparing teaching material for use as e-learning is actually very time consuming - I would very much like if this work was more recognized by the administration.</li> <li>• Second, I don't see my management paying much attention to teaching, Nice speeches on official meetings but teaching (and good teaching) is not recognized.</li> <li>• More exchange of knowledge and experience between teachers. More acknowledgement from the management that teaching is as important as research.</li> <li>• This is very little incentives for me to improve teaching as I am constantly measured on research output and the ability to attract external funding.</li> <li>• It is important that the use of educational technology is to a high degree volunteer for the teachers when it deals with technology beyond the basic level (e.g. blackboard)</li> <li>• Most efforts needed to improve teaching is associated with increased time consumption which needs to be acknowledged by the management</li> </ul>
Staff development	8	<ul style="list-style-type: none"> <li>• workshop at the university about collaborative learning</li> <li>• Help to develop digitalization of mass exams</li> <li>• Two hours of teaching at the institutes for us teachers - on the practical use of clickers - to overcome the small hurdles that prevents us using it in practice.</li> <li>• Reviews and sharing of international experience with online teaching/e-learning is of high interest as a base of avoiding pitfalls and go directly to successes. Seems to be cases in USA that were disasters. We must ensure Deep learning - ability to use knowledge not only to repeat.</li> <li>• Maybe make workshops for teachers that will help us get started using these new opportunities.</li> <li>• Blackboard course to better use the various functionalities of the system. I would like to include videos to show practical work in the lab or other practical issues</li> <li>• Short courses with focus on developing content of e-ressources, not just the technical side.</li> <li>• a (bi-)annual "teacher's day" where teachers are updated on teaching techniques, tricks, tools (incl. IT tools) etc.</li> </ul>
Pedagogical, media, and technical support	17	<ul style="list-style-type: none"> <li>• Collection of best practices at the department; ideas for "smooth" move to flipped classroom models</li> <li>• Support that can help us configure BlackBoard to suit needs, it does NOT currently. Videotaping lectures is a greta idea, but currently some lecturers arrange it themselves. This should be instead be a service that is offered to all lecturers.</li> </ul>

		<ul style="list-style-type: none"> <li>• I would be happy to introduce e-learning in my teaching where applicable - but only if there is a strong technical support and all technical details are being taken care of by relevant technical staff.</li> <li>• Support for the teacher to use the new tools is very important. There has been too much 'do it yourself via a webpage' in the AU system</li> <li>• It would be nice to have a simple and working solution for educational screen cast videos, with easy editing option, that can be used "spontaneously", i.e. from the teacher's own computer, and integrates with blackboard. Even better if this could be combined with quizzes. If such a thing exists, can you put instructions / links on your web page?</li> <li>• Cutting edge hands on knowledge to consult concerning tech tools for teaching i.e. BB etc.</li> <li>• Help to develop digitalization of mass exams</li> <li>• Det ville være yderst ønskværdigt, såfremt AU IT gjorde det nemt for studerende at installere software på deres egne computere, så de havde adgang til gode programmeringsmuligheder, data analyse, plotte porgrammer osv.</li> <li>• Professional support for implementing new technologies is very important</li> <li>• Simply a course presenting all the options for us! - then I can giev recommendations...</li> <li>• Good examples of course outline/architecture to be used in Black-Board</li> <li>• I plan to start with the video recordings. It would be nice to have easy access to high quality audio and video equipment.</li> <li>• Provide us with equipment and software for home production of material. No need and no use for a studio facility or similar.</li> <li>• easy access to software required to produce e-learning material</li> <li>• more support and ressources</li> <li>• More help from the university to engage in using new platforms like Coursera and iTunes Education. Maybe make workshops for teachers that will help us get started using these new opportunities.</li> <li>• procedures for feed-back from 'distance' students</li> </ul>
IT, facilities, and other provisions	10	<ul style="list-style-type: none"> <li>• get a better and more intuitive e-learn platform than BB.</li> <li>• BB as really bad support for student peer review - AULA actually had much better facilities.</li> <li>• I would like to use video lectures, but there are no facilities (camera, pod, microphone etc.) in Foulum. Good video lectures require that the person(s) operating camera and sound know what they are doing; otherwise they are unwatchable. Our PhD students now haven't got a clue. They would need training.</li> <li>• Also, video lectures are for a number of reasons most relevant to teachers not based at the 8000 campus. It makes little sense locating all the facility exactly there.</li> <li>• Better rooms and facilities</li> <li>• Smartboards</li> <li>• on line tool that make dialog posible during lectures e.g. kind of chat room where students can post more sophisticated ans</li> <li>• What about having a teachers tech wiki, where anyone who is interested can contribute on the fly?</li> <li>• We have frequently discussed using video lectures, but always given up as we have no equipment in Foulum. The best we've done is recorded "lectures" with PowerPoint. It's not a good system. It completely lacks interactivity.</li> <li>• Having one central repository for technical stuff in Aarhus is just too tedious to use when you're a teacher not based at the campus in 8000. The practical overhead is just too great. Careful with solutions that rely on interaction with MS Office tools. A lot of science disciplines use other tools - not least the LaTeX - PDF combo to produce lecture slides.</li> </ul>
Institutional impact	3	<ul style="list-style-type: none"> <li>• Vi skal tilbage til rødderne, højt fagligt niveau, engagerede og dygtige undervisere, der driver læring med entusiasme. Der skal stilles større krav til studerende. Gør det klart at detat være studerende på AU er et elite projekt, kræver absolut focus og er tidskrævende. Så ved destuderende hvad de går ind til. Når vi har styr på basis kan vi se om vi gider bruge tid på detaljer så som de teknologier der spørges om her.</li> <li>• Mit allerstørste ønske er at vi formår at undervise differentieret, og især giver et ægte tilbud til den "tunge ende" af midtergruppen, hvor gevinsten kan være enorm - uden at tabe de stærkes interesse. Forelæsninger bør fremover ligge på nettet med pauser og hints - der ska stilles flere træningsopgaver i den lette del af stoffet.</li> <li>• More skilled students thanks</li> </ul>
Educator effort	29	
Time consumption	8	<ul style="list-style-type: none"> <li>• more time</li> </ul>

		<ul style="list-style-type: none"> <li>• great with new ideas, but we are very busy, so a minimum of disturbance is also a good thing. So limit the number of initiatives!</li> <li>• Preparing teaching material for use as e-learning is actually very time consuming - I would very much like if this work was more recognized by the administration.</li> <li>• Some of my classes are quite large and giving feedback on papers handed in is impossible due to the workload it would create. I would like to be able give individual feedback on papers handed in during the course but it would demand more resources than what are currently allocated.</li> <li>• TIME! and courses</li> <li>• Jeg mener ikke at implementering af de metoder bør have høj prioritet da vi jo har meget begrænsede ressourcer for tiden. De har meget begrænset impact.</li> <li>• Most efforts needed to improve teaching is associated with increased time consumption which needs to be acknowledged by the management</li> <li>• The most important issue is TIME. It takes time to develop new teaching materials and habits and this time must be allocated by the university to us as individuals.</li> </ul>
Uptake of learning design model and defeated barriers	0	
Attitude and perception	19	
Educational development	6	<ul style="list-style-type: none"> <li>• Collection of best practices at the department; ideas for "smooth" move to flipped classroom models</li> <li>• I think the focus should be on the quality of the teaching and what the students learn, and not on peripheral aspects.</li> <li>• Mit allerstørste ønske er at vi formår at undervise differentieret, og især giver et ægte tilbud til den "tunge ende" af midtergruppen, hvor gevinsten kan være enorm - uden at tabe de stærkes interesse. Forelæsninger bør fremover ligge på nettet med pauser og hints - der ska stilles flere træningsopgaver i den lette del af stoffet.</li> <li>• You are doing a good job - very important to inform of the services you have and what you can support us with</li> <li>• More exchange of knowledge and experience between teachers. More acknowledgement from the management that teaching is as important as research.</li> <li>• Jeg mener ikke at implementering af de metoder bør have høj prioritet da vi jo har meget begrænsede ressourcer for tiden. De har meget begrænset impact.</li> </ul>
Educational technology	13	<ul style="list-style-type: none"> <li>• Better whiteboards in auditoriums that can actually be erased * Whiteboard pens in auditorium that work * Projectors in auditoriums get new lightbulbs before the projectors brake, so that they always are clearly readable * Consistent technology in auditoriums (eg PC in Aud E has touch screen, other auditoriums not) * Blackboard interface needs a lot of improvements - it is continuously a test of the users patience</li> <li>• BB as really bad support for student peer review - AULA actually had much better facilities.</li> <li>• Vi skal tilbage til rødderne, højt fagligt niveau, engagerede og dygtige undervisere, der driver læring med entusiasme. Der skal stilles større krav til studerende. Gør det klart at det at være studerende på AU er et elite projekt, kræver absolut focus og er tidskrævende. Så ved destuderende hvad de går ind til. Når vi har styr på basis kan vi se om vi gider bruge tid på detaljer så som de teknologier der spørges om her.</li> <li>• Flere undervisningslokaler med to projektorer (så kan man have gang i to ting ad gangen, en power point og en web-applikation, fx). Udskift whiteboards med gammeldags tavler. Man kan ikke skrive i 2 timer med whiteboard penne uden at de løber tør.</li> <li>• Replace whiteboards with Blackboards. The use of new technology must not spoil the possibilities for other types of teaching. Use of technology can be used to improve the teaching, but it's not all ways the case. And don't forget there are a lot of others possibilities to improve the teaching.</li> <li>• The technology needs to be simple - but all methods comes with a cost to introduce both in terms of hardware and brainware</li> <li>• Blackboard is one of the most user hostile pieces of software I have encountered. It is very frustrating to use. I would highly encourage seeking an alternative that would be easier to use and more sensible.</li> <li>• I'm especially interested in helping students to enhance concentration and in-depth learning. I fear that much of current e-media draw in the opposite direction.</li> <li>• Honorstly with the switch to blackboard we there is many more tools available - however I really do not see , what we have gained expect from increased complexity. I am afraid that the increased complexity is not going to make</li> </ul>

more of my colleageaus use e-learning.

- Talking from a personal perspective, I see a greater challenge in actually setting up a course well, aligning learning objectives, and overall making it into a coherent course. My feeling is that the current emphasis on digital services distracts from the core of the teaching.
- This survey focus not on modern teaching as mentioned in the mail, but solely on educational technology. Educational technology is a part of modern teaching but it's not equal to it.
- It should be possible and easy to change minor parts of the cirriculum of a course up to the time where the course is starting, for example to include the newest hot research topics.
- we have smartboards every where - I have never seen them in use.

Knowledge	3	<ul style="list-style-type: none"> <li>• You are doing a good job - very important to inform of the services you have and what you can support us with</li> <li>• Reviews and sharing of international experience with online teaching/e-learning is of high interest as a base of avoiding pitfalls and go directly to successes. Seems to be cases in USA that were disasters. We must ensure Deep learning - ability to use knowledge not only to repeat.</li> <li>• As I teach chemistry which requires hands-on learning, tools supporting working from home is irrelevant, I need for them to come to campus.</li> </ul>
Knowledge sharing	1	<ul style="list-style-type: none"> <li>• The P2P platform is a nice idea, in principle. Perhaps it would be used more if there were some more informal ways to contribute. Say, if someone finds out how to produce screencasts easily, they could post it there. Or report on good and bad experience with clickers and co.</li> </ul>
Motivation and rationale	0	
Educator impact	0	
Flexibility in time, place, and pace	0	
Satisfaction and perception of the intervention	0	
Other affordances	0	
Student effort	0	
Student impact	2	<ul style="list-style-type: none"> <li>• I think the focus should be on the quality of the teaching and what the students learn, and not on peripheral aspects.</li> <li>• Digital examination for written exams. Made in a way where the students for preparation can simulate a real exam situation with last year's exam question. We should start on this yesterday.</li> </ul>

# Appendix I: The student perspective survey

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## Questionnaire

The questionnaire for the online student survey is provided in Figure I1. The survey was carried out between 17 and 30 January 2015 together with an end-of-module evaluation of a first-year module. The questions were based on the Inventory of learning with Learning Design (Appendix E). That is, the conceptualisation of the student perspective of LD efficiency in Chapter 3 and phrased in Danish. The first question asks about the primary reason for studying (cf. Section A in the inventory), the second question about teaching type preferences (cf. Section B of the inventory), the third question about their study preferences (which relates to the perception of technological affordances in Section C of the inventory), and the fourth question about their preferences regarding workload and learning with technology (Section D of the inventory).

## Generelle studiepræferencer

De sidste 4 spørgsmål omhandler dit studium og dine studiepræferencer generelt. Dvs. ikke kun Calculus 2.

Dine svar på disse spørgsmål vil i særlig høj grad hjælpe os med at udvikle og forbedre undervisningen fremadrettet.

Hvad er din **primære** grund til at studere?

- For personlig udvikling
- Pga. prestigen og/eller den anerkendelse, uddannelsen giver
- For at lære faget og dets faglighed
- For at få en uddannelse
- For at forbedre mine chancer for at få et godt job.
- Anden grund: \_\_\_\_\_

Hvad er dine præferencer for de følgende former for kurser og undervisning?

	Værdsætter i høj grad	Værdsætter i nogen grad	Værdsætter ikke i særlig høj grad	Værdsætter slet ikke
Undervisere, der fortæller os præcist, hvad vi skal tage af notater.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Undervisere, der tilskynder os til at tænke selv og viser os, hvordan de selv tænker.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Eksamen, der tillader os at demonstrere, at vi selv har tænkt over pensum.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Eksamen, der alene tester pensum, som er gennemgået i vores forelæsninger.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Kurser, som tydeligt forklarer, hvilke bøger og andet materiale, vi skal læse/se.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Kurser, som tilskynder os til selv at læse uden for pensum.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Bøger og andet undervisningsmateriale, der udfordrer os fagligt og går videre end forelæsningerne og videoerne.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Bøger og andet undervisningsmateriale, der giver os præcise facts og information, som let kan læses	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Hvad finder du vigtigt for dit studium?

	I meget høj grad	I høj grad	I nogen grad	I mindre grad	I meget lille grad	Slet ikke	Ved ikke/ikke relevant
At eksamensformen afspejler pensum og de konkrete færdigheder, vi har lært	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
At undervisningen er i fuld overensstemmelse med kursets læringsmål og estimeret timeforbrug.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
At jeg kan studere, hvor jeg vil og ikke altid behøver at tage på universitetet.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

At jeg udvikler konkrete færdigheder til et kommende arbejde.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
At jeg kan repetere forelæsninger og anden undervisning efter behov.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
At undervisningen er spændende/underholdende	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
At jeg får feedback på min læringsproces, afleveringer og svar på mine faglige spørgsmål.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
At undervisningen understøtter samarbejde med mine medstuderende	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
At jeg lærer at koble teori med praksis.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

I hvilken grad er du enig i de følgende udsagn?

	I meget høj grad	I høj grad	I nogen grad	I mindre grad	I meget lille grad	Slet ikke	Ved ikke/ikke relevant
Jeg er villig til at bruge mere tid på mine studier, hvis jeg føler, jeg lærer en masse.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Jeg er overordnet set positiv over for initiativer, der involverer brugen af ny teknologi i undervisningen (fx clickers, videoer, online opgaver, animationer, simuleringer, Blackboard, AULA m.m.).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Jeg foretrækker at bruge mere tid på mine studier hjemme end på universitetet.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Må vi kontakte dig for et kort, opfølgende interview? Hvis ja, angiv venligst din e-mail-adresse. Din deltagelse og svar vil blive behandlet anonymt.

Når du klikker Afslut lukkes skemaet, svarene indsendes og du deltager i lodtrækningen. Vi takker mange gange for dine svar og din tid. Vinderne findes i slutningen af februar.

Venlig hilsen  
Center for Scienceuddannelse

Figure 11. The student survey (in Danish).



# Responses

The respondents in the student survey were distributed as illustrated in Figure I2.

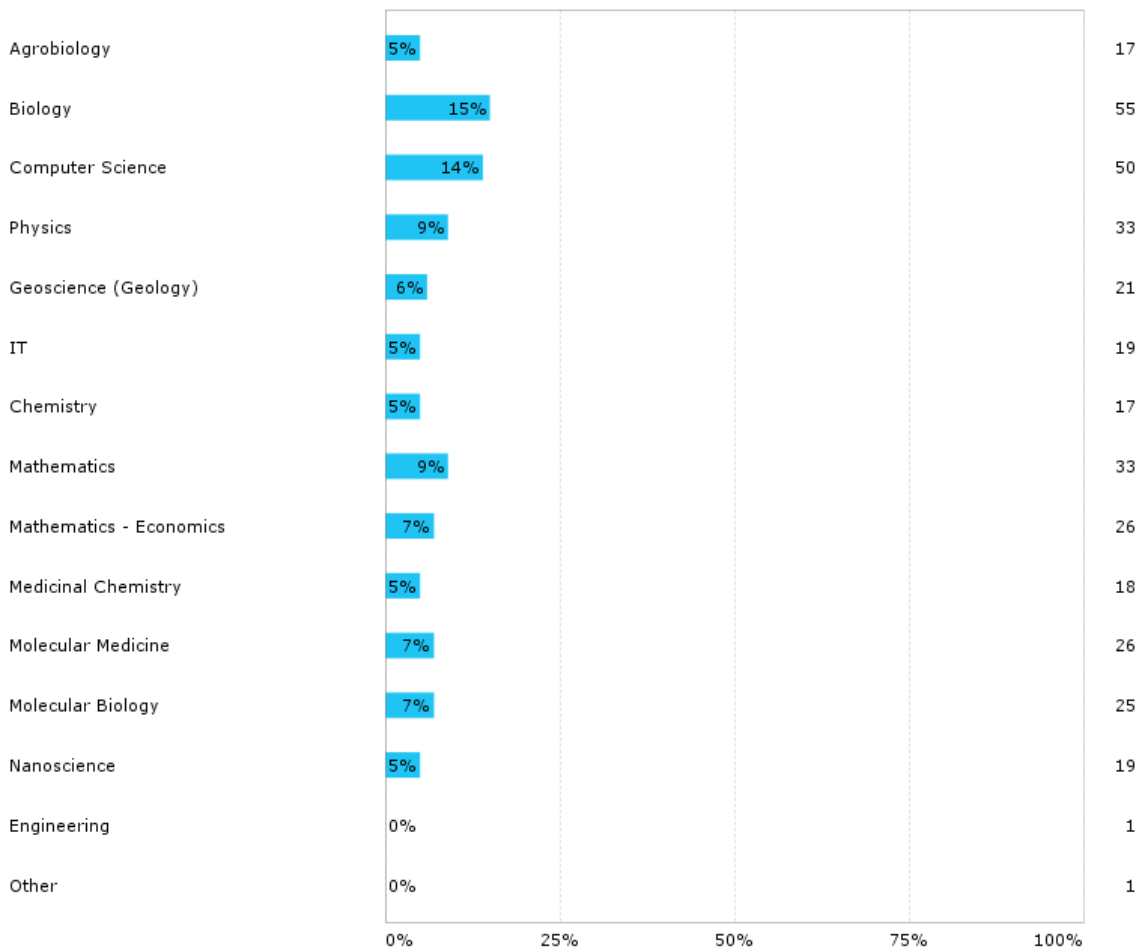


Figure I2. Distribution of student respondents across programmes.

# Appendix J: Perspectives on Learning Design at AU

Overview of the count of codings and categories of the institutional and general educator perspective on TEL and LD is provided in Table J1.

Table J1

*Cross-case query with the complete set of categories, subcategories, and count of codings of both the institutional and the generic educator perspective*

Name of category and codes	Institutional perspective 2010–2012	Institutional perspective 2013–2017	PVC interview 2016	Educator comments
Descriptive and interpretive	34	27	16	66
Institutional effort	9	11	11	41
Digital competencies	0	1	0	0
Educational development services, training, etc.	0	0	0	8
Funding, provisions, and facilities	3	3	0	10
Governance in practice	0	3	2	0
Management acknowledgement	0	0	0	5
Pedagogical, media, and technical support	0	0	0	17
Perception of educational technology and TEL	0	1	6	0
Strategy	6	3	4	3
Institutional impact	25	22	12	3
Business potential*	14	8	7	2
Branding	3	0	0	0
Competitive parameter	0	0	1	0
Completion	0	0	1	0
Cost-effectiveness	1	1	3	0
Digitisation	0	0	1	0
Educator preparation	1	0	0	0
Educator satisfaction	0	2	0	0
Increased intake	2	0	0	0
Organisational development	0	0	1	0
Professional development of educators	3	3	0	0
Programme flexibility	2	0	0	0
Recruitment of students	3	1	5	2
Retention	0	0	0	0
Scholarship of teaching and learning	1	0	0	0
Time efficiency	0	1	0	0
Educational limitations	0	0	4	0
Educational potential*	16	19	5	1
Accommodate student diversity and support pace flexibility	2	5	0	1
Alignment	0	0	1	0

Communication and collaboration	4	1	0	0
Digital competences	1	0	2	0
Digital expectations	0	1	2	0
Employability of candidates	1	1	1	0
Feedback	1	1	0	0
Flexibility in time and place	0	1	0	0
Grades and pass-rates	0	1	0	0
Modern teaching	2	2	0	0
Multimedia-supported learning	1	0	0	0
Personalised learning	1	1	0	0
Quality in education	5	7	2	0
Skills development and competencies	0	3	1	0
Student satisfaction and engagement	0	3	0	0
Student-centeredness	0	0	0	0
Study environment	2	2	1	0
Study intensity	0	1	0	0
<b>Educator effort</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>29</b>
Attitude and perception	0	0	0	19
Educational development	0	0	0	6
Educational technology	0	0	0	13
Identity	0	0	0	0
Authority and ownership	0	0	0	0
Confidence with technology	0	0	0	0
Responsibility of quality	0	0	0	0
Knowledge sharing	0	0	0	1
Knowledge	0	0	0	3
Learning Design and STREAM	0	0	0	0
Pedagogical	0	0	0	2
Technical	0	0	0	1
Motivation and rationale	0	0	0	0
Extrinsic	0	0	0	0
Intrinsic	0	0	0	0
Time spent on teaching and transforming the module	0	0	0	8
Uptake of learning design model and defeated barriers	0	0	0	0
<b>Educator impact</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>
Flexibility in time, place, and pace	0	0	0	0
Other affordances	0	0	0	0
Satisfaction and perception of the intervention	0	0	0	0
<b>Student effort</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>
Attitude towards technology in education	0	0	0	0
Time spent on the module	0	0	0	0
<b>Student impact</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>2</b>
Flexibility	0	0	0	0
Improved learning	0	0	0	1
Other actualised affordances	0	0	0	1
Perceived learning outcome	0	0	0	0

Satisfaction and preferences

0

0

0

0

---

\*These categories include codes that may relate to effort and impact on other perspectives.



# Appendix K: Astrophysics (Case 1)

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## Learning goals and outcome

The learning goals of AP are listed below together with the students' perceived outcome in Figure K1. In addition, the students' most frequent pace of participation is provided in Figure K2–K3.

- 'Describe the physics behind and perform calculations of the mutual impact objects in the Solar System have on each other.
- Describe and calculate physical properties of objects in the Solar System and compare with exoplanets.
- Describe and calculate physical properties of stars and account for the physics behind the emission of radiation from stars.
- Compare different types of stars and give explanations for differences.
- Describe the physics behind the evolution of stars from gas cloud to compact object.
- Describe the structure of galaxies and use equations to describe the dynamics of a spiral galaxy like the Milky Way.
- Describe the evolution of galaxies and put in relation to the large-scale structure of the Universe.
- Describe the physics behind the evolution of the Universe from Big Bang to now.
- Discuss the necessity of general relativity in the description of the Universe and use relevant physical equations to calculate properties of the Universe.
- Formulate written answers to astrophysical problems.' (Course Catalogue, 2016a).

The learning goals of AP (2015), which were identical with AP (2014).

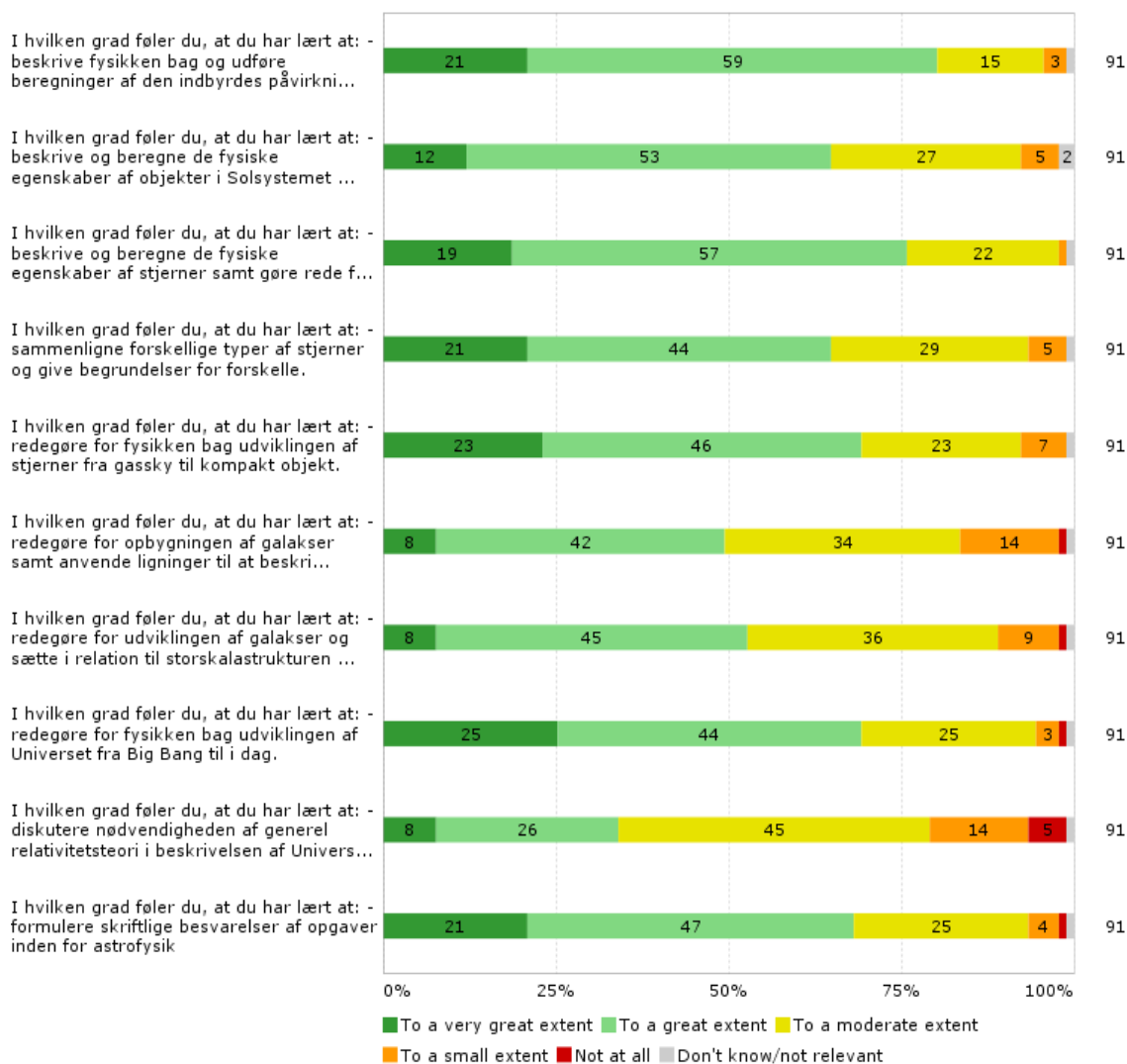


Figure K1. Students' perceived accomplishment of AP (2015)'s ten learning goals (in Danish). Data not available from 2014 (see Chapter 4 for further details).

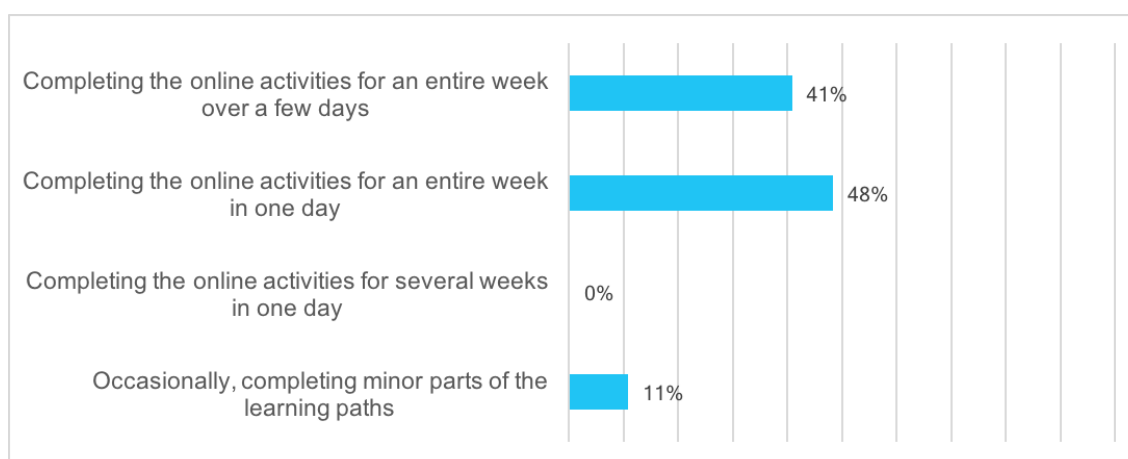


Figure K2. Pace of participation in the online activities in AP (2014). That is, 59% (or 68%) most frequently participated in another pace than regular lecturing pace.

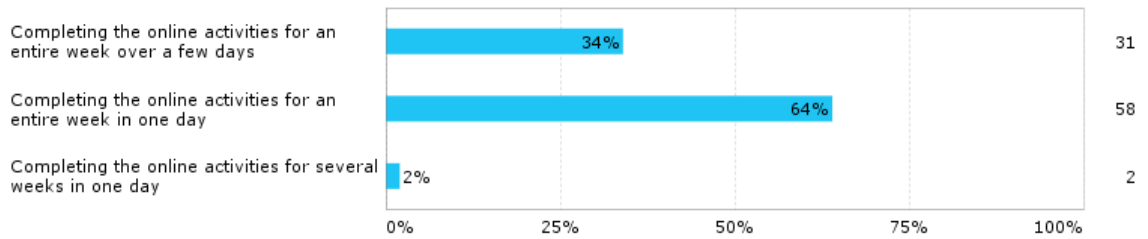


Figure K3. Pace of participation in the online activities in AP (2015). That is, 66% most frequently participated in another pace than regular lecturing pace.

## Learning Design

The LD is described in Chapter 6 and further documented in Table K1 and Figure K4–K7.

Table K1

Overview of the online materials and activity in AP (2014) and AP (2015)

	Online materials	Online activity	
	Learning paths (contents)	Announcements	Posts
<b>2014</b>	7 learning paths (51 items, comprising 17 videos and 21 activities*)	20	29
<b>2015</b>	7 learning paths (68 items, comprising 27 videos, 23 activities*, and 18 items of extra material**)	28	32

\*Only embedded, online activities are included in this figure. Additional offline and reading/watching activities were present. \*\*This also includes videos.



Hjem

Astrofysik - F [225141U003]

- Hjem


**Astrofysik**

- Meddelelser
- Kursusbeskrivelse
- Forum
- Spørgetimer

**Undervisning**

- Ugesedler
- Slutevaluering
- Uge 1 (30/10-5/11)
- Uge 2 (6/11-12/11)
- Uge 3 (13/11-19/11)
- Midtvejsevaluering (deadline 26/11)
- Uge 4 (20/11-26/11)
- Uge 5 (27/11-3/12)
- Uge 6 (4/12-10/12)
- Uge 7 (11/12-17/12)
- Pensumliste og noter til eksamensforberedelse
- Forelæsningslides
- Formelsamling
- Gamle eksamensopgaver


## Hjem

 **.Hjem**

Velkommen til forsiden for kurset i Astrofysik.

Brug menuen i venstre side af skærmen til at navigere på siden.

Sombrero Galaxy • M104



Hubble Heritage

NASA and The Hubble Heritage Team (AURA/STScI) • Hubble Space Telescope ACS • STScI-PRC03-28

Figure K4. AP's home page in 2014.

Uge 1 (30/10-5/11)

**Uge 1 (10 point)**

Herunder finder I online-aktiviteterne til uge 1. Der er i alt fem aktiviteter samt et spørgsmål, som bliver synligt, når I har gennemført aktivitet 5.

Hvis I gennemgår alle elementer i uge 1 kan I opnå en samlet score på max 10 point. **Deadline for aktiviteterne i uge 1 er 5/11 kl. 23.59.** Jeg vil anbefale at I starter så tidligt som muligt med at gennemføre ugens online-aktiviteter, da det formentligt ikke er muligt at få teknisk eller anden hjælp kort før deadline.

Pensum til uge 1 er:

- Kapitel 3 (Det hele)
- Kapitel 4 (S. 1-4.3)
- Kapitel 5 (S. 1-5.3)

**Uge 1, Aktivitet 1: Velkomstvideo**

Optagelse på CSE - 01 October 2014



Bemærk at alle leg-videoer, forelesninger og optagelser fra 1.1.13-14

Hvis der er problemer med at afspille video skal du klikke på det lille skjold oppe i toppen af skærmen, hvor du skriver din url (dvs. www.bb.au.dk eller lignende). Når du klikker på skjoldet stopper browseren med at blokere videoen.

**Uge 1, Aktivitet 1a: Note om virialsætningen**

Attached Files: Virialsætningen.pdf (104.882 KB)

Denne note uddyber afsnit 3.4 om virialsætningen.

**Uge 1, Aktivitet 2: Forum (4 point)**

Gå ind på arkivet for NASA-hjemmesiden *Astronomy Picture of the Day* og find et billede i arkivet du finder særlig interessant. Skriv en post om billedet i dit holds diskussionsforum, hvor du gør rede for hvorfor du finder det særlig interessant (2 point). Der er desuden et bonuspoint (1 point) at hente, hvis du kan blande noget fysik ind i din post. Svar på mindst en anden post i dit forum (skrevet af en anden end dig selv...), hvor du fx bidrager med bonus-info, kommer med kritik eller feedback eller andet konstruktivt (1 point). Point-tildelingen fremgår af rubricen, som I finder i jeres forum.

For at finde vej til dit holds diskussionsforum skal du klikke på linket, derefter tilmelde dig dit TØ-hold og til sidst vælge Discussion Forum.

Lad venligt være med at lægge nonsens-indlæg i fora.

Jeg har lagt et eksempel på en post og et svar i jeres forum.

**NB: I skal klikke på Uge 1, Aktivitet 2: Forum (4 point) ovenfor for at komme videre til forumet.**

**Uge 1, Aktivitet 3: Video om tidevand**

Optagelse på CSE - 08 October 2014



NB: I denne video (og alle der kommer senere i kurset) kan I toggle mellem at se skærmen, se mig eller se begge på forskellige måde. Brug ikonet oven for med en firkant i en firkant til det (den bliver synlig når I starter videoen).

**Uge 1, Aktivitet 4: Test (4 point)**

Besvar de tre spørgsmål ud fra ugens pensum og videoer. De to første spørgsmål giver 1 point, mens det sidste spørgsmål kan give op til 2 point.

**Uge 1, Aktivitet 5: Feedback (2 point)**

Feedback til ugens pensum. De første to spørgsmål giver hver 1 point – det sidste kan I udfylde hvis I har ris, ros, forslag til forbedringer eller andet.

**NB: Når I har gennemført dette survey kommer et spørgsmål til syne nedenunder, hvor I skal svare på om I har svaret på minimum de første to spørgsmål i surveyet. For at få de 2 point for at gennemføre surveyet skal I svare ja til det spørgsmål.**


Bemærk jeres svar i surveyet her er anonyme, så jeg kan ikke se hvem som har svaret hvad.

Figure K5. Week 1's learning path in AP (2014).

Astrofysik

**Astrofysik**


Velkommen til Astrofysik



Et supermassivt sort hul i aktion: [http://www.esa.int/spaceinimages/Images/2015/11/A\\_supermassive\\_black\\_hole\\_in\\_action](http://www.esa.int/spaceinimages/Images/2015/11/A_supermassive_black_hole_in_action)

**Video fra introdudagen**

**Webcast Studio 1 - 17 August 2015 - 2**



00:00 06:03

Figure K6. AP's home page in 2015.

**Uge 2, Aktivitet 2: Aflevering (15 point)**

Attached Files: [Latex-template \(1.458 KB\)](#)  
[Word-template \(21.537 KB\)](#)

Upload jeres aflevering her. I kan enten vælge at skrive besvarelsen på en laptop (fx i LaTeX eller Word - [hvis I skriver i Word så gem filen som pdf inden I uploader](#)) eller at skrive den i hånden og tage et billede af afleveringen med jeres telefon, som I så uploader. I må også gerne finde på noget andet kreativt (video med jeres gennemgang eller måske bygge afleveringen i Lego?) så længe instruktorerne kan læse den. Opgaven her er en individuel opgave.

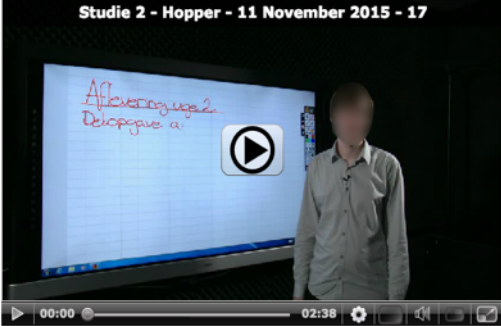
Se den medfølgende rubric for en guide til pointgivningen.

Templates til LaTeX og Word er vedlagt.

---

**Uge 2, Aktivitet 2a: Videoer med gennemgang af afleveringen**

**Studie 2 - Hopper - 11 November 2015 - 17**



**Studie 2 - Hopper - 11 November 2015 - 20**

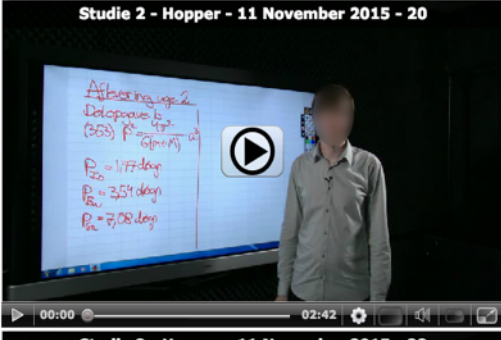


Figure K7. Feedback-videos on assignments with worked examples provided by the e-instructor in AP (2015).



# Appendix L: Calculus 2 (Case 2)

## Learning goals and outcome

The learning goals of C2 are listed below together with the students' perceived outcome in Figure L1. In addition, the students' most frequent pace of participation is provided in Figure L2–L3.

- 'apply basic techniques and results from calculus to solve prescribed exercises within: differentiation and integration of functions in one and several variables, linear algebra, and infinite series.
- use mathematical terminology and symbols' (Course Catalogue, 2016b).

The learning goals of C2 (2015)

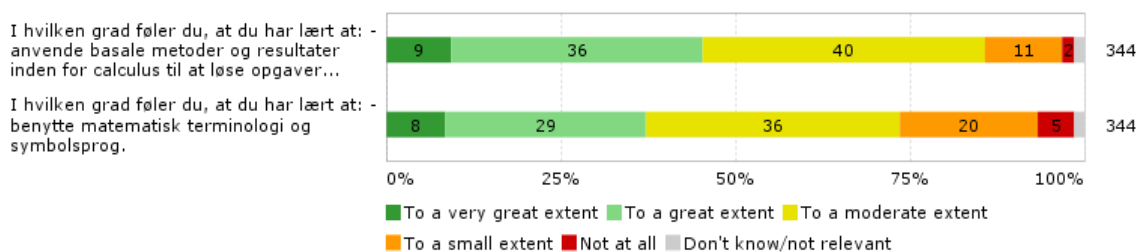


Figure L1. Students' perceived accomplishment of C2's (2015)'s two learning goals (in Danish). Data from 2014 was not available.

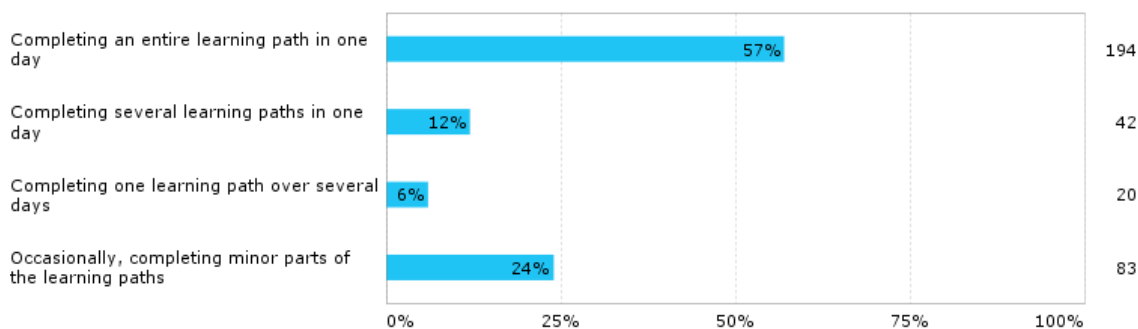


Figure L2. Pace of participation in the online activities in C2 (2014). That is, 43% most frequently participated in another pace than regular lecturing pace.

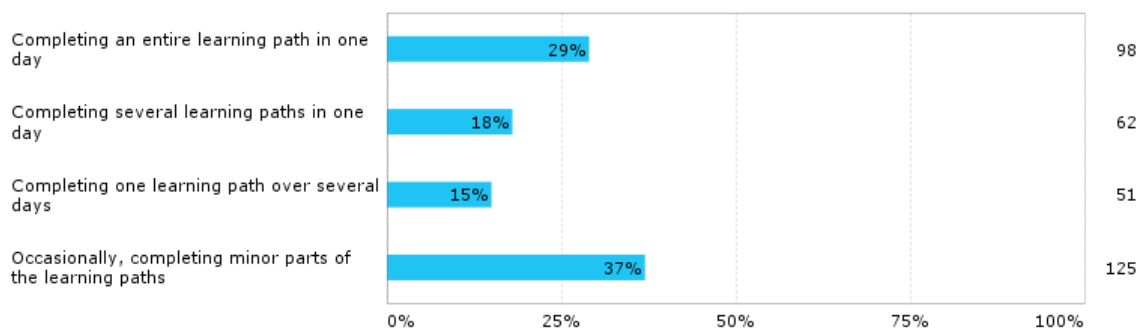


Figure L3. Pace of participation in the online activities in C2 (2015). That is, 71% most frequently participated in another pace than regular lecturing pace.

## Learning Design

The LD is described in Chapter 6 and further documented in Table L1 and Figure L4–L8.

Table L1

*Overview of the online materials and activity in C2 (2014) and (2015)*

	Online materials	Online activity	
	Learning paths (contents)	Announcements	Posts
<b>2014</b>	15 learning paths (171 items, comprising 81 videos, 66 MCQ activities, 12 reflection exercises, 4 feedback items)	9	6
<b>2015</b>	14 learning paths (146 items, comprising 81 videos, 59 MCQ activities, and 14 reflection exercises)	0	0

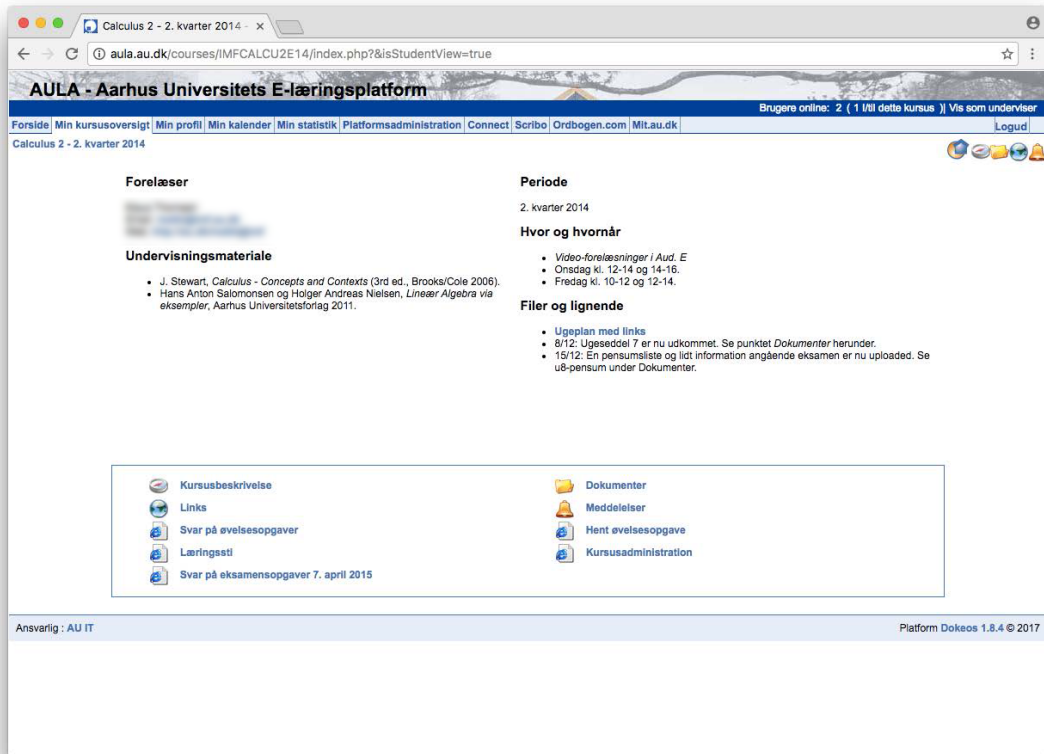


Figure L4. C2's main home page in 2014.

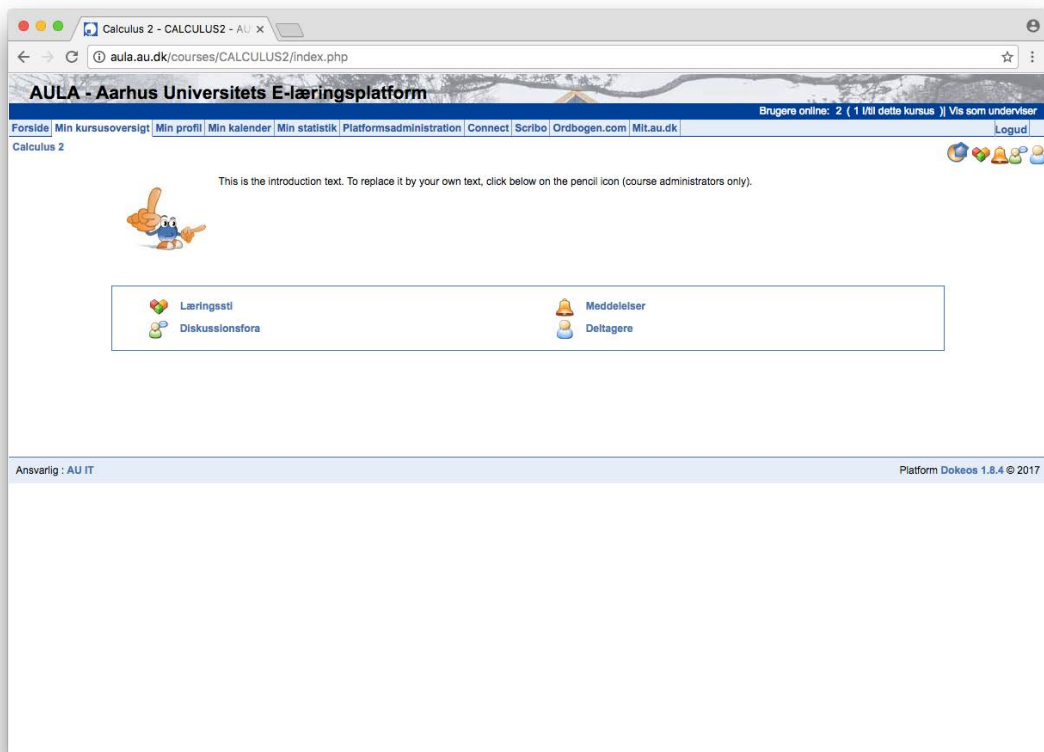


Figure L5. C2's additional page with the learning path in 2014.



The screenshot shows a web browser window displaying the AULA - Aarhus Universitets E-læringsplatform. The page title is "Øvelse 1 til 5. forelæsning, film 01". The main content area contains the following text:

Hvor mange løsninger  $y_1, y_2$  til differentialligningerne

$$y_1' = 2y_1 + 2y_2$$

$$y_2' = y_1 + 3y_2$$

findes der, som opfylder at  $y_1(0) = y_2(0)$ ?

(1) Uendeligt mange,  
 (2) Netop en,  
 (3) Ingen,  
 (4) Ved ikke.

Below the question, there is a "Spørgsmål 1" section with a "Svar:" label and a radio button next to the option (1).

Figure L6. Step with MCQ activity in the learning path in C2 (2014).

Hjemmeside Calculus 2 2015

## Hjemmeside Calculus 2 2015

E15Q2 – Calculus 2 [250151U005]  
Hjemmeside Calculus 2 2015

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**Information**

Meddelelser

Kursusbeskrivelse

Ugeplan

Læseplan

Deltagerliste

---

**Undervisning**

Uge 1: Projektioner og ortogonalitet samt dobbelt integral

Uge 2: Projektioner og ortogonalitet samt polære koordinater

Uge 3: Egen værdi og egenvektorer

Uge 4: Uendelige rækker og den retningsafledte af en funktion af flere variable

Uge 5: Potensrækker og anvendelse samt kritiske punkter og lokale ekstremumpunkter

Uge 6: Taylor- og Maclaurin rækker samt Lagranges metode

Uge 7: Repetition og gennemgang af eksamensopgave

Opgavebesvarelser

---

**Fora**

Calculus 2 Forum

Teknisk Forum

**Velkomst**

Velkommen til kurset Calculus 2. Kurset er en direkte fortsættelse af kurset Calculus 1, og undervisningen vil forløbe på samme måde. Den eneste ændring er, at Sci2u ikke vil være et fast element i forbindelse med de obligatoriske afleveringsopgaver, men sandsynligvis blive en del af en enkelt af disse. Yderligere information om kurset vil blive annonceret på ugesedlerne for kurset. Også af den grund er det vigtigt at læse ugesedlerne. De vil fremkomme onsdag sidst på dagen og/eller torsdag formiddag, og kan findes enten som pdf-filer her på kursets hjemmeside, eller på papir ved Calculus 2 tavlen udenfor Aud D1.

Forelæsningsvideoerne og læringsstierne er nu tilgængelige for alle kursets 7 uger. De kan tilgås via de links der står under 'Undervisning' til venstre her på hjemmesiden. Videoerne findes i 3 versioner, hvor de første to er de Vimeo- og toggle-versioner I kender fra Calculus 1. Desværre er der en fejl ved toggle-versionerne af de første 5 forelæsninger. En software opdaterings-fejl sørgede for at kun den ene kanal blev optaget, og som følge heraf kan man faktisk ikke 'toggle' i toggle-versionen af disse forelæsnings-videoer. Bl. a. af den grund er der også mulighed for at se de video-forelæsninger der blev brugt til kurset i 2013 og 2014. De kan tilgås via linkene 'Link til 2013-version' som står efter linket til toggle-versionen. Indholdsmæssigt er der ingen forskel til 2015-videoerne, men længden af de enkelte optagelser er ikke den samme, og den tekniske kvalitet måske ikke så god. Men til gengæld kan man toggle uhæmmet, også i de første 5 forelæsninger.

Med venlig hilsen, [Redacted]

---

**Ugesedler**

Ugeseddel 1 [u1.pdf](#)

Ugeseddel 2 [u2.pdf](#)

Ugeseddel 3 [u3.pdf](#)

Ugeseddel 4 [u4.pdf](#)

Ugeseddel 5 [u5.pdf](#)

Ugeseddel 6 [u6.pdf](#)

Ugeseddel 7 [u7.pdf](#)

Ugeseddel 8 – med pensum og information om eksamen [u8-pensum.pdf](#)

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**Indholdsfortegnelse til videoerne**

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**Holdliste med instruktører**

Filen nedenfor indeholder en holdliste med instruktør-navne og kontakt info.

[Holdoversigt – Instruktører Calculus 2 \\_ret\\_.pdf](#)

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**Hent øvelsesopgave**

---

**Svar på øvelsesopgave**

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**Eksamensopgaver fra 2015**

Figure L7. C2's home page in 2015.

Figure L8. Step 1, in one of two learning paths in Week 1, C2 (2015).

## Dissemination

Between the two iterations, the main results of C2 (2014) (see Figure L9) were shared with the educator and programme manager by email on 18 May 2015 together with the following interpretation:

'Despite the fact a smaller group of students prefer the traditional lectures (and judging by their comments it appears as if they have a picture-perfect perception of traditional lectures), there is a significant majority who prefers the online lectures (and there is plenty of appreciation in the comments!). Furthermore, it appears that the students are making good use of the flexibility provided by the technology. Judging by the comments it appears that the criticism of Calculus 2 relates to AULA [the previous LMS] and the quality of the videos (which are better in Calculus 1 — new webcast studio and Blackboard). In addition, there is some criticism of the examination, which many found difficult this year' (the researcher).

Furthermore, the results of Calculus 1 (2015), which had also been transformed and had been taught just prior to C2 (2015), were e-mailed to the educator and programme manager on 4 November 2015 together with the following interpretation:

'It appears that a considerable share of the first-year students have a picture perfect of lectures (i.e., with plenty of time for questions and discussion). The students are very satisfied with Sci2u and find it very useful, the student satisfaction is higher on the module compared to last year, the preference for the online format is approximately the same as last year, the materials have also this year been used very flexible and it appears that the learning goals are well achieved. Unfortunately, it does also appear as if the activities in Blackboard and the feedback has not really been of much use this year' (the researcher).

## Resultater fra evalueringen af Calculus 1+2 E2014 (udpluk)

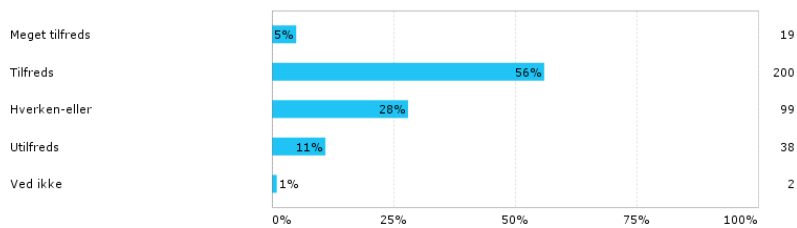
Mikkel Godsk, Center for Scienceuddannelse, [godsk@cse.au.dk](mailto:godsk@cse.au.dk)

### Calculus 1 E2014 (Svarprocent: 34-38 %)

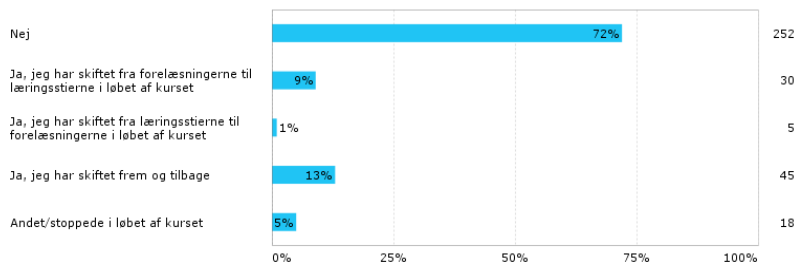
[omitted]

### Calculus 2 E2014 (Svarprocent 40-44 %)

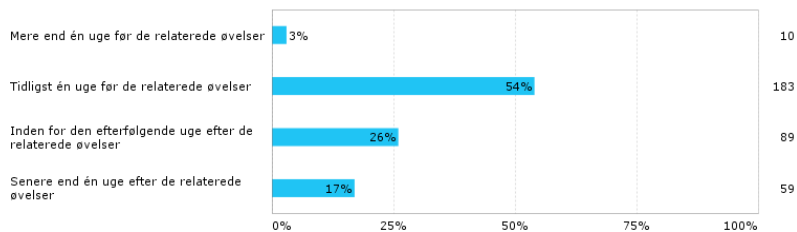
Overordnet set, hvor tilfreds er du med læringsudbyttet af Calculus 2?



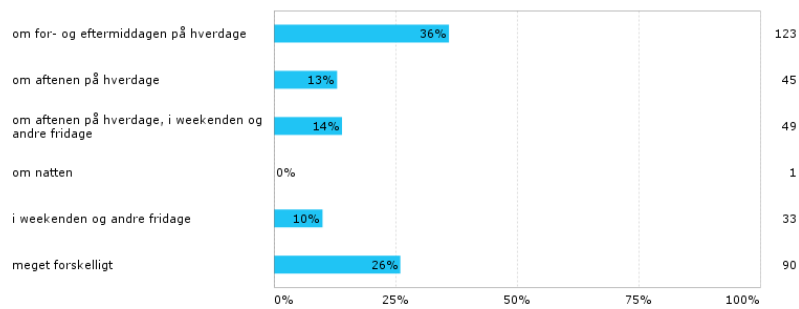
Har du skiftet undervisningsform i løbet af kurset?



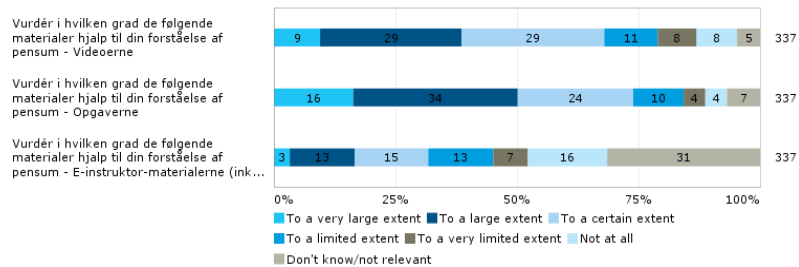
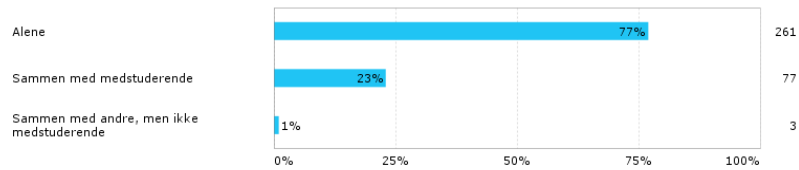
Hvornår har du oftest gennemgået læringsstierne?



Hvilket tidspunkt på ugen har du oftest gennemgået læringsstierne?



Har du oftest gennemgået læringsstierne alene eller sammen med andre?



Hvad foretrækker du: undervisning med online læringsstier i stil med Calculus 2 eller traditionelle forelæsninger i et auditorium?

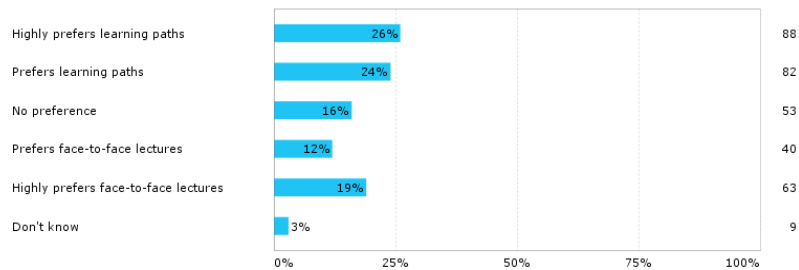


Figure L9. Evaluation report C2 (2014) (in Danish). Results from C1 (2014) were omitted in this Figure.



# Appendix M: General Chemistry (Case 3)

## Learning goals and outcome

The learning goals of GC are listed below together with the students' perceived outcome in Figure M1. In addition, the students' most frequent pace of participation is provided in Figure M2.

- 'Carry out calculations of simple problems in general chemistry with focus on: thermodynamics, chemical equilibrium, acid/base theory and electrochemistry.
- Make use of chemical nomenclature for balancing chemical reactions and for calculating quantity of substances.
- Describe the electron structure of an atom and the structure of the periodic table of the elements.
- Describe various models for chemical bonding and molecular structure.
- Describe structures of typical crystalline compounds.
- Exhibit good laboratory praxis.
- Carry out simple laboratory exercises.
- Elaborate on the experimental results with respect to theory.' (Course Catalogue, 2017b).

The learning goals of GC.

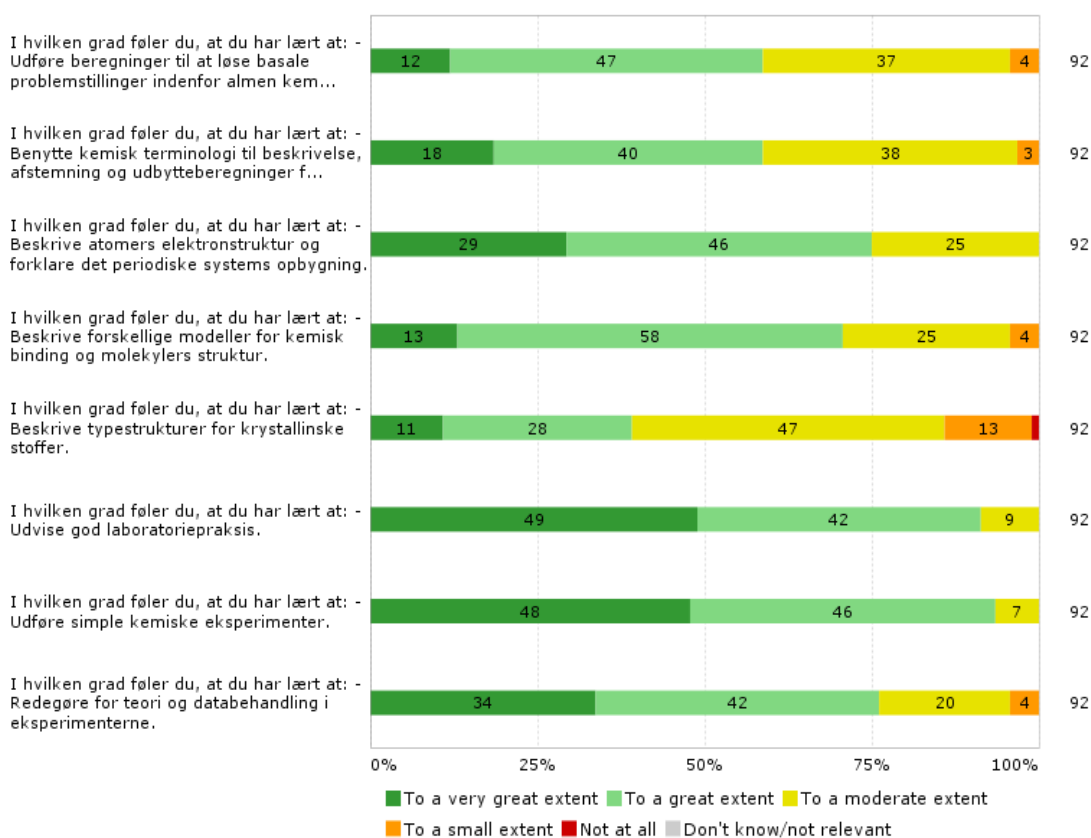


Figure M1. Students' perceived accomplishment of GC's eight learning goals (in Danish).



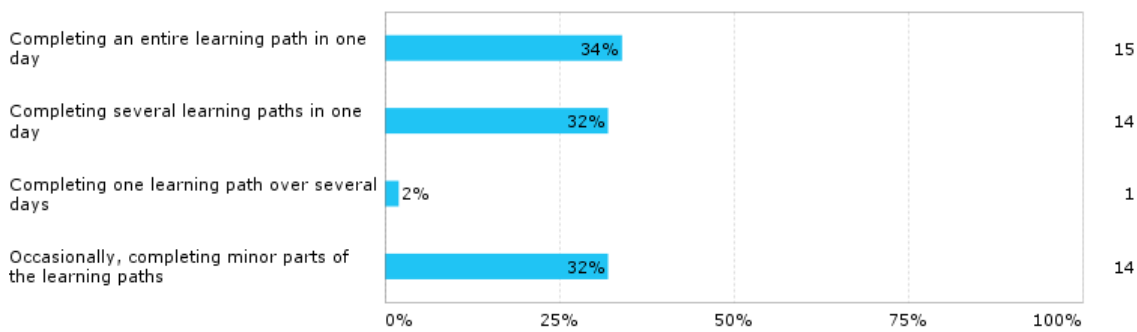


Figure M2. Pace of participation in the online activities in GC. That is, 66% (or 68%) most frequently participated in another pace than regular lecturing pace.

## Learning Design

The LD is described in Chapter 6 and further documented in Table M1 and Figure M3–M5.

Table M1

### Overview of the online materials and activity in GC

Online materials		Online activity	
Learning paths (contents)		Announcements	Posts
2016	3 (25 items, comprising 1 video and 22 MCQ activities with feedback)	3	0

Test dig selv i pH- og ligevægtsberegninger

**Test dig selv i pH- og ligevægtsberegninger**

**Velkommen**

Herunder er der en video (14 min) om pH udregninger, samt tre multiple choice opgaver. Her vil I blive ledt igennem nogle ligevægts og pH beregninger af forskellig sværhedsgrad. 1. opgavesæt er lettest, 3. opgavesæt er sværest.

Målet med disse opgaver er dels at hjælpe jer igennem nogle regneeksempler, som forhåbentligt hjælper jer til at løse lignende opgaver til TØ og eksamen, samt at give os noget statistik på hvilke trin i pH og ligevægtsberegninger der er svære for jer.

Det I svarer i disse opgaver bliver ikke bedømt på nogen måde, og er udelukkende for at hjælpe jer. Det betyder også at I gør jer selv en bjørnetjeneste ved at få svarene fra andre, bruge solve-funktionen på en lommeregner og lignende. Jeg vil derimod foreslå, at I finder papir og skriveredskab frem ved siden af computeren, og laver udregninger og lignende i hånden, lige som til eksamen. Til denne eksamen og rigtig mange andre eksaminer senere på studiet vil det være helt OK at bruge solve-funktionen til at finde svar på ligninger, men jeg vil kraftigt anbefale jer ikke at bruge den, da øvelsen i at rykke rundt på led og ligningsløsning generelt er utrolig nyttig for resten af jeres studietid. Man kan selvfølgelig altid benytte solve-funktionen bagefter til at tjekke om man er kommet frem til det rigtige resultat!

**Video om pH beregninger**

**Om pH beregninger**  
from Media Lab - STLL

Opgave: pH i svag syre...

Et velkendt spørgsmål. Det første man (ALTID!) gør er at skrive reaktionen op.

$$HB(aq) \rightleftharpoons H^+(aq) + B^-(aq)$$

Vi opskriver alt vi ved – ligning (1)-(4):

- $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq);$   
 $K_w = [H^+][OH^-] = 10^{-14}$
- $K_a = \frac{[H^+][B^-]}{[HB]}$  Den kender vi
- $C = [HB] + [B^-]$  Den kender vi
- $[H^+] = [B^-] + [OH^-]$

Link til toggle version

**Opgavesæt 1**  
Dette opgavesæt indeholder opgaver der omhandler basisviden om pH- og ligevægtsberegninger

**Opgavesæt 2**  
Dette opgavesæt indeholder mellemsvære opgaver i pH- og ligevægtsberegninger.

**Opgavesæt 3**  
Dette opgavesæt indeholder svære opgaver der omhandler pH- og ligevægtsberegninger, og er en god indikator for din eksamensparathed.

Figure M3. Overview of the self-test in GC.

Test dig selv i pH- og ligevægtsberegninger > Opgavesæt 1 > Take Test: Spørgsmål 1

## Take Test: Spørgsmål 1

**Test Information**

Description  
 Instructions  
 Multiple Attempts This Test allows multiple attempts.  
 Force Completion This Test can be saved and resumed later.

**Question Completion Status:**

**Question 1** 10 points Save Answer

Beregn pH i en saltsyreopløsning med koncentrationen  $C_{HCl} = 10^{-8} M$

Nyttige informationer:  
 $K_{HCl} = 10^4 M$   
 $HCl(aq) \rightleftharpoons H^+(aq) + Cl^-(aq)$   
 $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$

Her benyttes notationen  $H^+$ , selv om der i virkeligheden bliver dannet oxonium ( $H_3O^+$ ) i en sur opløsning. Dette har dog ingen indflydelse på beregningerne.  
 Hvilken ligning skal bruges for at løse denne opgave?

a. Saltsyre er en stærk syre, og pH kan derfor regnes ved brug af:  $pH = -\log(C_{HCl})$

b. Saltsyre er en svag syre, og pH kan derfor regnes ved brug af:  $pH = \frac{1}{2}(pK_s - \log(C_{HCl}))$

c. Vi skriver ligevægtsbrøken op, og finder  $[H^+]$  ved brug af solve-funktionen:  $K_{HCl} = \frac{[H^+][Cl^-]}{[HCl]}$

d. Ingen af ovenstående

**Save and Submit**

*Click Save and Submit to save and submit. Click Save All Answers to save all answers.*

Figure M4. Question 1 in the self-test in GC.

Teaching

- Ugesedler
- Slides fra forelæsninger
- Kahoot-scores
- Noter og supplerende materiale
- Flowcharts til LØ
- Holdtider og instruktører
- Course Evaluation
- Test dig selv i pH- og ligevægtsberegninger

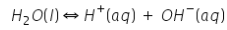
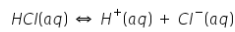
Question 1

10 out of 10 points

Beregn pH i en saltsyreopløsning med koncentrationen  $C_{HCl} = 10^{-8}M$

Nyttige informationer:

$$K_{HCl} = 10^4 M$$



Her benyttes notationen  $H^+$ , selv om der i virkeligheden bliver dannet oxonium ( $H_3O^+$ ) i en sur opløsning. Dette har dog ingen indflydelse på beregningerne.

Hvilken ligning skal bruges for at løse denne opgave?

Selected Answer: d. Ingen af ovenstående

Answers: a. Saltsyre er en stærk syre, og pH kan derfor regnes ved brug af:  $pH = -\log(C_{HCl})$

b. Saltsyre er en svag syre, og pH kan derfor regnes ved brug af:  $pH = \frac{1}{2}(pK_s - \log(C_{HCl}))$

c. Vi skriver ligevægtsbrøken op, og finder  $[H^+]$  ved brug af solve-funktionen:  $K_{HCl} = \frac{[H^+][Cl^-]}{[HCl]}$

d. Ingen af ovenstående

Response: Rigtigt

Feedback: Her er tale om en meget fortyndet syre, og vands autoprotolyse skal tages i betragtning. Til samtlige pH og ligevægtsopgaver i kommer til at lave kan/bør følgende fremgangsmåde tages i brug:

1. Opstil alle relevante ligevægtsbrøker, f.eks.  $K_{HCl} = \frac{[H^+][Cl^-]}{[HCl]}$  for saltsyre

2. Opstil ladningsbevarelse, f.eks.  $[H^+] = [OH^-] + [Cl^-]$ . Hvorfor? Har du nogensinde fået stødt af at stikke en

finger ned i et glas mælk? Eller når du har spildt den koncentrerede saltsyre ud over din hånd? Nej, det er fordi en væske altid er ladningsneutral (der er lige så mange positive ladninger som negative ladninger). Du stiller en ladningsbevarelse op ved at putte alle positive ioner på den ene side og alle negative ioner på den anden side. (HUSK at hvis en ion har mere end én ladning, skal der en koefficient foran, f.eks. for svovlsyre:  $[H^+] = [HSO_4^-] + 2[SO_4^{2-}] + [OH^-]$ )

3. Opstil massebevarelse, f.eks.  $C_{HCl} = [HCl] + [Cl^-]$ . Hvorfor? Dette er kemi, ikke trolddom, der opstår ikke atomer ud af det blå, og der forsvinder heller ikke nogen. Massebevarelsen sørger derfor for, at der er lige så mange atomer før ligevægt/reaktion, og efter ligevægt/reaktion.

4. Lav approksimationer. Denne del er den sværeste del for de fleste, og kræver at man laver nogle kvalificerede bud på hvad der er meget af, og hvad der er lidt af. Er  $pH=5$  er opløsningen svagt sur, så man skulle måske tro at  $[OH^-]$  fra vands autoprotolyse til dels havde en betydning i en beregning? Regner man det ud, så er  $[H^+] = 10^{-pH} = 10^{-4}M$  og  $[OH^-] = 10^{-(14-pH)} = 10^{-9}M$ , så koncentrationen af hydroxid ioner er 10.000 gange mindre end koncentrationen af  $H^+$ , koncentrationen af hydroxid ioner kan derfor negligeres.

5. Løs de ligninger du har stillet op. Det er en god idé at tjekke om du har lige mange ligninger og ubekendte, har du f.eks. 3 ligninger, og 4 ubekendte kan det ikke løses, og du har i så fald nok glemt at skrive en ligning op.

Jeg har svært ved at forstå masse- og ladningsbevarelse, fortæl mig mere - [Klik her](#).

[Klik OK for at få næste spørgsmål.](#)

Monday, 16 October 2017 20:30:50 o'clock CEST

← OK

Figure M5. Feedback upon correct test answer in GC.



# Appendix N: Digital Electronics (Case 4)

---

## Learning goals and outcome

The official learning goals of the two DE modules are provided below together with the students' perceived accomplishment of the learning goals in Figure N1–N2. In addition, the students' most frequent pace of participation is provided in Figure N3–N4.

- 'Redegøre for og anvende digitale grundbegreber, herunder Boolsk algebra, Karnaugh-kort, talsystemer og digitale koder
- Analysere digitale grundelementer (logiske gates og flip-flops), herunder And, Nand, Or, Nor, Xor, Not, SR latch, JK flip-flop
- Analysere og syntetisere kombinatoriske og sekventielle kredsløb, herunder multipleksere, decodere, encodere, addere, registre, tællere og simple tilstandsmaskiner
- Anvende standard digitale IC'er til konstruktion af digitale kredsløb
- Anvende værktøjer til simulering og verificering af digitale kredsløb Udføre laboratorieøvelser og udforme laboratoriejournaler
- Præsentere resultater skriftligt.' (Course Catalogue, 2017c).

The learning goals of Introduction to DE (2015) (in Danish).

- 'Redegøre for synkrone designprincipper
- Anvende test- og simuleringsværktøjer til at verificere HDL-designs
- Designe funktionelle digitale kredsløb med VHDL
- Anvende modulære og objektbaserede begreber til at opdele digitale designs
- Redegøre for de forskellige abstraktionsniveauer (og forskellene på disse): *Register-transfer level* (RTL), *technology schematics* samt fysisk implementering
- Demonstrere kendskab til de væsentligste arkitekturkomponenter i moderne FPGA'er
- Modellere og designe digitale systemer med tilstandsmaskiner (*finite state machines* (FSM))
- Anvende relevant teori i projektopgaver.' (Course Catalogue, 2017a).

The learning goals of DE (2016) (in Danish).

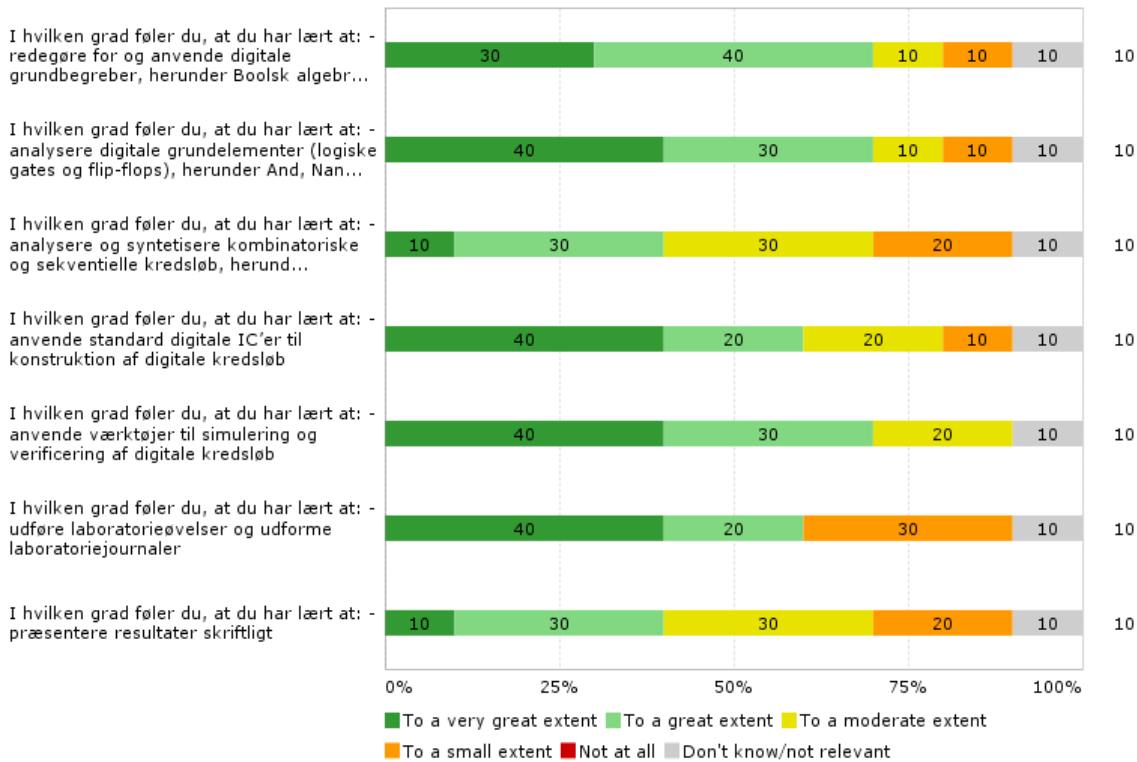


Figure N1. Students' perceived accomplishment of DE (2015)'s seven learning goals (in Danish).

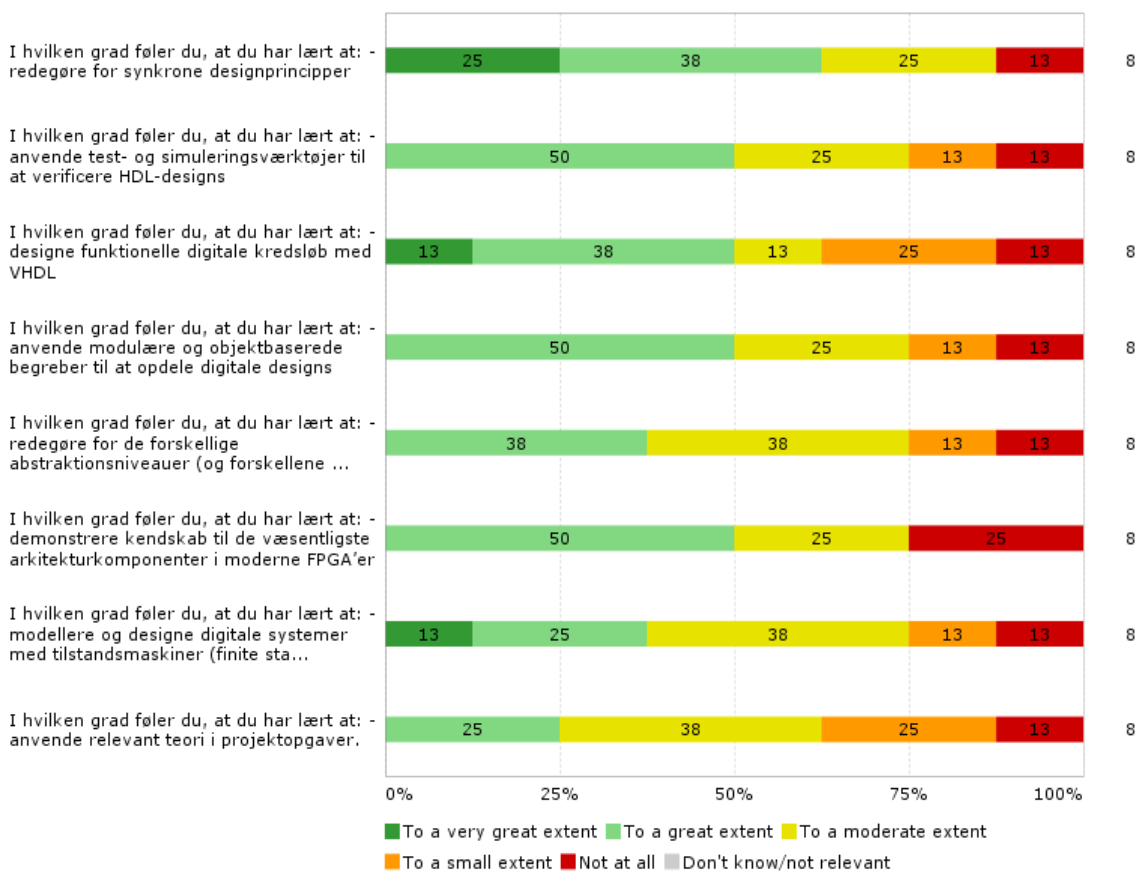


Figure N2. Students' perceived accomplishment of DE (2016)'s eight learning goals (in Danish).

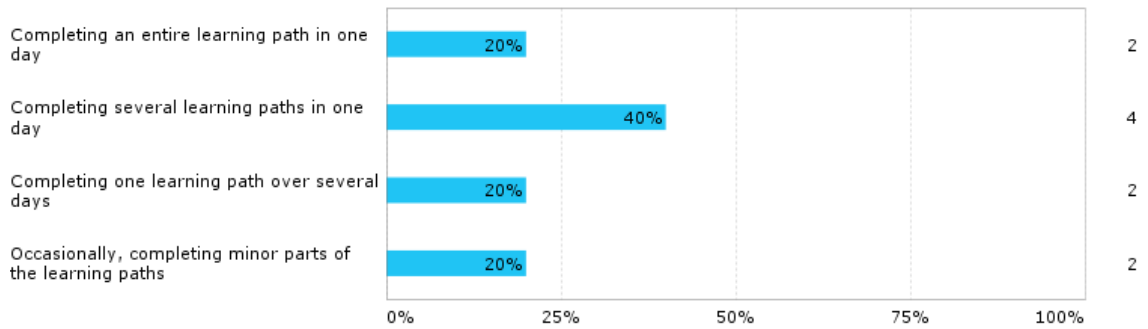


Figure N3. Pace of participation in the online activities in DE (2015). That is, 80% most frequently participated in another pace than regular lecturing pace.

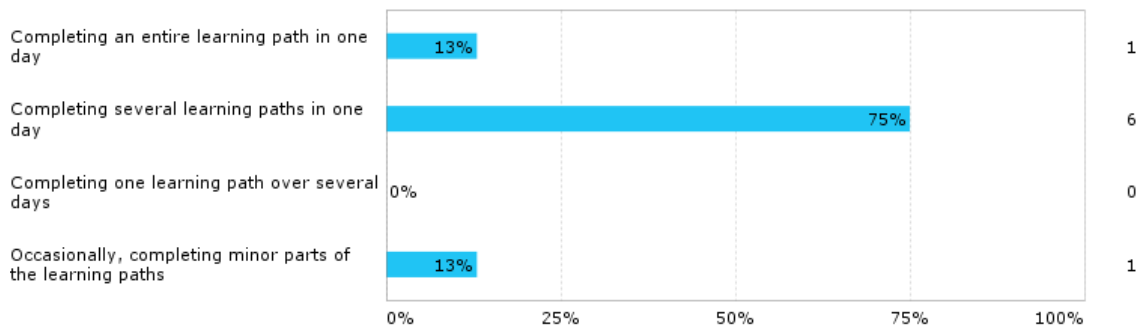


Figure N4. Pace of participation in the online activities in DE (2016). That is, 100% most frequently participated in another pace than regular lecturing pace.

## Learning Design

The LD is described in Chapter 6 and further documented in Table N1 and Figure N5–N12

Table N1

Overview of the online materials and activity in DE (2015) and (2016)

Online materials		Online activity	
	Learning paths	Announcements	Posts
<b>2015</b>	16 (73 items*, comprising 26 videos and 17 activities — 13 MCQ/warm-up activities as illustrated in Figure N8 and 4 lab assignments)	22	72
<b>2016</b>	20* (69 items, comprising 23 videos and 1 MCQ)	11	21

\*Items without content as folders are not included in this figure. \*\*Most of the learning paths included only one step and only one included an embedded, online MCQ/warm-up activity. However, a collaborative wiki activity with build-in feedback activities on VHDL was included.



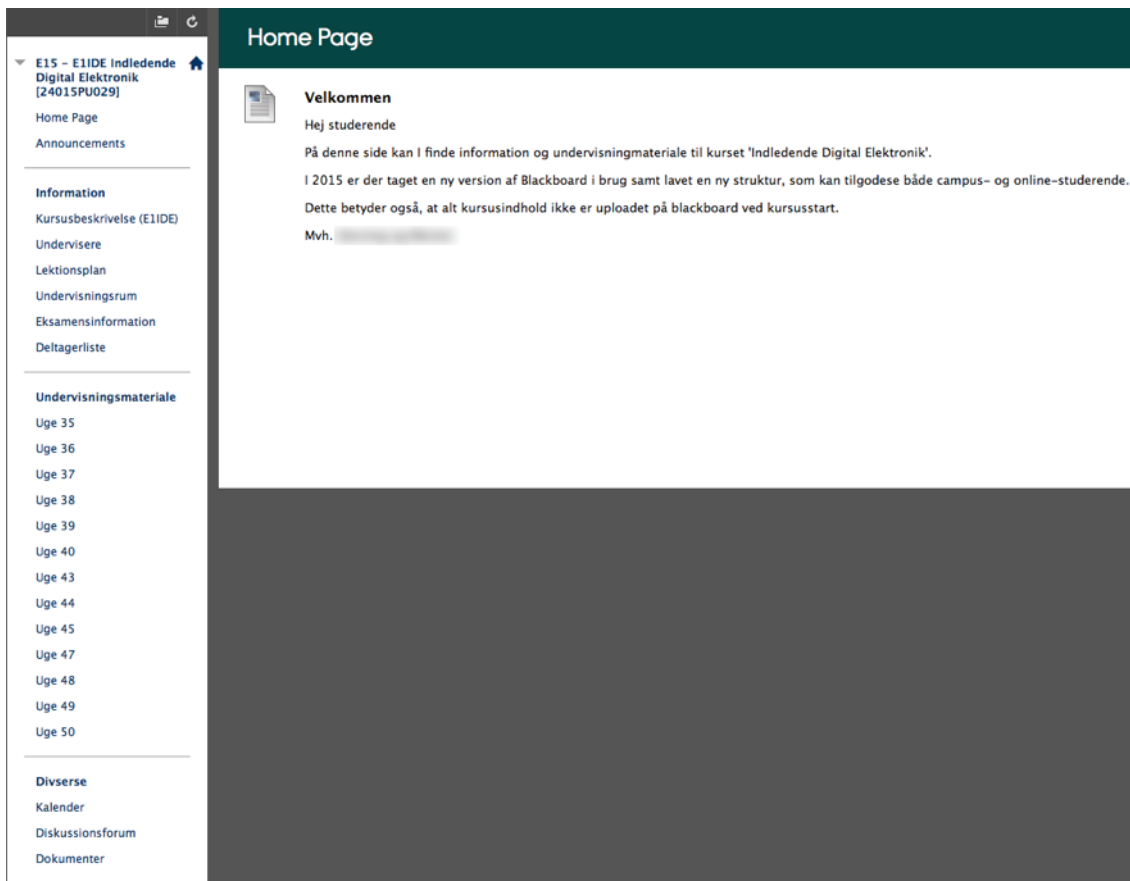


Figure N5. DE's home page in 2015.

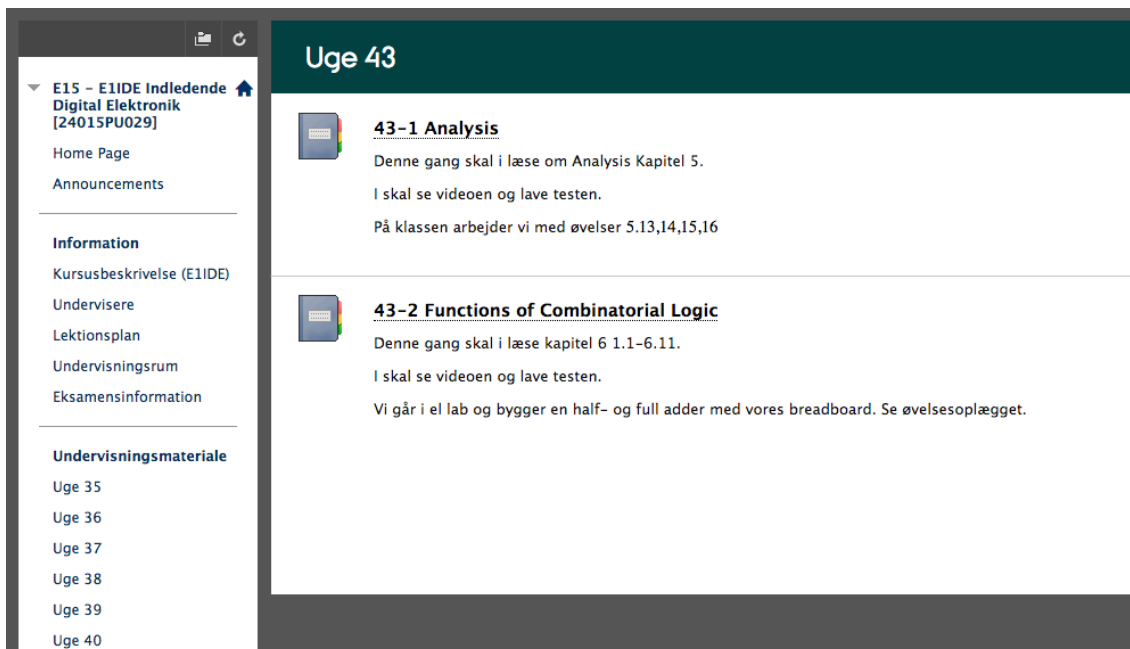



Figure N6. Overview of the two learning paths in Week 43, DE (2015)

Indholdsfortegnelse

Side 1 af 4

- Analysis
- 43-1
- Dagens Optagelse
- Dagens tavle

# Analysis



- Download video file: [E1IDE1-kap5.mp4](#)

*Figure N7.* The typical structure of learning paths in DE (2015). Here illustrated by the first learning path in Week 43. Besides the video, the learning path consists of a MCQ ('43-1') (see also Figure N6), a recording of the lecture (see also Figure N9), and a picture of the whiteboard (see also Figure 31).

E15 - E1IDE Indledende  
Digital Elektronik  
[24015PU029]

Home Page  
Announcements

**Information**  
Kursusbeskrivelse (E1IDE)  
Undervisere  
Lektionsplan  
Undervisningsrum  
Eksamensinformation

**Undervisningsmateriale**  
Uge 35  
Uge 36  
Uge 37  
Uge 38  
Uge 39  
Uge 40  
Uge 43  
Uge 44  
Uge 45  
Uge 47  
Uge 48  
Uge 49  
Uge 50

**Diverse**  
Kalender  
Diskussionsforum  
Dokumenter

## Take Test: 43-1

**Test Information**

Description

Instructions

Multiple Attempts Not allowed. This Test can only be taken once.

Force Completion This Test can be saved and resumed later.

**Question Completion Status:**

**Question 1** 10 points Save Answer

Et AOI udtryk kunne være  $(AB + CD)'$  Det equivalente POS udtryk er

- $(A + B)(C + D)$
- $(A' + B')(C' + D')$
- $(A + B)'(C + D)'$
- Ingen af delene

**Question 2** 10 points Save Answer

En sandhedstabel er vist for en :

- NAND gate
- NOR gate
- EX-OR gate
- EX-NOR gate

**Question 3** 10 points Save Answer

En LED skal være tændt er

- LED-1
- LED-2
- ingen
- Begge

**Question 4** 10 points Save Answer

For at implementere SOP udtrykket  $X=A'BC'+AB'D+BD'E$  skal vi bruge en

- 3-input AND gate
- 3-input NAND gate
- 3-input OR gate
- 3-input NOR gate

**Save and Submit**

Click Save and Submit to save and submit. Click Save All Answers to save all answers.

Save All Answers Save and Submit

Figure N8. The MCQ/warm-up activities included in Week 43 in DE (2015).

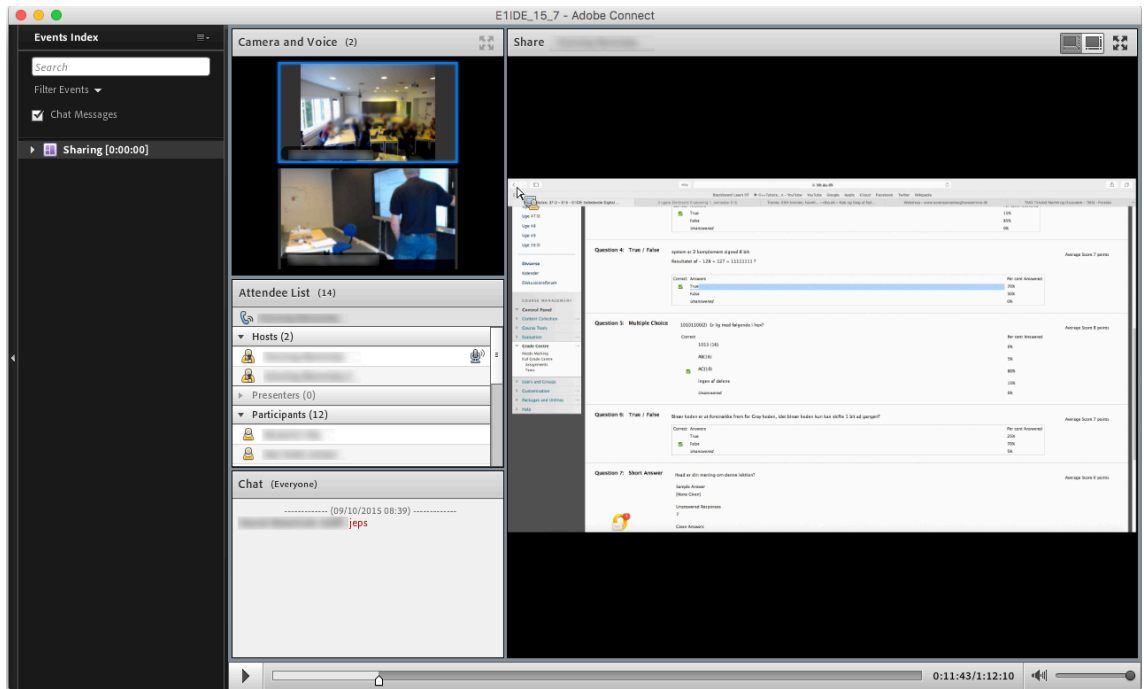


Figure N9. Video recording of in-class lecture in DE (2015) containing feedback on out-of-class MCQs with both face-to-face and online students.

**Home Page**

**Digital Elektronik på 2 semestre**  
**E2DEL, Digital elektronik, 2 semestre**

Hej og velkommen til E2DEL hjemmesiden.

Dette kursus omhandler digital elektronik, med fokus på brugen af VHDL, og struktureret design af digitale kredsløb, samt simulering og afprøving af disse i en FPGA.

Kurset indeholder et antal obligatoriske afleveringer, og indholdet i disse danner basis for eksamen.

Derfor er det vigtigt at du som studerende deltager aktivt i alle øvelser, og forbereder dig inden lektionerne. Vi bruger "flipped classroom", dvs du må afsætte tid til forberedelse inden vi mødes i klassen, for at samle op på nøglebegreber, og arbejde med stoffet gennem opgaver og øvelser.

**Hvad med eksamen ?**

Eksamen er individuel og mundtlig. Eksamen vil indeholde spørgsmål evt kombineret med en kort fremlæggelse af een af de obligatoriske øvelser, du har afleveret.

**Hvad skal jeg bruge af udstyr ?**

Øvelserne og opgaver kræver at du har følgende hardware, samt værktøjer installeret (inden kursus-start) :

- **Xilinx vivado** (kan kun køre på windows og linux, så hvis du ejer en Mac, ligesom jeg, skal du have en windows eller linux du kan boote, og køre værktøjerne her). Vivado installationen er forklaret her: <http://www.xilinx.com/training/vivado/vivado-design-suite-installation-overview.htm>  
 Du skal oprette og registrere dig inden du kan downloade.  
 Når du køber et Vivado board (hos Jens i Ellab) er der i dette kit en "voucher" som giver adgang til en "Node-locked-licens" med ekstra features i Vivado.
- **Sigasi** en VHDL plugin til eclipse, som gør det mere effektivt at skrive VHDL, da Vivado har code-completion, templates osv., find information om hvordan du installerer denne i eclipse, her: <http://www.sigasi.com/download>, vælg "Install Eclipse Plugin"
- **Eclipse**, hvis du allerede har denne fra programmering på 1 semester er det fint
- Vi skal bruge et Evaluation Board, til at lave øvelser på, dette er et board Xilinx, Digilent og Avnet har designet i fællesskab. Du kan læse mere om det her: <https://reference.digilentinc.com/artv:refmanual>, Jens Mortensen har dem på lager, i de skulle også fremgå af litteraturlisten.
- I de forskellige øvelser skal vi bruge nogle småkomponenter, 7-segment-displays, transistorer, komparatorer og nogle modstande.  
 Øvelses-vejledninger er tilgængelige i god tid, så onliners kan nå at bestille evt manglende komponenter.

**Hvem underviser ?**

[\[Redacted\]](#) se lektionsplanen for detaljer

FPGA'er giver mange muligheder for avanceret systemdesign, indeholdende både HW og SW, signalbehandling, processorer osv, så der burde være noget for enhver...

*-glæd jer, det gør vi :-)*

Figure N10. Home page of DE (2016).

**Uge 16**

**Mandag FSMD**

FSMD er FSM'ens storebror, så sørg for at have fat i hvad FSM'en er for en størrelse, inden du går igang

**Torsdag - Finonacci numbers med FSMD**

I skal se videoen hvor listing 6.3.1 fra bogen bliver gennemgået.

I den næste video vises hvordan denne kode er applied på ARTY boarded udvist som Hex værdier på 7 segment displayet.

**Øvelse på klassen:**

I skal hente koden fra listing 6.3.1 og lave en test bench og demonstrere at det kører som det skal.

Dernæst skal i lave en top fil og intaniere de nødvendige filer for at vise det på jeres ARTY board hvor I viser resultatet som hex værdier

Happy coding

**optagelser**

Mandag : [\[Redacted\]](#)

Torsdag: [\[Redacted\]](#)

Figure N11. Overview of Week 16 of DE (2016), including its two learning paths (see Figure N12) and links to recordings (similar to Figure N9).

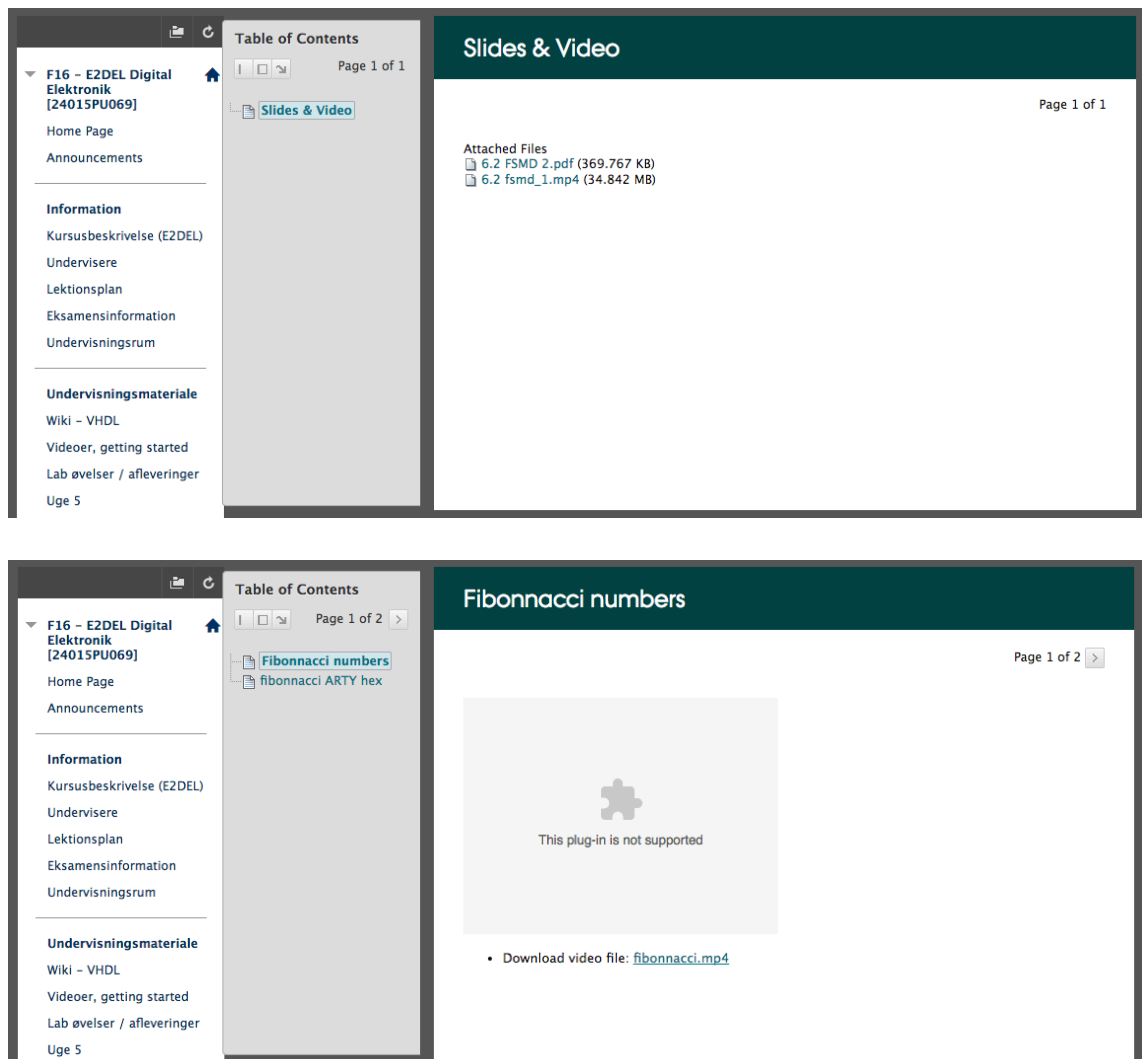


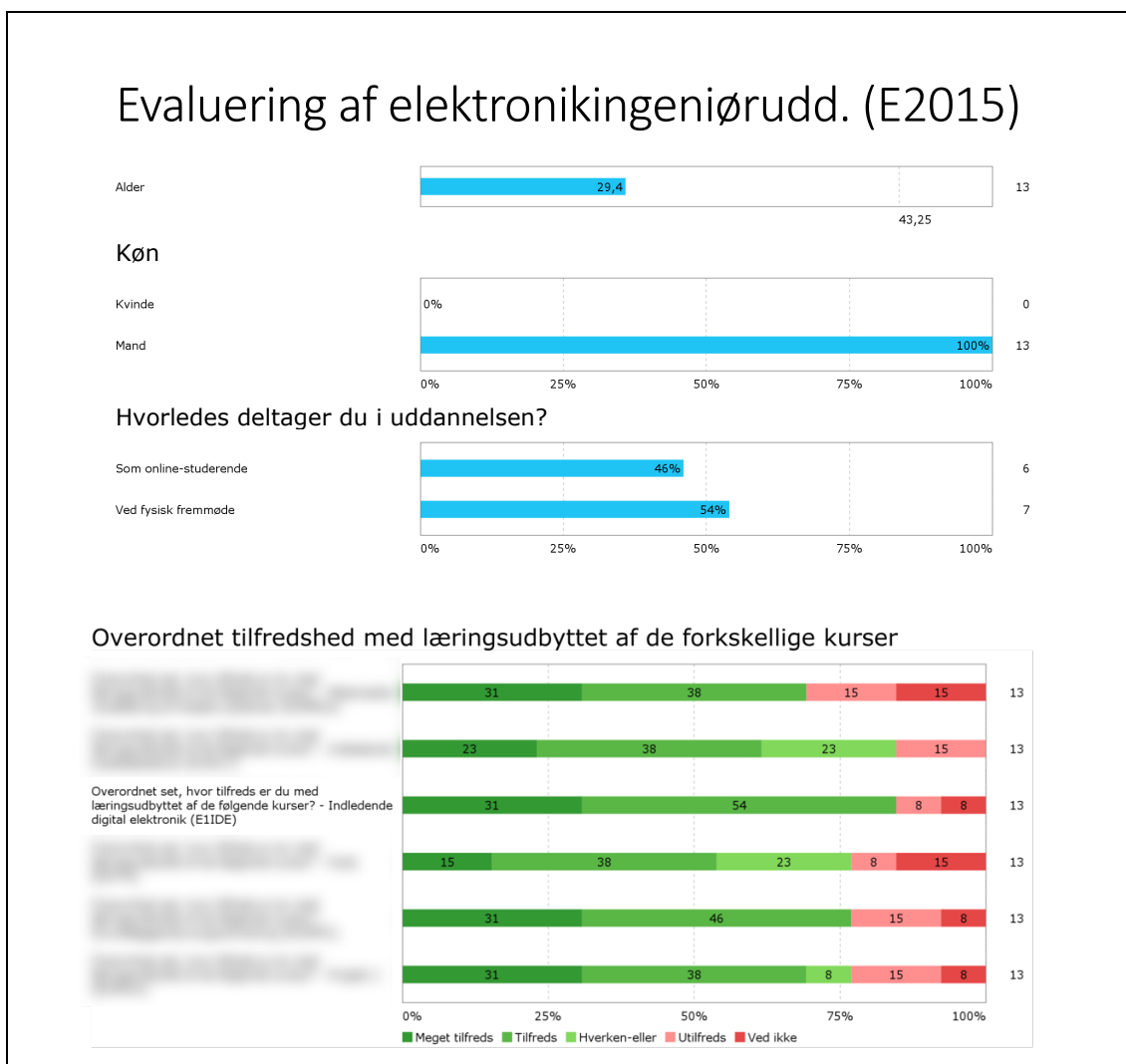
Figure N12. The two learning paths in Week 16 in DE (2016).

## Dissemination

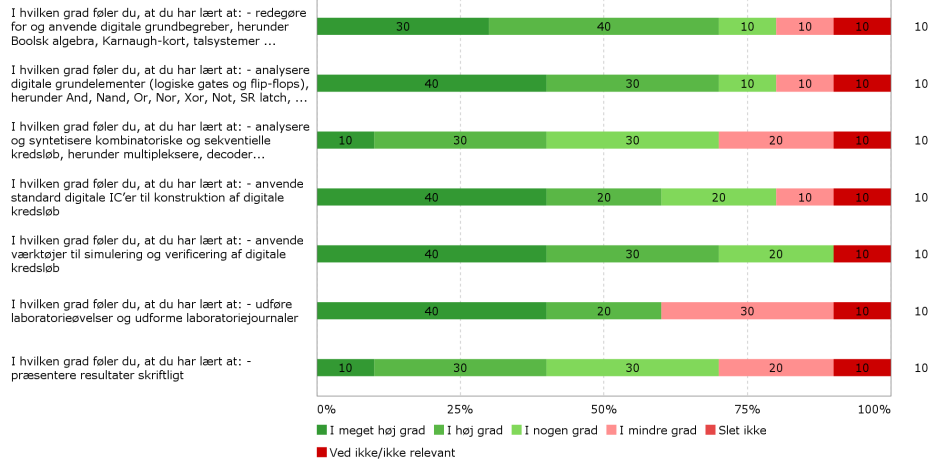
Between the two iterations, the main survey results of DE (2015) (see Figure N13) were shared with Educator 4 and the project manager per e-mail on 19 February 2016 together with the following interpretation/observations:

- 'The students are generally satisfied with the learning outcome of all modules and most learning goals appear achieved
- The students use a lot of time on their studies — more than full-time on average. (40 hours)
- The students find the learning paths useful — in particular for going over the curriculum, repetition, problem solving, and exam preparation

- The students are not really benefitting from the online supervision forum
- As opposed to many other ST modules, the students on the programme are using the learning paths for deep learning purposes (not only to pass the exam and/or to learn only the most necessary parts of the curriculum)
- The students appreciate the format with the learning paths and are generally positive towards online education
- The students are often using the learning paths alone and at home
- The students are fully benefitting from the flexibility in time and pace of the learning paths' (the researcher).

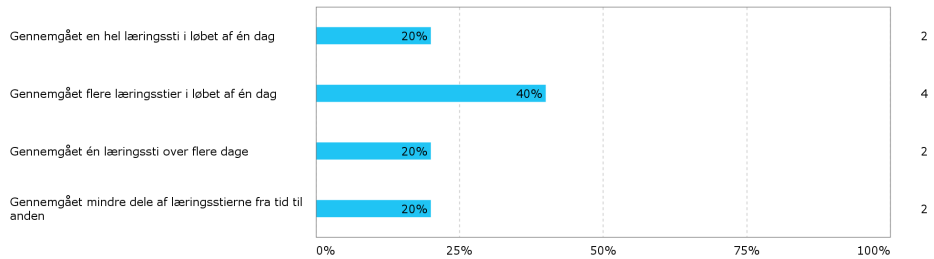


## Oplevet opfyldelse af læringsmål i Indledende Digital Elektronik

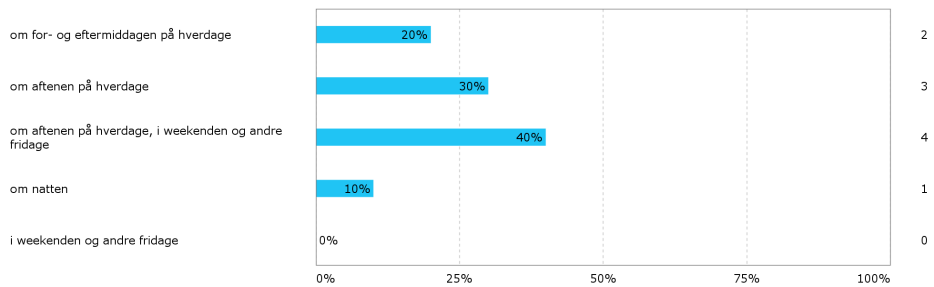




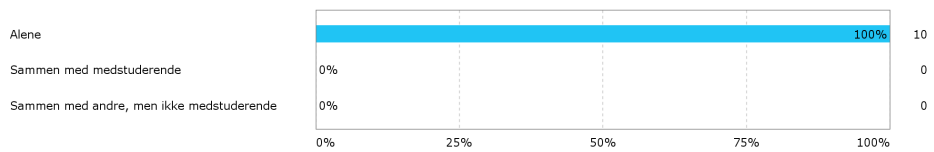
### Hvordan har du oftest gennemgået læringsstierne?



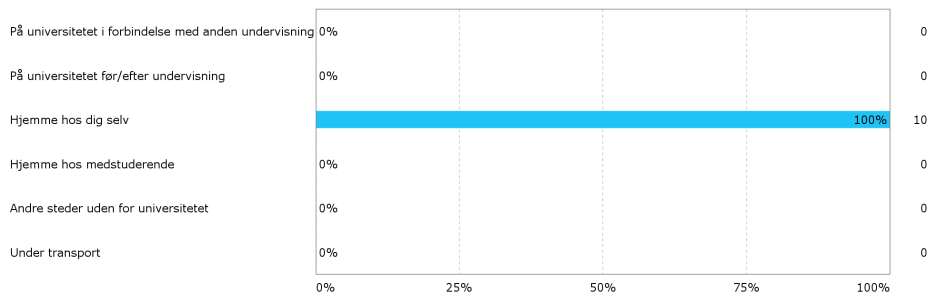
### Hvilket tidspunkt på ugen har du oftest gennemgået læringsstierne?

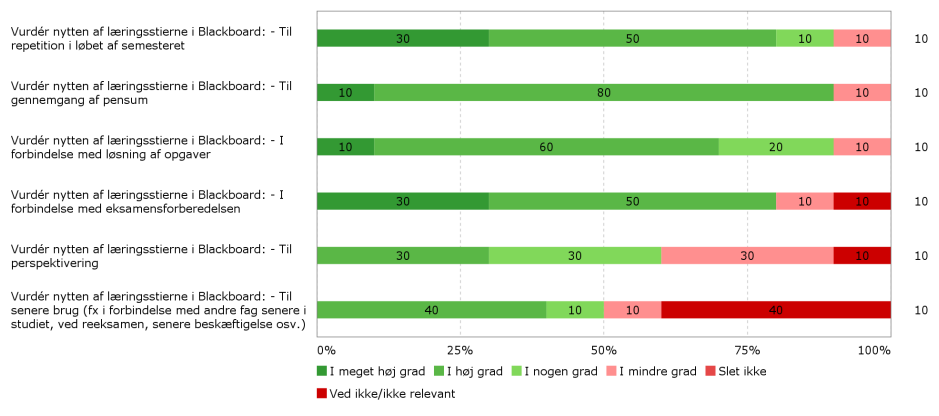
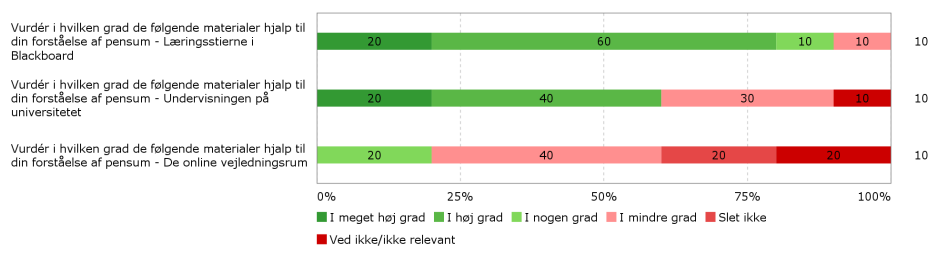
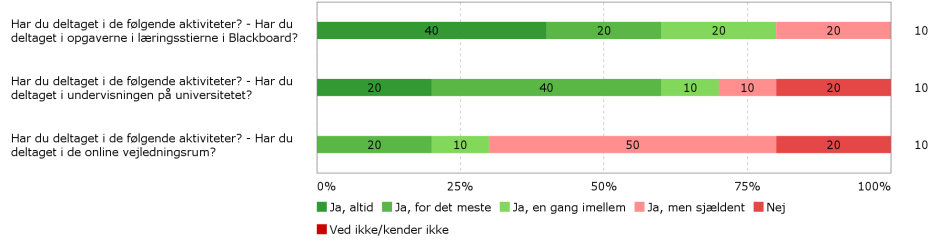


### Har du oftest gennemgået læringsstierne alene eller sammen med andre?



### Hvor har du oftest gennemgået læringsstierne?





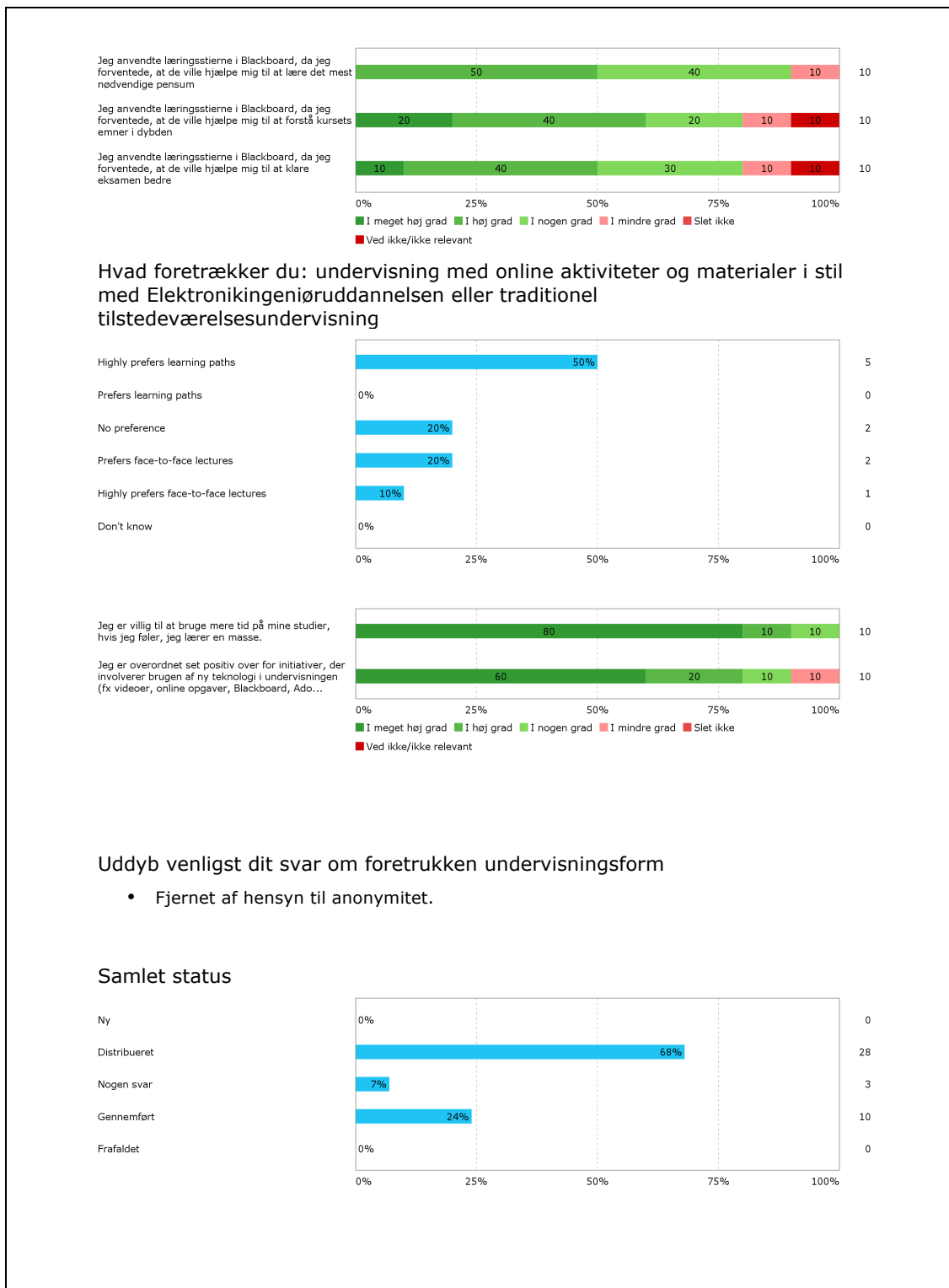


Figure N13. Evaluation report of the engineering programme, including DE (2015) (in Danish). Results from the other modules are omitted in this Figure.

## Herning Online toolkit and course page

The *Herning Online Toolkit* as introduced to the educators on Herning Online (in Danish) is provided in Figure N14 with lectures/lessons ('forelæsninger'), lab ('laboratorie-

undervisning), and exercises ('øvelser/regneopgaver') to the left, the pedagogical models and available technologies in the middle of the arrow, and online learning to the right.

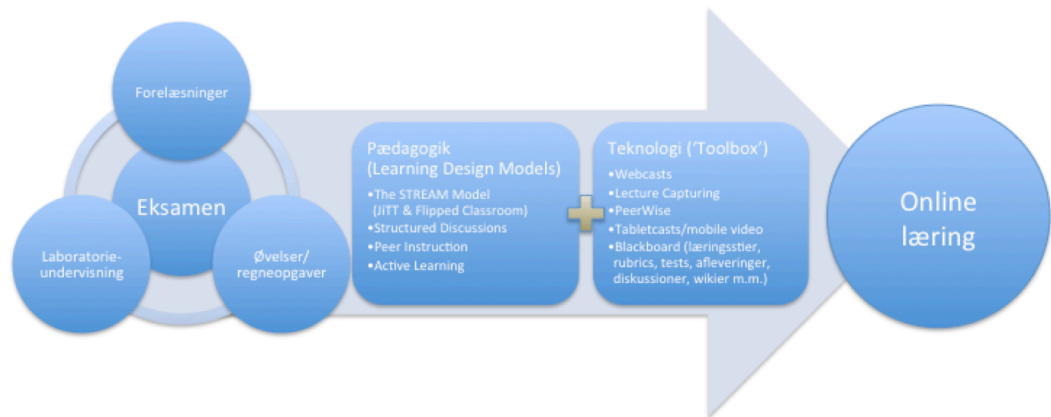


Figure N14. The Herning Online Toolkit including STREAM.

Screenshot of the Herning Online course home page is available in Figure N15. Aside from the course home page, two learning paths were provided and supplemented with forums for activities and questions.

The screenshot shows the Blackboard interface for the 'Herning Online' course. The browser address bar indicates the URL: [https://blackboard.au.dk/webapps/blackboard/content/listContent.jsp?course\\_id=-38595\\_1&content\\_id=-236074\\_1](https://blackboard.au.dk/webapps/blackboard/content/listContent.jsp?course_id=-38595_1&content_id=-236074_1). The Aarhus University logo is visible in the top left. The navigation menu on the left includes sections like 'Herning Online', 'Kursusstyring', 'Kontrolpanel', 'Samlet indhold', 'Kursusfunktioner', 'Evaluering', 'Karaktercenter', 'Brugere og grupper', 'Tilpasning', 'Pakker og hjælpeprogrammer', and 'Hjælp'. The main content area is titled 'Velkommen (forside)' and contains a 'Velkommen til Herning Online' section. This section includes a welcome message, a course plan overview, and a list of activities for the first two weeks. A 'Læringsmål' (Learning Objectives) section follows, detailing the course's goals. Below that is the 'Bemanding' (Staff) section, which lists the course coordinator and moderators. The 'Blackboard og Sprog' (Blackboard and Language) section provides information about the course's use of Blackboard and the Danish language. The 'Spørgsmål og Svar' (Questions and Answers) section includes a Q&A forum link. The page also features a 'Hurtig afmelding' (Quick Unenroll) button in the bottom left corner.

Figure N15. Herning Online course home page.

# Appendix O: STREAM compliance

Table O1 provides an overview of the actualised LDs' compliance with STREAM. The overview is the consensus/agreed outcome of two individual observations of the online teaching practice and materials, which subsequently have been intercoder reliability tested and discussed (see also Lombard, 2010). The intermediate test results are available in Table O2.

The explanation of keys is: 'x' — the characteristic in question was identified — directly or indirectly — in the available material to a greater or a lesser extent; '-' — the characteristic in question was not identified — directly or indirectly — in the available material though it ought to be identifiable; and '?' — the characteristic may be present, but it was not possible to identify it neither was it expected to be identifiable in the available materials. In addition, the following keys are used for the intercoder reliability test: '(x)' — it appears that the characteristic is present but it needs further validation; and '(-)' — it appears that the characteristics is not present but it needs further validation.

Table O1  
*The STREAM compliance*

STREAM criteria		Case 1: Astrophysics		Case 2: Calculus 2		Case 3: General Chemistry	Case 4: Digital Electronics	
		2014	2015	2014	2015	2016	2015	2016
No.	<b>The major cyclical process ('the feedback loop')</b>							
1	the module is designed with a cyclical process shifting between out-of-class, online preparatory content and/or activities followed by in-class activities,	x	x	x	x	-	x	x
2	out-of-class activities are designed so they <i>provide data</i> to the educator and/or tutors about the students' learning,	x	x	x	x	x	x	?*
3	the educator and/or tutors <i>provide</i> online and/or in-class <i>feedback</i> on the out-of-class activities based on the generated data,	?	?	x	x	-	x	?*
4	the data is used to adjust in-class and/or online activities,	?	?	x	x	-	?	?
5	the experiences with the in-class and/or online activities are used to adjust the following week's out-of-class online content and/or activities	-	-	-	-	-	?	?
No.	<b>The out-of-class loop</b>							
6	the out-of-class activities are designed as a cyclical process	x	x	x	x	-	x	-

	with several steps shifting between content and activities that activate the content,							
7	the out-of-class process includes a set of reflection exercises (warm-up questions or similar),	x	x	x	x	-	x	-
8	content and activity support is provided online,	x	x	x	x	-	x	x
9	a notable extent of the out-of-class activities are designed to be thought-provoking and/or require the student to explore, synthesize, and/or formulate answers for actualising higher levels on the SOLO or Bloom's taxonomies.	x	x	-	-	-	-	-

\*Most likely this is not available/significant as only one MCQ activity and one wiki activity were present, and no feedback was observed.

## Intercoder reliability test

The intercoder reliability test was carried out by having the researcher and an external coder review the seven module pages in the LMS looking for evidence of the nine STREAM characteristics listed in the first row by means of the aforementioned set of keys. The results were subsequently discussed and the reached agreement was listed after the equals sign in Table O2. That is, the key prior to the '/' sign refers to the external coder's observation and the key after refers to the researcher's observation. The agreed observation is listed after the '=' sign.

Table O2:

### *The intercoder reliability test results of the STREAM compliance*

Module and delivery	STREAM characteristics	FB1 (coder) // (researcher)	FB2	FB3	FB4 (in-class/online)	FB5	OOC1	OOC2	OOC3	OOC4
	<p>The major cyclical process ('the feedback loop', FB)</p> <ul style="list-style-type: none"> <li>• FB1: the module is designed with a cyclical process shifting between out-of-class, online preparatory content and/or activities followed by in-class activities,</li> <li>• FB2: out-of-class activities are designed so they <i>provide data</i> to the educator and/or tutors about the students' learning,</li> <li>• FB3: the educator and/or tutors <i>provide</i> online and/or in-class <i>feedback</i> on the out-of-class activities based on the generated data,</li> <li>• FB4: the data is used to <i>adjust</i> in-class and/or online <i>activities</i>,</li> <li>• FB5: the experiences with the in-class and/or online activities are used to adjust the following week's out-of-class <i>online</i> content and/or activities.</li> </ul> <p>The out-of-class loop (OOC)</p> <ul style="list-style-type: none"> <li>• OOC1: the out-of-class activities are designed as a cyclical process with several steps shifting between content and activities that activate the content,</li> <li>• OOC2: the out-of-class process includes a set of reflection exercises (warm-up questions or similar),</li> <li>• OOC3: content and activity support is provided online,</li> <li>• OOC4: a notable extent of the out-of-class activities are designed to be thought-provoking and/or require the student to explore, synthesize, and/or formulate answers for actualising higher levels on the SOLO and Bloom's taxonomies.</li> </ul>									

---

**Case 1: Astrophysics**

2014	x = x // x	x = x // x	? // ? = ?	? // - = ?	(x) // - = -	x // x = x	x // (x) = x	x // x = x	x // x = x
2015	x = x // x	x = x // x	x // ? = ?	x // - = ?	(x) // - = -	x // x = x	x // (x) = x	x // x = x	x // x = x

---

**Case 2: Calculus 2**

2014	x // x = x	? // x = x	x // x = x	x // x = ? / x	? // - = -	x // x = x	? // x = x	x // - = x	? // - = -
2015	- // x = x	- // x = x	x // x = x	x // x = x	? // - = -	x // x = x	? // x = x	(x) // x = x	x // (x) = -

---

**Case 3: General Chemistry**

2016	(x) // x = -	(x) // // (x)	- // - = -	- // - = -	- // - = -	- // - = -	- // - = -	- // - = -	- // - = -
------	--------------	---------------	------------	------------	------------	------------	------------	------------	------------

---

**Case 4: Digital Electronics**

2015	x // x = x	x // x = x	(x) // x = x	- // (x) = (x) / ?	- // ? = ?	- // x = x	? // (x) = x	x // x = x	- // (-) = -
2016	x // x // x	(x) // - = (-)	x // (-) = (-)	? // - = (-)	? // ? = ?	- // - = -	- // - = -	x // x = x	- // - = -

---





# Appendix P: Module educator interviews

## Interview guide

Table P1  
*The module educator interview guide*

No.	Questions	Aim and comments
	<p>Introduction and formalities</p> <ul style="list-style-type: none"> <li>• Make note of when (date and time), where (face-to-face somewhere, phone, etc.), and how/format (filled-in by educational developer, by the educator),</li> <li>• Short introduction to the aim of the interview,</li> <li>• Informed consent, possibilities of withdrawal, audio recording consent (if interview).</li> </ul>	To inform the educator about the aim of the interview/survey, etc.
0	<p>The exact set of questions depends on the specific module and educator but may include:</p> <ul style="list-style-type: none"> <li>• How long have you taught the module?</li> <li>• How was the module previously taught?</li> <li>• What is your background (as an educator)?</li> <li>• How many is assisting with teaching the module and what is their role?</li> <li>• What is the typical cohort (programme background, level, etc.)</li> </ul>	Clarifying questions about background, module format, etc.
1	Please describe your aims with transforming the module?	<p>To make the educator explicate the incentives and identify the intended affordances.</p> <p>Also, to identify the intended transformational level according to SAMR.</p>
2	<p>To what extent do you find the following nine aspects important to your transformation of your module?</p> <p style="text-align: center;"> <small>a very high extent   a high extent   a certain extent   a limited extent   a very limited extent   not at all   don't know/not applicable</small> </p> <p>that the students can study from where they want and do not always have to come to campus <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/></p> <p>that the students develop skills for a future job <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/></p> <p>that the students learn to link theory to practice <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/></p> <p>that the examination reflects the curriculum and skills the students are supposed to have learnt <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/></p> <p>that feedback is provided to the students' learning process, their assignments, and answers to their questions <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/></p> <p>that the teaching supports collaboration and interaction among the students <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/></p> <p>that the students find the teaching and learning is enjoyable <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/></p> <p>that the teaching is in complete concordance with the formal requirements (i.e. learning goals and the estimated study time/ECTS) <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/></p> <p>that the students can repeat lectures and other teaching activities as they prefer <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/></p>	In this survey, the aim is to compare the transformation with the general affordances of educational technology and the students on module and their assessment of the nine affordances compared to the transformed module.
3	What kind of previous experience with educational technology and learning design do you have? E.g., have you previously transformed a module with webcasts, learning paths, online quizzes and activities, or similar (and how many modules)?	To analyse the educator's prior experiences and knowledge (and its influence on the transformation) and partly to understand the educator's perception/attitude towards learning design
4	Do you remember and use the STREAM model?	A direct question about their

	<ul style="list-style-type: none"> <li>• Don't remember having heard about STREAM</li> <li>• I've heard about it, but I am not using it (to my knowledge)</li> <li>• I've heard about it, but I am mostly using it for (loose) inspiration</li> <li>• I use it as a guide/model for the design/transformation of the module</li> </ul>	use of STREAM
5	<p>Which of the following components did you include in your transformed module?</p> <ul style="list-style-type: none"> <li>• Webcasts recorded in the webcast studio</li> <li>• Follow-up videos (and other kinds of follow-up materials) based on online activities</li> <li>• Online quizzes</li> <li>• Learning paths (also referred to as learning modules in Blackboard)</li> <li>• An e-instructor to follow up on questions, moderate discussions, etc.</li> <li>• Follow-up on the online activities in-class</li> <li>• ...</li> </ul>	An indirect question about their use of STREAM by asking to its characteristics. I.e., the use of learning pathways, webcasts, e-instructor, online quizzes/activities, follow-up videos and materials, other follow-up online or in-class.
6	Did you acquire any assistance during the development or while the module was running from Science Media Lab, Blackboard support, Centre for Science Education/STLL, peers, other?	
7	What are the differences in format compared to regular teaching practice?	
8	<p>Did you spend more or less time on preparing and teaching the transformed module compared to business-as-usual (in percentages)</p> <ul style="list-style-type: none"> <li>• Half the time (50%)</li> <li>• More or less the same (100%)</li> <li>• Twice the time (200%)</li> </ul>	To make the educator estimate his/her time consumption.
9	<p>What are your experiences with the format and being an online educator</p> <ul style="list-style-type: none"> <li>• What did work well?</li> <li>• What would you like to improve?</li> <li>• Difficult on a scale from 0–5 (0 very easy - 5 very hard)</li> <li>• How does it feel to teach online? ('resistance to change'/educator satisfaction/attitude)</li> <li>• Your general attitude towards new educational initiatives such as using technology in teaching.</li> </ul>	To address educator satisfaction, 'resistance to change',
10	Any other comments to the format or to STREAM?	

The questionnaire in question no. 2 was sent to the educators two days prior to the interview forming the basis for a discussion of their aim of the transformation and priorities.

## Coding and coding frame

In the context of this project, coding refers to the process of categorising pieces of the interview transcripts to a predefined set of categories described in the coding frame. The coding was carried out in NVivo 11.4 for Mac using the coding frame "LD Perspectives and practices" based on the conceptualisation of LD efficiency in Chapter 3 and the cross-case coding framework (Miles & Huberman, 1994). The procedure was the following for both the researcher and the external coder:

1. Open the project and familiarise with the coding frame, including its structure and the description of codes;
2. Go through each code in NVivo to understand its meaning. If the meaning is not obvious, refer to the detailed description of the code available in the coding frame

below. The codes are organised under three overall headings (also called ‘parents’): *descriptive*, *interpretive*, and *pattern*. Descriptive covers text referring to the direct effort or impact that the educator has put into or been impacted by the intervention or background information. Interpretative is text that expresses the attitude, identity, knowledge, and motivation of the educator. Pattern is used for recurring themes across codes. This heading is — most likely — not used in this part of the coding process.

3. Code each interview thoroughly by reading the text and assigning the relevant code (or codes) to each piece of text. Guidelines for the coding are:
  - a. Code entire sentences and, if relevant, paragraphs and include the interview question in the code to make it easier to understand the context.
  - b. Text not related to the intervention/module, such as interview formalities and other irrelevant small talk is not coded. That is, not all text has to be coded.
  - c. Should there unexpectedly be text that does not fit into any existing code a new code is made and placed under ‘residual’.
  - d. Parent codes are, to the extent possible, not used.
  - e. The codes ‘impact on students’, ‘student effort’, and any of their children codes are, most likely, not used in this coding as well as the two pattern codes.
  - f. More than one code may be used at text pieces if applicable; however, not if it is in the same branch. That is, text pieces are not coded more than once in the same family.

Table P2  
*The coding frame for educator interviews*

Code	Description
Descriptive and interpretive	
<b>Background information</b>	Various information about the module and the educator
<b>Module design and history</b>	Information about the module design and practice, and background information about the module, its history, staff, etc.

<b>Educator background</b>	Information about the educator's background. Notice that, educational training
<b>Educator effort</b>	The direct and indirect effort the educator puts into the intervention
<b>Time spent on teaching and transforming the module</b>	The time spent on the module, including both transforming the module, developing materials, and teaching the module.
<b>Uptake of learning design model and defeated barriers</b>	To what extent the educator has adopted the learning design approach and the STREAM model and/or its principles. This includes the concepts of out-of-class loop, feedback loop, follow-up activities (see Godsk, 2013), and the five characteristics of learning design: pedagogy-informed, learning-centred, design-oriented teaching, and the use of aids and resources for representation and/or sharing practices.
<b>Attitude and perception</b>	The educator's attitude towards and perception of educational development and educational technology in general and/or in her/his teaching practice.
<b>Educational development</b>	The educator's attitude towards and perception of educational development in general and/or in her/his teaching practice. This also includes attitude towards professional development and updating teaching practice.
<b>Educational technology</b>	The educator's attitude towards and perception of educational technology in general and/or in her/his teaching practice. This also includes attitude towards IT systems and IT support at the university, including Blackboard, educational IT, and tools used in-class.
<b>Identity</b>	
<b>Authority and ownership</b>	To what extent the educator feels an ownership of her/his module and acts as an authority on it.
<b>Confidence with technology</b>	How easy the educator feels the transformation process and teaching with technology was, including her/his general confidence with technology.
<b>Responsibility of quality</b>	To what extent the educator feels a responsibility for the quality of the module in general.
<b>Knowledge</b>	
	The expressed and/or demonstrated knowledge of the following subcategories.
<b>Learning Design and STREAM</b>	The expressed and/or demonstrated knowledge of learning design and/or STREAM.
<b>Pedagogical</b>	The expressed and/or demonstrated pedagogical knowledge, including potential misconceptions.
<b>Technical</b>	The expressed and/or demonstrated technical knowledge, including potential misconceptions.
<b>Motivation and rationale</b>	
<b>Extrinsic</b>	I.e., where the educator's motivation for the transforming the module comes from others/is initiated by others. This includes the official rationale, official aims, and ambitions for the transformation.
<b>Intrinsic</b>	I.e., that the educator has a 'self-desire to seek out new things' and is motivated by enjoyment or an interest in the transformation itself.
<b>Impact on educator</b>	The impact the intervention has had on the educator and her/his teaching practice and work at the university.
<b>Flexibility in time, place, and pace</b>	Flexibility in time (e.g., during the week), place (location), and pace (teaching rhythm and speed, e.g., allowing for consecutive time for other duties) due to the transformation of and teaching the module.
<b>Satisfaction and perception of the intervention</b>	The educator's subjective satisfaction with the intervention and the work associated with it. This also includes dissatisfaction.
Pattern	
<b>Strong extrinsic motivation induces an outperforming intervention</b>	(not in use) I.e., there is a clear focus on actualising the educational and/or institutional benefits of the intervention
<b>Strong intrinsic motivation induces a progressive intervention</b>	(not in use) I.e., the efficiency (ratio between effort and impact) may be disregarded by the educator who sees module development as a goal in itself
Residual	

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(new codes as required)

For text and any new information and themes that do not belong in any other category.

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## Intercoder reliability test

An intercoder reliability test was conducted by means of the coding frame provided in Table P2 and an external coder and guided by Lombard et al.'s resource on intercoder reliability testing (Lombard et al., 2004). The coding comparison was carried out in NVivo by means of Cohen's Kappa coefficients (K) and the results are reported in Table P3.

Table P3  
*Kappa coefficients of the coding comparison*

Code	Source Size (sentences)	Kappa
Descriptive\Educator effort		0.67
Descriptive\Educator effort : InterviewAstrophysics	443	0.83
Descriptive\Educator effort : InterviewCalculus2	428	0.49
Descriptive\Educator effort : InterviewGeneralChemistry	269	0.74
Descriptive\Impact on educator		0.21
Descriptive\Impact on educator : InterviewAstrophysics	443	0.32
Descriptive\Impact on educator : InterviewCalculus2	428	-0.09
Descriptive\Impact on educator : InterviewGeneralChemistry	269	0.41
Interpretive\Attitude and perception		0.16
Interpretive\Attitude and perception : InterviewAstrophysics	443	0.02
Interpretive\Attitude and perception : InterviewCalculus2	428	0.29
Interpretive\Attitude and perception : InterviewGeneralChemistry	269	0.14
Interpretive\Identity		0.05
Interpretive\Identity : InterviewAstrophysics	443	-0.05
Interpretive\Identity : InterviewCalculus2	428	0.06
Interpretive\Identity : InterviewGeneralChemistry	269	0
Interpretive\Knowledge		0.21
Interpretive\Knowledge : InterviewAstrophysics	443	0.16
Interpretive\Knowledge : InterviewCalculus2	428	0.32
Interpretive\Knowledge : InterviewGeneralChemistry	269	0.13
Interpretive\Motivation and rationale		0.33
Interpretive\Motivation and rationale : InterviewAstrophysics	443	0.39
Interpretive\Motivation and rationale : InterviewCalculus2	428	0.15
Interpretive\Motivation and rationale : InterviewGeneralChemistry	269	0.41
<b>Overall Unweighted Kappa</b>		<b>0.27</b>

The test was carried out on three full interviews (Case 1–3), whereas Case 4 was not tested (due to the resignation of the external coder during the project). The external coder had some previous knowledge of the material as she had also transcribed the interviews but no previous knowledge of coding or NVivo. Thus, the external coder was provided with instructions of how to code the interviews in NVivo together with the coding frame

above. Besides this, there had been no training of the coder to reach the reliability levels reported and limited time was available. The three interviews were coded by the external coder on 2 March 2017 and the coding was subsequently compared and discussed.

The overall unweighted Kappa is 0.27, which is to be considered as *fair* according to Landis and Koch's (1977) nomenclature. In particular, there was a *fair to almost perfect* level of agreement among the descriptive codes, typically ranging from 0.32 to 0.83, whereas among the interpretive codes the Kappa was lower and typically below 0.4. By discussing and comparing the codings it appears that the low Kappa values were mainly related to: (1) the description of the codes in the coding frame, (2) how explicit statements should be made before they were coded, (3) how much surrounding text was included in the codes, and (4) how interpretative the code would be. The latter relates to how much background knowledge the coder had of the LD processes and educators, and thus is able to relate the statements to the educator's attitude, identity, knowledge, or motivation.

In general, this highlights a potential inherent problem in conducting intercoder reliability tests in action research in which the researcher also participates in the cases being developed and studied. It is inevitable that the researcher will have a much more exhaustive knowledge of the case, and thus potentially be more capable of identifying more interpretative codes. However, this problem can be addressed by providing more background knowledge and/or training and detailed descriptions of the codes to a new group of external coders. Furthermore, it also highlights a potential methodological problem in using semi-structured interviews for both revealing factual and descriptive details as well as looking for more interpretative codes and underlying explanations. For instance, both the interviewer and interviewee may find it difficult shifting between relatively close-ended questions to more open-ended questions. On the other hand, as the questions were deducted from theory, the themes of the interviews were to a large extent already defined. This ensured that all necessary topics were covered.

# Appendix Q: Module student survey

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## Questionnaire

The questionnaire for the module student surveys is provided in Figure Q1. The structure of the survey and its questions have to the extent possible been reused across surveys in order to be compatible with other/previous surveys; however, minor variations occur. This includes learning goal specific questions; questions dependent on the exact learning activities, materials, and the level of transformation, such as perceived utility of the activities and provided materials, as well as the supported pace flexibility; and questions proposed by the educator. In addition, the questions regarding time consumption and learning goal accomplishment did not evolve before late 2014, and thus were not included in the early C2 (2014) survey, whereas other questions are sustained with previously used Likert scales to be compatible with previous surveys. Figure Q1 shows the questionnaire used for evaluating C2 (2015).

The first three questions are on background information, including age, gender, and study; the next three questions are on learning outcome and time consumption; the next four questions are on the time, place, and pace of the online learning materials/learning paths; the next four questions are on the use and utility of the materials; and the last four questions are on study preferences and attitude towards TEL as well as comments on the module in general.



## Evaluering af Calculus 2, efteråret 2015

Formålet med spørgeskemaet er at evaluere kurset Calculus 2 og dets brug af online materialer. Endvidere indgår resultaterne i et forskningsprojekt med henblik på at forbedre undervisningen på Aarhus Universitet.

Din deltagelse er en stor hjælp.

Spørgeskemaet tager ca. 7-10 minutter at udfylde og besvarelserne behandles anonymt.

Alder

\_\_\_\_\_

Køn

Kvinde

Mand

Hvad læser du på universitetet?

Agrobiologi

Biologi

Datalogi

Fysik

Geoscience (Geologi)

It

Kemi

Matematik

Matematik-økonomi

Medicinsk kemi

Molekylær medicin

Molekylærbiologi

Nanoscience

Ingeniøruddannelse

Andet

Overordnet set, hvor tilfreds er du med læringsudbyttet af Calculus 2?

Meget tilfreds

Tilfreds

Hverken-eller

Utilfreds

Ved ikke

I hvilken grad føler du, at du har lært at:

anvende basale metoder og resultater inden for calculus til at løse opgaver i differential- og integralregning i én og flere variable, lineær algebra og række-teori

I meget  
høj  
grad

I høj  
grad

I  
høgen  
grad

I  
mindre  
grad

Slet  
ikke

Ved  
ikke/ikke  
relevant

benytte matematisk terminologi og symbolsprog.

Hvor mange **timer** har du brugt på Calculus 2 **pr. uge i gennemsnit**?

De næste 4 spørgsmål drejer sig **udelukkende om læringsstierne i Blackboard** i Calculus 2 (dvs. IKKE læringsstierne i sci2u).

Med **læringsstier** i Blackboard menes de online sekvenser på bb.au.dk med videoer, opgaver og refleksionsspørgsmål. Kurset bestod af i alt **14 læringsstier (2 for hver uge)**.

Eksempelvis består Uge 1 af to læringsstier: "Projektioner og ortogonalitet" og "Dobbelt integral".

**Hvordan** har du **oftest** gennemgået læringsstierne?

- Gennemgået en hel læringssti i løbet af én dag
- Gennemgået flere læringsstier i løbet af én dag
- Gennemgået én læringssti over flere dage
- Gennemgået mindre dele af læringsstierne fra tid til anden

**Hvilket tidspunkt** på ugen har du **oftest** gennemgået læringsstierne?

- om for- og eftermiddagen på hverdage
- om aftenen på hverdage
- om aftenen på hverdage, i weekenden og andre fridage
- om natten
- i weekenden og andre fridage

Har du **oftest** gennemgået læringsstierne alene eller sammen med andre?

- Alene
- Sammen med medstuderende
- Sammen med andre, men ikke medstuderende

**Hvor** har du **oftest** gennemgået læringsstierne?

- På universitetet i forbindelse med anden undervisning
- På universitetet før/efter undervisning
- Hjemme hos dig selv
- Hjemme hos medstuderende
- Andre steder uden for universitetet
- Under transport

Har du deltaget i de følgende aktiviteter?

	Ja, altid	Ja, for det meste	Ja, en gang imellem	Ja, men sjældent	Nej ikke/kender ikke	Ved ikke
Har du deltaget i opgaverne i læringsstierne i Blackboard?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Har du benyttet refleksionsspørgsmålene i Blackboard? (hvor man skulle angive, hvad der var vanskeligt eller særligt interessant)?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Har du deltaget i læringsstierne i sci2u?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Har du læst de anbefalede kapitler i bogen "Calculus - Concepts and Contexts"?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Har du læst de anbefalede kapitler i bogen "Lineær Algebra via eksempler"?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Har du deltaget i Teoretiske Øvelser (TØ)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Har du deltaget i Matematiklaboratoriet (MatLab)

Har du deltaget i forelæsningerne

Vurdér i hvilken grad de følgende materialer og aktiviteter hjalp til din forståelse af pensum

	I meget høj grad	I høj grad	I nogen grad	I mindre grad	Slet ikke	Ved ikke/ikke relevant
Videoerne i Blackboard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Opgaverne i Blackboard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Læringsstjerne i sci2u	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Indlæggene i diskussionsforummet "Calculus 2 Forum"	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Deltagelse i Teoretiske Øvelser (TØ)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Deltagelse i Matematiklaboratoriet (MatLab)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Deltagelse i forelæsningerne	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Vurdér nytten af læringsstjerne i **Blackboard** og **sci2u** samlet set i forhold til følgende:

	I meget høj grad	I høj grad	I nogen grad	I mindre grad	Slet ikke	Ved ikke/ikke relevant
Til gennemgang af pensum	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I forbindelse med løsning af opgaver	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Til perspektivering	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Til repetition i løbet af kvarteret	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I forbindelse med eksamensforberedelsen	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Til senere brug (fx i forbindelse med andre fag senere i studiet, ved reksamen, senere beskæftigelse osv.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

I hvor høj grad passer de følgende tre udsagn på din anvendelse af læringsstjerne?

	I meget høj grad	I høj grad	I nogen grad	I mindre grad	Slet ikke	Ved ikke/ikke relevant
Jeg anvendte læringsstjerne i Blackboard, da jeg forventede, at de ville hjælpe mig til at klare eksamen bedre	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Jeg anvendte læringsstjerne i Blackboard, da jeg forventede, at de ville hjælpe mig til at lære det mest nødvendige pensum	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Jeg anvendte læringsstjerne i Blackboard, da jeg forventede, at de ville hjælpe mig til at forstå kursets emner i dybden	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Hvad foretrækker du: undervisning med online læringsstier i Blackboard i stil med Calculus 2 eller traditionelle forelæsninger i et auditorium?

- Foretrækker i høj grad læringsstier
- Foretrækker i nogen grad læringsstier
- Ingen særlig præference
- Foretrækker i nogen grad forelæsninger
- Foretrækker i høj grad forelæsninger
- Ved ikke

I hvilken grad er du enig i de følgende udsagn?

	I meget høj grad	I høj grad	I nogen grad	I mindre grad	Slet ikke	Ved ikke/ikke relevant
Jeg er villig til at bruge mere tid på mine studier, hvis jeg føler, jeg lærer en masse.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Jeg er overordnet set positiv over for initiativer, der involverer brugen af ny teknologi i undervisningen (fx clickers, videoer, online opgaver, sci2u, Blackboard m.m.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Uddyb venligst dit svar om foretrukken undervisningsform

Andre kommentarer til undervisningen i Calculus 2?

Må vi kontakte dig for et kort, opfølgende interview? Hvis ja, angiv venligst din e-mail-adresse. Din deltagelse og svar vil blive behandlet anonymt.

---

Når du klikker Afslut lukkes skemaet og svarene indsendes. Vi takker mange gange for dine svar og din tid.

Venlig hilsen  
Science and Technology Learning Lab

*Figure Q1. Module student survey of C2 (2015) as the example.*



# Appendix R: Module data

In addition to the observations, interviews, and surveys, data on module pass-rates (Table R1), GPAs (Table R2), and online time consumption (Table R3) was obtained to estimate the student efforts and impacts (see Chapter 6).

Table R1  
*Module pass-rates*

	<b>Astrophysics</b>	<b>Calculus 2</b>	<b>General Chemistry</b>	<b>Intro to Digital Electronics</b>	<b>Digital Electronics</b>	<b>AU ST (baseline)</b>
<b>2011</b>	77.4%	83.2%				
<b>2012</b>	72.1%	83.5%				87.6%
<b>2013</b>	78.4%	82.3%		93.3%		86.2%
<b>2014</b>	80.3%	73.7%	96.0%	85.7%	60.0%	83.6%
<b>2015</b>	81.6%	74.7%	98.3%	57.1%	33.3%	80.7%
<b>2016</b>	85.6%	83.8%	97.8%	96.4%	61.5%	82.0%
<b>2017</b>					76.0%	

Table R2  
*GPAs for the graded modules*

	<b>Astrophysics</b>	<b>Calculus 2</b>	<b>Digital Electronics</b>	<b>AU ST (baseline)</b>
<b>2011</b>	7.6	8.8		
<b>2012</b>	6.2	8.5		7.3
<b>2013</b>	6.6	7.6		7.3
<b>2014</b>	7.1	5.7	7.6	6.9
<b>2015</b>	7.0	6.4	5.6	6.9
<b>2016</b>	7.7	6.9	7.6	7.0
<b>2017</b>			7.6	

Table R3  
*Average online time per active student in hours*

	<b>Astrophysics</b>	<b>Calculus 2</b>	<b>General Chemistry</b>	<b>Introduction to Digital Electronics</b>	<b>Digital Electronics</b>	<b>AU ST (baseline)</b>
<b>2014</b>	2.49*		1.26			
<b>2015</b>	26.82	15.97	3.46	13.66		11.57
<b>2016</b>	85.55	46.19	11.95	33.98	38.61	18.88
<b>2017</b>					57.74	

\*This is suspected to be an outlier.



# Appendix S: Translated quotations

Table S1  
*Translated quotations*

Chapter / section	Translation	Original (in Danish)
<b>Chapter 5, 'The institutional perspective'</b>	'61 per cent of young people that have completed 9th grade are expected to get a higher education. Denmark has a high educational level. Now it is about improving learning and preparing the students for the future job market'	'61 procent af de unge, der afsluttede 9. klasse i 2015, forventes at få en videregående uddannelse. Danmark har et højt uddannelsesniveau. Nu handler det om at styrke læringen og ruste de studerende til fremtidens arbejdsmarked'
	'Since we developed ... the educational IT strategy the world has changed — the education market has changed completely. There has been a massive slowdown in influx [funding] ... in terms of "dimensioning", neither do we see the previous development of educations — a large focus on improving student completion times has arisen. So, ... we now have a completely different focus on quality in recruitment [and] rethinking education [with technology] ... We are highly focused on recruiting the motivated students with good qualifications — this has been dramatically intensified' (PVC)	'Men fra vi lavede AU's strategier, også Educational IT-strategien, der har omverdenen jo ændret sig, uddannelsesmarkedet ændret sig fuldstændig. Der er kommet en massiv opbremsning i tilgangen, der er kommet, altså blandt andet i form af dimensionering, der er heller ikke tidligere udvikling af (...) bare masser af uddannelser, der er kommet stor fokus på, at de studerende gennemfører hurtigere, øhm. Så jeg tænker, altså vi har ... Det gælder stadigvæk, men vi har nok fået et helt andet kvalitetsfokus på, og det gælder både i rekruttering, men det gælder med dem der, du nævnte, eller listede, der tænker jeg især den her med gentænkning af, af undervisningen er nok den jeg tænker står stærkest. Og noget jeg tænker også har ændret sig, fordi man kan sige, det du læste op, det var sådan meget fokus på de studerende. Det har vi stadigvæk. Vi er meget fokuserede på at få fat i studerende, der er motiverede og har gode adgangsgivende forudsætninger; det er skærpet voldsomt,
	'... I don't believe in fully online education. I still believe in the meeting between the student and the educator and the curriculum — and I am aware that it can happen in another way too. ... We have an attractive campus and ... study environment... and it is our ambition that this physical and psychological working environment is to support this meeting' (PVC)	'...jeg tror ikke på det, på ren online-undervisning. Jeg tror stadigvæk på mødet mellem den studerende og underviseren og stoffet og jeg er godt klar over, at det kan godt ske på anden måde også. Det fysiske møde, det og ... og vi har en attraktiv campus. Vi har en god campus og vores studiemiljø håber jeg også på kommer til at, altså det er i hvert fald visionen, at det skal støtte det fysiske og psykiske studiemiljø skal støtte op om det møde.'
<b>Chapter 6, 'Case 1...'</b>	'it [STREAM] has ... inspired me to the large transformation in 2014 and to combine the so-called in-class out-of-class activities with each other. For instance, Just-in-Time Teaching, etc.... This is also where I've made activities that subsequently test the students. In other words, I've taken the STREAM model and tuned it a little bit according to the way I wanted to teach this module' (Educator 1).	'Og den har da haft, den har da inspireret mig til den store omlægning, som kom i '14 (Pause: 3.0s) i og med det her med at bruge de her 'in-class-out-of-class-aktiviteter' til at flyde ind i hinanden. For eksempel alt det med 'just-in-time-teaching' og sådan noget. Det er noget, jeg har haft glæde af (Pause: 3.5s), blandt andet i form at streammodellen. Det er også der, hvor jeg har lavet de her aktiviteter, der udprøver de studerende efterfølgende. Så jeg har taget STREAM-modellen og så har jeg tunet den lidt, så det passede til den måde, jeg gerne vil undervise i dette kursus på.'
	'It has ... been easy for me to have this model because it has helped me realise what I find appropriate in the module and what I could apply as is, and what I wanted to develop according to [my] mission as an educator and do differently... So, the model provides a lot of answers and you can take	'Det har også været nemt for mig at have den model, for så har jeg også kunne se, hvad jeg finder særligt hensigtsmæssigt her i forhold til modellen, nå men så bruger jeg det, som det er, og hvad kunne jeg tænke mig at udvikle på, så udvikler jeg bare på det, fordi der har man jo tit en eller anden mission som underviser og



	what you can use. In addition, I appreciate to have a model to build upon — otherwise you'll sort of have to reinvent the wheel by yourself' (Educator 1).	siger, at det kunne jeg godt tænke mig at gøre det på en lidt anderledes måde, og så gør man jo bare det. Så modellen, den giver en helt masse svar og så kan man jo tage det, man kan bruge. Så, jeg synes, det er dejligt at have en model at støtte op på, for ellers skal du jo ligesom genopfinde den dybe tallerken selv.'
	'I haven't used the little loop [i.e., the out-of-class loop] to a very large extent. The activities I've made do not loop, i.e., there isn't a content activity followed by a test or similar. I do that in another way... the five activities can be completed in random order... So, I am more thinking it as an entirety instead of what feeds what in such a loop' (Educator 1).	'Altså, det lille loop har jeg for eksempel ikke brugt i særlig vid udstrækning. De aktiviteter, jeg har sat op er... Jeg har fem onlineaktiviteter hver uge, og de fem onlineaktiviteter jo ikke som sådan looper ikke, så det er ikke sådan at der er en indholdsaktivitet, der bliver efterfulgt af en test eller sådan noget. Det gør jeg i et eller andet format, men de fem aktiviteter, der er, kan godt laves i en tilfældig rækkefølge, uden at det ødelægger det alt for meget. Så jeg tænker mere helheden i det (Pause: 3.0s) end jeg har tænkt, hvad de føder ind i hinanden i et sådan loop.'
	'... I have also been adjusting the large loop [i.e., 'the feedback loop'] so it would suit me better. I have changed the aspect of adjusting out-of-class after in-class so that I instead test the students out-of-class after in-class, so it's another version of the STREAM model...' (Educator 1).	'Jeg har også pillet lidt i det store loop, sådan at det passede bedre til mig. Så det her med at man justerer, efter in-class bruger man til at justere out-of-class, den del har jeg lavet lidt mere om, således at den det, der sker efter in-class er at jeg tester de studerende out-of-class, så det er en lidt anden version af STREAM-modellen, men altså, det passer jo fint ind under.'
<b>Chapter 6, 'Case 2...'</b>	'... actually, it is you who all along insisted that those reflection exercises where the students were asked to answer what they found easy and interesting and that sort of thing should be included' (Educator 2).	'ja det er jo faktisk jer, der har insisteret på det fra starten af, ik', at der skulle være de der refleksions spørgsmål, hvor de skulle svare på, hvad der var svært eller var let og hvad der var interessant og sådan noget. '
	'I had used clickers and that was also one of the reasons that I, from the beginning, tried to find a way to preserve the good effect of clickers in lectures. And that is what we have done in the learning paths by separating the videos with questions related to what they [the students] had previously seen. So, this element in the learning paths simply came due to my previous experience with clickers' (Educator 2).	'Jeg havde brugt clickere, ikke også, og det var så også en af grundene til, at jeg fra starten forsøgte at finde en facon, hvor vi kunne bevare det der (2,5s), den gode effekt af clickere i forbindelse med forelæsningserne, ik'. Og det er det, vi har gjort i læringsstierne, ik', hvor videosegmenterne bliver adskilt af nogle spørgsmål, der relaterer sig til det foregående de har set, ik'. Så det element i læringsstierne, det er simpelthen kommet fordi at jeg havde erfaring med clickere på forhånd.'
<b>Chapter 6, 'Case 3...'</b>	'I think I will suggest that some of these things were expanded to also cover other parts of the curriculum' (Educator 3).	'Jeg tror, at jeg ville foreslå, at man udbyggede nogle af de her ting til andre dele af pensum også. '
<b>Chapter 6, 'Case 4...'</b>	'We had an intake of seven in ... 2014. The year before it was around 12–14. And the year before that a few more.... We had to do something' (Educator 4).	'vi havde et optag på syv i, hvad bliver det, '14. Året før, der var det 12–14 stykker. Året før igen, der var det lidt mere... men altså der skulle også ske noget markant.'
	'... we have had displayed [the STREAM model] a few times or more... and I do not think that anyone was in doubt about how it worked.... We have shown the model and discussed it... and we have concentrated on what is going on in the model' (Educator 4).	'Altså vi har jo haft den oppe på projekteren et par gange eller tre eller hvad vi nu har haft, ikke også. Og jeg tror ikke, at der er nogen, der har været i tvivl om, at øh, at det var sådan, det fungerede... vi har vist modellen og vi har diskuteret den, ikke også, altså. Men men men (2,0s) og vi er gået så dybt ned i, hvad der sker i modellen. '
<b>Chapter 6, 'Educator effort'</b>	'I've used more time than a regular educator would because I use it for exemplary use of Blackboard, which is a goal in itself in this module' (Educator 1).	'Men ellers har jeg jo brugt; jeg har nok brugt mere tid end en almindelig underviser ville gøre i kraft af min rolle hermede også, fordi vi jo ligesom bruger det til at øh, (Pause: 3.5s), ja, eksemplarisk brug af Blackboard, for eksempel, er jo også et mål i sig selv i det kursus her,'

	'if I merely had transformed it once and run the module the same way year after year, I could have done it quite cheap' (Educator 1).	'... altså hvis jeg bare havde omlagt det én gang og så ligesom kørt et omlagt format på samme måde år efter år, så havde jeg kunne gøre det ret billigt'
	'actually, it [the quality] does not have to have to be perfect... If you are recording a video and the son or the dog turns up. Well, you will just put the recording on pause, right?' (Educator 4).	'at det der med kvaliteten af videoerne, at den behøver faktisk ikke at være så god (2.0s), fordi du laver videoen mere personlig. Altså, sagt på en anden måde, hvis du sidder og er ved at optage en video og så kommer drengen eller hunden og lige et eller andet, jamen så sætter du den på pause, ik', og så fortsætter du.'
	'Because I got [a tutor] involved in the development of the activities ... I have spent approximately one week on the development' (Educator 3).	'I og med at jeg fik ... involveret i at lave selve opgaverne og finde nogle forkerte og rigtige svar og sådan noget... Jeg ved ikke, jeg tror, jeg har brugt cirka en uges arbejde på sådan noget. '
	'If we compare to when I merely had the role as lecturer on one-fourth ... my effort has increased... Now I only have to prepare my single, weekly follow-up lecture. So, the preparation time for the lecture is significantly reduced; however, as I am the sole responsible for the module there has been a damn lot of other work of various kinds associated with Sci2u, video recording, and tutor meetings and such like' (Educator 2).	'Hvis vi sammenligner med den gang, hvor jeg bare var forelæser på en fjerdedel... er min arbejdsindsats nok vokset altså...Nu skal jeg kun forberede den ene opfølgingsforelæsning, som jeg holder om ugen. Så den forberedelsestid til forelæsningen, er jo blevet væsentligt reduceret ik', men fordi jeg er den eneste ansvarlige for kurset ik', så har der været, ja, en pokkers masse andet arbejde af forskellig karakter i forbindelse med Sci2u og videooptagelser og instruktormøder og alt sådan noget der'
	'I probably use twice as much time now... but bear in mind... that I previously merely covered less than a quarter of the work effort' (Educator 2).	'jeg bruger nok næsten dobbelt så meget tid nu, vil jeg sige, som... Men du skal bare huske på, ikke også, at før i tiden dækkede jeg også under en fjerdedel af arbejdsbyrden '
	'I hadn't had a chance doing this without Media Lab.... the service provided has been comprehensive and qualified and an absolute prerequisite in order to make this happen ... I simply couldn't do this by myself' (Educator 2).	'Uden Media Lab havde jeg jo aldrig fået lavet det her, ik'. Det havde jeg ikke haft en jordisk chance for, så øh, altså den service jeg har fået derfra, den har været meget stor og kvalificeret og det har været en absolut forudsætning for, at det her overhovedet kunne lade sig gøre, fordi jeg ville simpelthen ikke kunne gøre det overhovedet for egen motor. '
	'In the beginning, it was absolutely a fiver, but now I think it is decreasing. I am not sure that we are at three yet, but they are getting there.... Because there are still things that act up. Technical things' (Educator 4).	'I starten, der lå de helt klart i en femmer, men nu, der tror jeg de på vej nedad. Jeg ved ikke, om de er nået ned på tre endnu, men de er på vej derned. Det er de. Fordi der er altså stadigvæk nogle ting en gang imellem, som der er driller. (3.0s) Noget teknik. '
	'It has been easy... That you can delegate parts of the understanding to not only occur during a lecture but that you can refer [to the online material]. They can review a video with almost the same lecture, they can train the different parts by means of the exercises. What this does is good, I think it is a good idea, and that is not difficult — it is easy' (Educator 3).	'Altså det har da været nemt... Det der med at man kan uddelegere noget af forståelsen til ikke bare at skulle komme direkte gennem en forelæsning, men at man kan henvise. De kan gå ind og se en video af den samme, næsten samme forelæsning, de kan, de kan træne de der forskellige dele ved at gennemføre de der opgaver. Så det, det gør, det synes jeg er godt. Det synes jeg er en god idé. Og det er ikke svært, det er nemt'
<b>Chapter 6, 'Impact on the educators'</b>	'It is a pleasure... That is, I like teaching and this is also why I find it highly valuable to be together with the students etcetera. That is great. But ... But it is fun being the educator on such a module, definitely' (Educator 1).	'Det er en fornøjelse, men det synes jeg nu egentlig også det var før, jeg omlagde det. Altså, jeg kan jo godt lide at undervise, og det er også derfor, jeg finder det enormt værdifuldt at være sammen med de studerende og så videre. Det er enormt fedt. Men altså, det er jo også sjovt at undervise på den her måde her, fordi man kan imødekomme de studerende på en helt anden måde ved at lave sådan nogle aktiviteter her. '

	'It has been really fun to me. And I think it has worked well. I can feel that I've personally developed through this. I've learnt some things on the personal level, which I highly appreciate' (Educator 2).	'Så det har været rigtig sjovt for mig. Og jeg synes, det har fungeret godt, altså. Ja, jeg har udviklet mig ved det, kan jeg mærke, altså. Jeg har lært nogle ting på det personlige plan, ved det, som jeg er meget glad for.'
	'... when for instance Rambøll [consultancy hired by the government] contacts us and are interested in the work they have done, they [the educators] are proud of what they have made' (Educator 4).	'at når nu for eksempel Rambøll kommer og interesserer sig for det arbejde, de har lavet, så er de stolte af det, de har lavet.'
	'You see, the purpose was to, er... (pause for thought). Basically, you will have to ask [the head of Department] about it, because it was him who initiated it and talked about being more efficient' (Educator 2).	'Ja altså, hensigten var jo nok at, øhh (2.0s). Dybest set må du jo spørge ... om det, fordi, det var ham, der satte det i værk, og han talte om, at vi skulle effektivisere.'
	'It was important to me to develop a teaching format that was as good as possible and as sustainable as possible and had some potential for the future...' (Educator 2)	'Det, der spillede en rolle for mig, det var at få lavet en undervisningsform, som var så god som muligt og så levedygtig som mulig og som havde nogle perspektiver i sig, som rakte ind i fremtiden, ik.'
	'The overarching purpose was not to close Herning [sic]' (Educator 4).	'Den helt store hensigt, det var at ikke lukke Herning.'
	'To modernise the teaching a bit, because I think it is also a purpose in itself — that you, sort of, updates yourself' (Educator 1).	'jeg gerne ville dels prøve at modernisere undervisningen lidt, for det synes jeg også er et mål i sig selv, at man ligesom opdaterer sig selv, '
	'...many, many students provide wrong answers at their examination and have had many difficulties grasping it... So, this was an attempt to help them because they should become as good to this as the other parts of the curriculum' (Educator 3).	'... rigtig rigtig mange studerende har de spørgsmål forkerte til eksamen og har haft rigtig svært ved at forstå det... Så det var et forsøg på at hjælpe dem, fordi de skulle blive ligeså gode til det, som de gør til de andre dele af pensum.'
<b>Chapter 6, 'Impact on students'</b>	'There are no possibilities for asking questions. At the same time it is much more difficult to focus on a screen compared to a real human being spending time giving lectures' (student).	'Man har ingen mulighed for at stille spørgsmål. Samtidig er det langt sværere at holde fokus på en skærm frem for et egentligt menneske, der står og bruger tid på forelæsninger.'

NB: Short quotations of merely a few words or a short sentence are not included.

# Appendix T: Candidate modules

In addition to the modules included in this thesis, 14 other candidate modules were not included in the research. A list of these candidate modules is provided in Table T1.

Table T1  
*Candidate modules not included in the research*

Module	Description and STEM area	Credits and level	Level of transformation	Main reasons for not being included
<b>Evolution and Diversity (2014, 2015)</b>	Bioscience module (science)	5 ECTS, undergraduate	Augmentation, blended/mixed mode	Not included due to limited LD uptake and STREAM compliance
<b>Calculus 1 (2014, 2015)</b>	Fundamental mathematics module compulsory in all science programmes (mathematics)	5 ECTS, undergraduate	Modification, blended/mixed mode	Module similar to C2, but did not have the same amount of historical data on the uptake of STREAM and the examination was not graded. In addition, the module also served as an early introductory module and thus possibly less representative for undergraduate students in general
<b>Microbiology: Microbial Physiology and Identification (2014, 2015)</b>	Bioscience module (science)	10 ECTS, undergraduate		Not included due to limited LD uptake, limited STREAM compliance, and a low response rate in the student survey
<b>Web Technology (2016)</b>	IT and computer science module (science, technology)	5 ECTS, undergraduate		The module eventually abandoned STREAM and returned to previous teaching practices due to an unexpected midway change of educators
<b>Basic Programming 1 (2015)*</b>	Programming module for engineering students (engineering, technology)	5 ECTS, undergraduate	Augmentation, blended/mixed mode and redefinition/online learning in parallel	
<b>Physics (2015)*</b>	Physics module for engineering students (engineering, science)	5 ECTS, undergraduate		A similar subject area was already covered in depth by the large-scale Astrophysics module
<b>Introduction to Circuit Techniques (2015)*</b>	Electronics engineering module (engineering, technology)	5 ECTS, undergraduate		Module similar to Introduction to Digital Electronics (2015) and with the same cohort of students. Digital Electronics was sampled due to better access to data and educators
<b>Mathematical Modelling of Linear Systems (2015)*</b>	Electronics engineering module (engineering, mathematics)	5 ECTS, undergraduate		A similar subject area was already covered in depth by the large-scale Astrophysics module

<b>Project 1 (2015)*</b>	A project module for electronics engineering students (engineering)	5 ECTS, undergraduate	Atypical module with few organised teaching activities and limited STREAM relevance
<b>Basic Programming 2 (2016)*</b>	Electronics engineering module (engineering, technology)	5 ECTS, undergraduate	
<b>Mathematical System Analysis (2016)*</b>	Electronics engineering module (engineering, mathematics)	5 ECTS, undergraduate	A similar subject area was already covered in depth by the large-scale Calculus 2 module
<b>Analogue Electronics 1 (2016)*</b>	Electronics engineering module (engineering, technology)	5 ECTS, undergraduate	Modules similar to Digital Electronics (2016) and with the same cohort of students. Digital Electronics was sampled due to better access to data and educators
<b>Analogue Signal Processing (2016)*</b>	Electronics engineering module (engineering, technology)	5 ECTS, undergraduate	
<b>Project 2 (2016)*</b>	A project module for engineering students (engineering)	5 ECTS, undergraduate	Atypical module with few organised teaching activities and limited STREAM relevance

\*Modules stemming from the same electronics engineering programme and thus also with the same student cohort as in DE.