Cultivating the growth of life-science graduates

On the role of educational ecosystems

Prof.dr Perry den Brok

Inaugural lecture upon taking up the position of
Professor of Education and Learning Sciences
at Wageningen University & Research on 20 september 2018

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Esteemed Rector Magnificus, distinguished colleagues, respected students, family and friends.

It is a great pleasure to see all of you here and to address this inaugural lecture[1] to you, both those present in the aula, as well as those watching WUR-tv. I would like to start by making an apology for the fact that this lecture is in English, as I know that for some of you this may present a challenge. However, Wageningen University and Research is a true international university, there are many international colleagues here, both from my own chair group as well as from other chair groups and units of the university, and much of our work is conducted in English.

Those of you that know me, would perhaps expect a lecture on teachers, learning environments and educational effectiveness. You may have been surprised a bit by the title, that contains none of these words, and that uses terms like cultivation, growth and ecosystems. This is not just to signify my move to this university and show that I have been 'converted' to the domain of agriculture, food-technology, and the life sciences; although I must admit that up to this point it has been a great pleasure and very inspiring to work in this new context.
In the upcoming 45 minutes, I will argue that current society needs a new type of graduates, a new type of life-science engineers. These graduates need new knowledge, qualities and competencies that have to be 'planted' or further 'cultivated' if already present to some degree. Hence the terms growth, cultivation and life-science graduates. I will argue that in order for these new qualities and competencies to develop, learning processes will also be different. This requires a context or environment with certain characteristics and processes that the traditional learning environment cannot offer. Hence, the term educational ecosystem comes into play.

[1] *I would like to express my thanks to colleagues Harm Biemans and Arjen Wals, who provided feedback and suggestions on a concept version of this lecture.*

This lecture will first address the need for new life-science engineers. Subsequently, I will provide an explanation of the term educational ecosystem. In the sections that follow, I will discuss the different dimensions and elements of the educational ecosystem, such as structures and learning processes, pedagogy, culture and learning spaces. I will discuss the need for new types of research to understand and modify educational ecosystems, and I will finally present some projects that my chair group is engaging in to start off these new research topics and methods.

The need for new types of life-science graduates

The world faces some daunting challenges. These challenges become very tangible when we watch the news. Think about recent news items about the rapid decline in the number of insects or about other endangered species, about rain falling in the arctic area in the middle of winter, about conflicts and people in hunger in countries such as Venezuela, Yemen, Syria, about terrorism in the UK, US and other countries, about water shortage in South Africa, about Q-fever, Tiger mosquitos or other 'alien' insects in our neighbourhoods, about chicken flu or food related issues in our own country, and the list goes on. It is up to future generations, and thus graduates to contribute to solutions for these challenges.

The United Nations has formulated 17 Sustainable Development Goals (SDGs) for 2030 in order to deal with these challenges (www.sustainabledevelopment.un.org/topics). These goals are: no poverty, zero hunger, good health and wellbeing for people, quality education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, industry innovation and infrastructure, reduced inequalities, sustainable cities and communities, responsible consumption and production, climate change, ensuring life below water and on land, peace justice and strong institutions, and developing partnerships for achieving all of these goals. In a similar fashion, the National Academy of Engineering (NAE), the domain to which WUR now also is explicitly linked as it has become one of the four Dutch universities of technology, has formulated grand challenges in engineering for 2030, 14 in total (http://www.engineeringchallenges.org/challenges.aspx).
These challenges largely overlap with the SDGs, but are more technology driven. They include, amongst others: make solar energy economical, provide energy from fusion, manage the nitrogen cycle, restore and improve urban infrastructure, engineer better medicines, prevent nuclear terror, secure cyberspace and advance personalized learning.

Closer to home, the green education partners (Groen Onderwijs,2016) have mentioned themes such as sustainable food supply, endurable use of environmental capital and sustainable production chains as most relevant to address in green education for the period 2016-2025.

It is interesting to see that the challenges or goals share their focus on economy, on food and water, on climate, on equality and social justice, on safety, on health and on infrastructure. Also interesting is that education is mentioned in all overviews as one of the goals; it could be argued that education, however, is one of the mechanisms through which to achieve all other goals (Wals, 2015). The conclusion is that education should prepare students to deal with these goals or challenges. In addition, collaboration is needed between education and other entities, such as companies, (local) governments or other institutions. This all occurs in a context in which educational institutions, increasingly are held accountable for the choices they make and the activities they engage in.

The need for new types of life-science engineers is also visible in the recent educational vision of Wageningen University. This vision states, among others (Wageningen University & Research, 2017a: p8):
"We educate students to become academic professionals, who can contribute to sustainable solutions for existing and future complex issues in the domain of "healthy food and living environment" all over the world, and who take their social, personal and ethical responsibilities seriously. Graduates will need a range of competencies to be successful in our changing world, including academic, engineering/design, sustainability, social/societal and personal development skills."
If you read further in the educational vision, it becomes clear what these different competencies and qualities involve. The vision mentions terms such as 'mastering relevant, state-of-the-art scientific knowledge', critical, investigative and creative thinking, external awareness, political and market sensitivity, flexibility, analysis, reflection, literacy, intercultural collaboration, writing, debating and argumentation. But also design, practical and technical skills, entrepreneurship, collaboration in interdisciplinary/transdisciplinary settings, personal leadership skills, lifelong learning, and striving for excellence.

If you hear this list, it almost feels like the graduate of the future needs to be some kind of superhero that needs special qualities and competencies ('superpowers') to help finding solutions to deal with the mentioned complex challenges. To achieve this, graduates have to be engaged in rich, relevant, authentic and effective activities that stimulate the learning and the development of these qualities and competencies, and this in turn requires an excellent context, including high-quality teachers.

The term educational ecosystems

At the start of this lecture, I already indicated that I will use the term educational ecosystem rather than the term learning environment to discuss the type of learning context that is needed to cultivate and grow the mentioned qualities and competencies. Let me briefly explain this choice.

The domain of learning environments research, the domain that also lies in the centre of my own expertise, defines the *learning environment* as the social context, physical and psychosocial factors that affect the learning, attitudes and achievements of students (Fraser, 1994; Gardiner, 1996). The physical part includes elements such as classrooms, materials, ICT, and facilities inside and outside the classroom. The social and psychosocial includes the interaction between learners, between learners and teachers, and between learners and the materials. Learning environments research emerged from research on school effectiveness, and both of these domains have a long tradition in describing factors and their effects on learning and learning outcomes (Creemers & Kyriakides, 2008; Fraser, 2014). While there is an increase of research within these domains on the relationships between the different factors, as I will also argue in the last part of my lecture, the definition of the learning environment already presents one of its major limitations: it has since long been more concerned about the different elements that constitute its presence, rather than the ways in which they interact.

The term *ecosystem* originates from the 1930s and from the British botanists Arthur Roy Clapham (Willis, 1994, in Mueller & Toutain, 2015) and Arthur Tansley (Trudgill, 2007, in Mueller & Toutain, 2015). As botanists, they specifically looked at the exchanges between living organisms and their environment inside the ecosystem. Ecosystems are constituted by networks of interactions among organisms and between organisms and their environment (Chapin et al., 2000). Educational ecosystems could be defined as the full range of actors (living organisms) and all non-living elements in use for teaching and learning (Mueller & Toutain, 2015). Actors can involve people within an educational institution – in our case the university – and outside the university. People within the university include the students, teachers, coordinators, support staff and management, among others. People or entities outside the university include entrepreneurs, associations, governmental institutions, parents, friends, companies and private persons, among others. The non-living elements are all available means, such as buildings, rooms, materials, IT resources, external locations, et cetera. It is important to realize that educational ecosystems cannot be understood by just creating an overview and description of the different elements and how they affect learning or learning outcomes, but that emphasis lies on the system as a whole and how the different parts interact with each other. According to Mueller and Toutain (2015), who wrote an interesting paper for the OECD about educational ecosystems, ecosystems should be seen as *dynamic, complex,* and operate within a social, political, cultural and economic *context*. They argue that it is essential to understand why and how relationships and networks are formed within the system, for example between lecturers and students, between students and external actors, or how materials, infrastructures and (digital) resources are used to support learning. Others also emphasize the *systemic nature* of ecosystems, the fact that they can have characteristics that cannot be directly or explicitly inferred from its separate components, that they try to move towards balance or some kind of steady state, while at the same time they are hardly ever at balance, always in development and change, and that they are even characterized by some degree of unpredictability or even chaos (Westra, Boersma, Savelsbergh & Waarlo, 2006). While the terms learning environment and educational ecosystem obviously have more in common than that they are different, I hope that the discussion I have provided here shows that the manner in which they emphasise different aspects or mechanisms differs. I feel that the term ecosystem better captures the characteristics, complexities and dynamics that make up the context needed for the new life-science graduates to flourish.

Mueller and Toutain (2015) suggest five dimensions that make up an educational ecosystem. These are *framework* or structure, *connections* or networks, *culture, pedagogy* and *spaces* (see Figure 1). In their view, structure refers to the goals or objectives of programmes, their assessment, as well as the number and nature of programmes. Connections are about the actors and elements involved and their interrelationships. Culture is about the values, symbols and shared language used by the actors in the system. Pedagogy in their view relates to all the factors that hinder or stimulate learning; typically, although not uniquely, teachers or supervisors play a central role in this. Space refers to the locations and spaces where learning takes place, and these can be both physical as well as virtual, lie within or outside the institutional context and be managed more by the university and teachers or by the learners. It also refers to questions such as who creates or co-creates materials, who owns the spaces, at what locations the spaces are, how flexible or modular resources and spaces are, and what diversity or collaboration takes place inside them. Finally, Mueller and Toutain argue that change and dynamics in the ecosystem are driven by the *motivations* of the actors inside the system, which can be both intrinsic as well as extrinsic (Deci & Ryan, 2000).

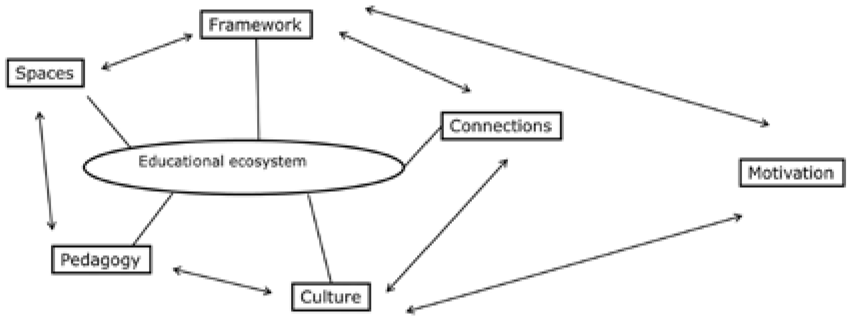

Figure 1. Educational ecosystem (adapted from Mueller & Toutain, 2015).

In this inaugural lecture, I will briefly discuss the motivations that lead universities, in this case Wageningen University and Research, to develop new educational ecosystems that support the development of the new life-science graduates. I will briefly discuss the culture of the Wageningen educational ecosystem. Next, I will describe the ecosystem in terms of its major characteristics and interactions, where I will use the dimensions of structure, connections, space and pedagogy.

Motivations: drivers for change

As stated, educational ecosystems, such as the Wageningen educational ecosystem, are driven by the motivations of their actors, and these can be more external or internal in nature. While many factors contribute to changes in education, in this lecture I will briefly discuss here those that I feel are especially relevant for the Wageningen context.

The first major factor is the *societal need* for a new type of life-science engineer. I addressed this factor already at the start of my lecture. The life-science engineers of the future need to contribute to the solutions for the grand challenges of the world, which implies they need new types of qualities and competencies, and which implies they need to be able to work in complex, uncertain, dynamic and multifaceted work environments (Wesselink, Biemans, Gulikers & Mulder, 2017). While one might typify this initially more as an external driver, it has of course been internalized via the vision on education, which has been broadly accepted and acknowledged by the staff of the university.

The second major factor driving change in the educational ecosystem is the *population of learners and changes therein*. Several changes can be observed in relation to the student population at WUR. First, similar to other universities in the Netherlands, in particular the universities of technology, WUR has to deal with a significant growth in its student population. According to the 2017 annual report by the university (Wageningen University and Research, 2017b), the total student population grew from 7,527 to 10,778 students between 2012 and 2016, with growth rates of close to 5% predicted for the years up to 2020 for both bachelor and master programmes. In addition to these programme-related numbers, WUR also caters for an increasing population of online students; at the end of 2017 the 500,000th student enrolling in a WUR MOOC was welcomed.
The student population is also growing more diverse, for example in terms of cultural and ethnic background, especially at the master level. In 2017, close to 40% of the students in WUR masters was of non-Dutch origin. In addition, students not only differ in their cultural values, but also in language proficiency, religion, economic background, et cetera. Due to flexibility in study programmes and due to increasing international influx, students also differ in prior knowledge. Students not only enrol in universities of technology with a pure interest in technology, increasingly they opt to do so because they have a more social or entrepreneurial interest (van Griethuijsen, 2015; Youngworks, 2016).
What is also of importance, is that the students that currently, and in the future, enter university education have been differently socialized and have grown up in a different context than their teachers or even recently graduated generations of students. The new generation is often referred to as 'generation alpha' or generation Z, and has been argued to show characteristics such as: more visually than verbally oriented, more inclined to 'try and see' than to 'sit and listen', more used to facilitators than to teachers, more used to flexibility than to job security, more used to collaborate than to be commanded, more used to learner centrism than to teacher centrism, more used to the open book than the closed book world, and more used to glass and devices than to books and papers (McCrindle & Wolfinger, 2010).
While differences in learners and their characteristics might also be regarded as an external driver or motivator, to some degree it can also be considered as internal, as the population of students of Wageningen University is of course unique in its own respect, and is also welcomed as such in the vision document as well as annual reports of the university.

The third major driver is the *increasing impact and role of ICT and digital resources in education*. At WUR there is not a single course in which ICT does not play a role, smaller or larger. In this respect, most courses at the university can be regarded as a form of blended education. Typically, course materials and assignments are located

within our digital learning environment or content or learning management system (CMS/LMS), in our case Blackboard (at least for the moment). Students hand in their assignments via this environment, which are automatically checked for plagiarism. Also, in many cases lectures are being recorded, and can be accessed by students from home or elsewhere. Also, more and more information becomes more widely and openly available, for example via open access policies. Lately, more and more innovation fund projects have been initiated at WUR, experimenting with digital tools, such as Feedback Fruits, flipped course concepts (reversing the role of lectures and assignments), apps or other digital activities.
There are, however, also more and more courses and even programmes that also have a complete online variant, such as MOOCs (Massive Open Online Courses) or SPOCs (Specific Private Open Courses). As said, at the end of 2017 WUR welcomed the 500.000th online student via a MOOC. The WUR webpage on online education shows that WUR offers for example MOOCs on nutrition and food related topics, on bio-based principles and processes, on genetics or animal breeding, on entrepreneurship and on sustainability related topics; but also micro-masters (small online programmes ending with a certificate), XSeries (a series of courses providing more in-depth expertise) and certificate programmes. For WUR, this is ideal to showcase unique or specific areas of expertise, or to attract new talent or a wider variety of students.
While these developments are impressive, further changes in this respect are to be expected. ICT has different potential affordances: it can be used to stimulate engagement in learning (e.g. being used as tool to construct knowledge), to connect to real-world contexts (access to databases, experts, etc.), to support collaboration in groups, and to stimulate feedback and interaction (Roschelle, Pea, Hoadley, Gordin, & Means, 2000). Both within as well as outside WUR, the first two types of affordances are often used in supporting or changing learning; the other two types of affordances, collaboration and enhancing and personalizing feedback, are much less common still (Voogt, Sligte, van den Beemt, van Braak, & Aesaert, 2016), although this is also increasing. More and more courses use student peer feedback.
Most digital learning environments and tools also keep logs of user presence and activity, and some systems even allow teachers and students to access learning analytics. These logs and analytics provide educational researchers with exciting new data that records moment-to-moment activity, rather than more outcome based data on a longer timescale.
More recent developments are the use of ICT to have students engage in other activities than lecturing or discussing. Virtual reality and augmented reality are finding their way to education. Examples of these are virtual labs or simulations, 3D video presentations, virtual internships or virtual field trips. The use of VR glasses or even holographic tools becomes part of the classroom experience. At the

chairgroup of Education and Learning Sciences (ELS), Hanneke Theelen, is for example, studying the use of virtual internships and 360 degree videos of classroom situations to train student teachers in classroom management skills before they enter the real classroom at their internship school. Another PhD student of ELS, Stan van Ginkel, is investigating how VR can support students in training presentation skills. Also, colleague Luuk Huijgen and myself are engaged in the evaluation of VR and AR as part of the master of Plant Sciences, in which students experience virtual visits to advanced farms and can even experiment with the systems of these farms to see their effects.
In all, the impact of ICT can, similar to previous drivers, be seen as both an internal as well as external motivator.

A fourth factor of influence is *change or development within science or research* itself. Some examples of changes within science that affect the content and nature of learning, education and curricula are the recent focus on nanotechnology (manipulation of atom-level structures), artificial intelligence and the increasing use of robots, convergence of various disciplines – such as computing and communication, biology and physics, and biology and neuroscience -, focus on both the very small as well as the very large (space), the link between science and ethics, identity driven solutions (such as photo recognition), and the convergence of devices with other products (internet of things).
On the one hand, this demands for increasing specialisation of knowledge and systems, creating the need for a growing and more diverse set of specialized experts. At the same time, many of the complex and demanding problems, as mentioned before, require knowledge and expertise from multiple domains, and even the creation of new domains. For engineers and students, this means that they need to be able to work and learn in multi- or interdisciplinary teams (Spelt, Biemans, Tobi, Luning & Mulder, 2010). It even requires being able to work in transdisciplinary teams, e.g. teams in which people from different types of organisations, such as companies, governmental or civic agencies, collaborate.
Science itself is becoming a ‘contested’ domain, with multiple actors next to scientists from universities involved in research. Citizen science is a new trend, with citizens involved in the collection of research data and analysis – think of the insect and bird counting days. People attract their own funding and materials via crowd sourcing and crowd funding. Practitioners become researchers of their own practices, think for example of teachers investigating their own classrooms.
Developments within science are mainly an external motivator, although, similar to some other mentioned factors, internally driven choices can be made in relation to this factor as well.

Culture and vision of the Wageningen educational ecosystem

The Wageningen vision on education, as well as the academic values that WUR adheres, can be regarded on the one hand as a dimension constituting the educational ecosystem, as mentioned in the beginning of my lecture, but at the same time as an internal motivator or driver for change. WUR is adapting its educational ecosystem to the aforementioned new demands and needed skills.
WUR is known for its innovative and high quality education, and for its focus on the life sciences and agri-food domain. The educational vision of WUR (Wageningen University and Research, 2017a) constitutes the important values and developments that are intrinsic to WUR and that play a role in the education of future engineers. First, it aims to base the contents of its education on high quality knowledge, knowledge that is derived from its research. As such, there should be a strong link between research and education. Second, WUR aims to provide its graduates with rich learning environments: environments that focus on authenticity, interdisciplinarity, multi-actor involvement, international collaboration and a variety of teaching and learning methods. Environments that I would call ecosystems. Third, because society and its developments require for a diversity in engineers or graduates, and because WUR attracts students from a variety of backgrounds and cultures, it aims to cater for flexible and personal learning paths, in which students can create their own profiles in terms of content and skills. As such, ICT plays an important role, as it on the one hand supports the personal and flexible approach, but at the same time allows for the catering of an increasing number of students, while helping to maintain small-scale, informal and direct interaction between students and between staff and students.
Finally, WUR education is characterized by its unique focus on the domain of life sciences, on topics such as health and food safety, sustainability and environmental responsibility, and its emancipatory and agentic nature. WUR does not innovate because it technically can do so, but because it can do so in a morally just, fair and responsible way, taking into account people, peace, planet and prosperity. It is the only academic university in the Netherlands that entirely focuses on the life-sciences.

Characteristics of modern educational ecosystems

As stated (Mueller & Toutain, 2015), educational ecosystems are not only constituted by their culture, but also involve structures or a framework, actors and their networks, pedagogy and spaces. Typically, all of these dimensions are interrelated. Ecosystems are vulnerable; if one element fails, the entire system can come into jeopardy, and in many cases multiple elements are affected. In order to cope with the driving forces mentioned before, and in order to achieve the qualities, competencies and knowledge required from the modern life-science graduates, I will argue that contemporary educational ecosystems at the university level need certain characteristics or design criteria[2]. I will discuss each of these criteria more in detail, using the ecosystems framework of Mueller and Toutain (2015) to order the different criteria[3].

Structure

In the introduction of this lecture, I already highlighted the new knowledge and skills that are expected from future life-science engineers to contribute to the grand challenges of contemporary society - such as problem solving, creativity, systems thinking, and entrepreneurial thinking, but also risk-taking, persistence, self-efficacy, collaboration, perspective taking, empathy and caring - and these form the deeper level goals of the educational ecosystems needed[4]. In terms of design, this leads to a first criterion: *educational ecosystems stimulate the development of complex skills and often focus on complex problems or issues as end goals*. They focus on non-routine learning tasks, on problems that are new, wicked, multidimensional and that incorporate dilemmas or tensions. Several authors in this respect make a distinction between simple problems, complex problems and wicked problems (Fox, 2018; Snowden & Boone, 2007; Wals, 2015). Simple problems are easy to solve and have a predictable, straightforward solution. Complex problems are less clear but can be resolved over time, contain many familiar elements but also hidden, non-linear and inter-operating elements. Wicked problems resist defining, cannot be easily understood or even shift when we try to describe them, are often ambiguous, require many stakeholders, hidden elements and have no right/wrong solutions. Educational ecosystems particularly need to address the latter two types of problems.

[2] *The overview of the characteristics will be presented at a more overarching level. Each characteristic often implies multiple sub characteristics. Obviously, characteristics can be ordered in different ways; in presenting this overview I do not claim to be complete; nor are the characteristics mutually exclusive. In practice, it will be hard to realize all of the characteristics within one context or ecosystem. However, they are considered typical for educational ecosystems aimed at supporting future oriented graduates. In a similar fashion, research will often focus on some unique or combined characteristics, rather than being able to include all.*

[3] *In doing so, I will also touch upon the elements that make up the major perspectives of designing learning environments (Carvalho & Goodyear, 2017; Zitter & Hoeve, 2012), namely the spatial perspective, the instrumental perspective, the temporal perspective and the social perspective. The temporal perspective discusses the timeframe and sequence of learning, and is included in the structure element of the ecosystem. The social perspective deals with the roles and activities of different actors and their interactions, and is included in the network element of the ecosystem. The instrumental perspective refers to the tools used to facilitate learning, and is included in the pedagogy element of ecosystems. The spatial perspective, finally, is included in the spaces element of the ecosystem.*

[4] *Important work on future-oriented competencies has been done by former chair of ELS, emeritus professor Martin Mulder, and by collaegues Valentina Tassone, Arjen Wals and others in the ENRRICH project. They for example distinguish between academic competences, operational competences and life-world becoming competences (Barnett, 1995; Mulder, 2017; Tassone, O'Mahony, McKenna, Eppink & Wals, 2018).*

In many ways, modern educational ecosystems do not just stimulate the development of new skills or qualities, but also *stimulate the development of the professional identity of the learner* (Beijaard, Meijer, & Verloop, 2004; Stets & Burke, 2014) they make the learner aware of his or her own strengths and weaknesses, but also of his or her future professional roles and the type of engineer they strive to become. They help the learner to become resilient, and to cope with issues or problems that may challenge the values of the learner, lead to dilemmas or tensions. The types of problems addressed and types of learning outcomes aimed for imply that learning often does not follow a pre-determined path or fixed time scheme. As such, *educational ecosystems should allow for non-linear learning*. The involvement of multiple actors and a variety of domains, tools and artefacts means that learning does not occur linearly, but may shift or unfold in different ways. Developments of skills often occur within shorter processes or timeframes than does the development of professional identity, for example. As such micro processes and moment-to-moment processes are also important, next to processes at the level of a course or trajectory. Learners need to learn to appraise situations, as they contribute to their learning processes and personal development (Stets & Burke, 2014). Learning can occur at different paces, sometimes slow and at other times quick; this means that learners need some freedom in how to deal with time during their learning (Davies, Jindal-Snape, Collier, Digby, Hay & Howe, 2013).

The focus on complex or wicked problems and complex skills and development of identity also have an implication for assessment. Assessment in educational ecosystems often is not only focused on knowledge acquisition and understanding, but also learning processes, non-cognitive elements and taking into account the context in which the processes unfolded. This also fits with the pedagogy in educational ecosystems, which is more student-centred and design-based or hands-on (Gomez-Puente, 2014). To allow for development and continuous learning, feedback should be provided at regular times; there needs to be a focus on assessment for learning, in addition to summative assessment. This means that *ecosystems need to allow for the use of formative assessment*, in order to provide feedback on both content, processes and personal development and to stimulate reflection (see pedagogy as well) (Gulikers & Baartman, 2017; Sluijsmans, Dochy & Moerkerke, 1998).

Connections
An important characteristic of educational ecosystems is that, as a result of the goals and types of learning processes they strive for, they require multiple and different types of actors or stakeholders, as well as processes in which these actors or stakeholders co-create and jointly learn (Gomez-Puente, 2014; Mueller & Toutain, 2015; Oonk, Gulikers & Mulder, 2017). As such, a major characteristic is that *educational ecosystems are collaborative in nature, allowing for learners to interact and co-create*. Collaboration means that there are ample opportunities to interact, to jointly create or design tools or artefacts, but also that materials and physical characteristics should allow for the formation of groups or networks. In networks, not only the amount and nature of interaction and collaboration are important, but also the reasons or values that people jointly aim to create, which can range from more direct and individually oriented to more group and reframing perspectives oriented (Wenger, Trayner, & de Laat, 2011). In turn, this requires attention for respect and organizing dialogue, but also opportunities of exchange and negotiation (Davies et al, 2013). It is important to realize that learners can learn differently within collaborative groups; this relates to the density of learning networks, the position of learners within in the network (centre versus periphery) as well as their potential role within the group, for example representing subgroups or acting as broker (Heldens, 2017; Hubers, Moolenaar, Schildkamp, Daly, Handelzalts, & Pieters, 2018).

As mentioned earlier, collaboration may involve a variety of actors, both internal and external. Typically, to optimally allow for such collaborations beyond contexts or institutions, *hybrid learning configurations* need to be designed (Oonk, 2016). To allow for strong networks or learning communities, two elements are of central importance: (1) a sense of community: a joint culture, mutual respect and curiosity for others; and, (2) learner equity, or the organisation of parallel trajectories of learners, of experts and novices working together. Collaboration may extend cultural borders; when collaborating beyond cultural and ethnic borders the development of intercultural sensitivity and cross-communication skills is required.

Educational ecosystems incorporate multiple domains or sciences, and as such are multidisciplinary, interdisciplinary or even transdisciplinary. The goals, tasks and activities in modern learning environments are so complex, that they often require multiple learners and the expertise and knowledge of multiple domains. As such, they require learners to cross boundaries (Akkerman & Bakker, 2011), e.g. to recognize their own expertise and background and understand and use the expertise of others. Typically, educational ecosystems go beyond multidisciplinarity, where the individual disciplines still remain visible and recognizable in goals and assessment. Instead, learning will often be interdisciplinary, in that separate disciplines are not visible anymore in goals, content or assessment, but are merged into new topics and skills (Gresnigt, Taconis, van Keulen, Gravemeijer, & Baartman, 2014; Spelt et al., 2010). Interdisciplinary learning as an important element of educational ecosystems has been stressed by a variety of authors (Barrett et al., 2015; Flynn & Vredevoogd, 2010; Grabinger & Dunlap, 1995; Gomez-Puente, 2014; Gresnigt et al, 2014; Spelt et al., 2010). Learning may also require the involvement of internal and external experts, of seniors next to beginning learners, and of actors outside the academic realm, and as such integrate different types of practices. The latter is often referred to as transdisciplinary learning (Gresnigt et al., 2014). The fact that problems, tasks and assignments require a multitude of knowledge domains or types of learners, also brings an advantage: it allows learners to make their personal talents explicit and brings a greater chance of alignment with learner interests. Wals (2010) in this respect speaks of social learning making use of pluralism.

Culture

Earlier in this lecture, I already addressed the culture of Wageningen University and Research, highlighting the importance of elements such as *high quality knowledge, rich learning environments* (see space element), *flexible and personal learning paths*, as well as *learning for agency, sustainability, environmental responsibility and emancipation* (see also Mueller & Toutain, 2015). Following some of the other elements of the educational ecosystem, learners, teachers and other actors are also expected to appreciate and value aspects such as diversity, unexpected learning processes and outcomes,

expertise from other domains, but also collaboration.
Mueller and Toutain (2015) in addition mention that for the people in an educational ecosystem it is important to *be aware of the local context and values* in which the system operates, and to value the different partners or stakeholders in the learning context. Finally, symbols and artefacts in educational ecosystems are not only created by teachers or experts, but also by learners (Flynn & Vredevoogd, 2010), and a variety of such tools and symbols is appreciated (Davies et al., 2013).

Pedagogy
Educational ecosystems require new roles from learners as well as teachers. *They are student-centred, allowing for an active, constructive role of the learner*. By putting learning at the centre, it is the activities and trajectories that learners engage in that form the core of the ecosystem. This means that responsibility is given to the learners for their own learning and functioning, rather than that others take over such responsibility (den Brok, Bergen, Stahl, & Brekelmans, 2004; Vermunt & Verloop, 1999). In this sense, learning is more emancipatory, rather than expert- or expertise-driven (Wals, 2010). It also means that the well-being and safety of learners is important: learners are allowed to make mistakes and to practice skills. Flexibility, open-endedness and freedom are balanced with structure. Structure can be created by having learners share their working space, but also by having important procedures or processes documented (Oonk & Gulikers, 2018). Such safety and responsibility is also stimulated by providing reciprocity in information exchange and in effort between learners, but also between learners and other actors. Senior and junior participants, for example, may share the learning context and tasks. Putting learners at the centre also means that learning can be flexible in duration, in content, or in profile or path. *Learning in educational ecosystems is often experiential in nature and hands-on* and learning in higher education is expected to take this form more and more (Flynn & Vredevoogd, 2010). As such, inquiry-, problem- or cased-based learning or design-based learning are suitable educational methods (Gomez Punte, van Eijck, & Jochems 2015). In such approaches students will learn by creatively solving problems or cases, or by creating designs (Davies et al., 2013). In these approaches, processes and procedures make up an important part, next to expertise and knowledge.
Because of the complex nature of the problems, tasks, processes and outcomes involved, as well as because learning is often expected to be non-linear, informal or even chaotic or unplanned, it is important that *metacognitive skills, especially planning, monitoring and reflection, are stimulated* (Vermunt & Verloop, 1999; Zimmerman, 2000). Thus, learning and performance should be evaluated at critical moments during the learning process. Reflection should be stimulated at both the individual and group level, as learning and learning outcomes also occur at these two levels. Typically, critical events in the learning or in the trajectory are taken as starting point

(Grabinger & Dunlap, 1995). To truly put learners at the centre, not only skills need to be reflected upon, but also the development of the learner as a person: the development of professional identity (Stets & Burke, 2014). The latter is especially important, as learners are faced with an increase of choice, diversity in contexts, and problems that involve dilemmas or tensions. These choices and dilemmas bring stress with them, and to withstand this, learners need to be made resilient. The focus on reflection makes learning more of a transformation-based process, rather than a transmission-based process (Wals, 2010).
As indicated, in modern educational ecosystems the role of teachers changes fundamentally. *Teachers are first and foremost coaches*. They need to be sensitive and aware of the learning processes and paths of learners, of their backgrounds and domain-specific expertise, and support learning and reflection (Gomez-Puente, 2014). Because learning also involves the personal development of learners, and because multiple domains are at play, next to their own expertise, *teachers need to be able to also judge interdisciplinary processes and outcomes or be able to collaborate with colleagues from other domains to do so*. They are able to link knowledge in their own and other areas of expertise to the professional world and the identity development of learners. *Teachers view and use ICT as a tool that enables and supports learning*, even if it replaces some of their original tasks, and are able to use ICT for its full purpose. For many teachers, using ICT to especially differentiate and allow for interaction (enrichment) is rather difficult (Voogt et al., 2016). *Teachers in educational ecosystems are networkers, boundary*

crossers, able to work in hybrid environments that sometimes extend the borders of their own institutions, and are able to collaborate with others – students or external experts - that may even take over some of their roles, for example in providing instructions or coaching, or in assessment (Mueller & Toutain, 2015). Given the complexity of the future learning environment and processes in it, it is likely there is a need for a variety of teachers, some more knowledgeable in ICT and design of learning materials, other more expert in the coaching and stimulation of group processes, still others expert in working with a variety of actors. Similar to learners, teachers will often be working in groups, and in the future potentially even together with digital coaches or robots.

Spaces

Educational ecosystems are rich and authentic (Davies et al., 2013; Grabinger & Dunlap, 1995, Gomez-Puente, 2014). There are several elements that address the authenticity of a learning context. Herrington and Oliver (2014), for example, mention: (1) authenticity of the context or the degree to which knowledge in tasks is used in real-life, (2) authenticity of the task or the degree to which a task resembles real-life practice, (3) access to expert performances or modelling of processes, (4) providing multiple roles and perspectives, (5) collaborative construction of knowledge, (6) promoting reflection to enable abstract knowledge to form, (7) articulation to enable tacit knowledge to be made explicit, (8) coaching and scaffolding by the teacher and (9) authenticity of the assessment or enabling assessment as part of the tasks. Several of these aspects relate to other elements mentioned before, for example pedagogy and connections. In most traditional learning environments or courses, only (a small) part of this authenticity is achieved. An authentic environment resembles working practice and allows for developing a professional culture (Zitter & Boeve, 2012; Oonk & Gulikers, 2018). It involves working for actual clients or with problems that are directly brought forward by clients. It means that learners are seen as employees or co-workers, rather than just as students. It also means that assignments are often ill-structured, non-routine, unique, and incorporate multiple dimensions or interests.

Educational ecosystems are ICT-infused. As mentioned before, ICT is becoming an integral part of the learning process and one of the driving forces behind the development of new educational ecosystems (Flynn & Vredevoogd, 2010).

ICT enables flexibility, both in terms of the temporal aspect of learning, as well as in the spatial aspect of learning, as learning spaces may be both physical as well as virtual, or even combinations of both (Davies et al., 2013; Mueller & Toutain, 2015). ICT also brings in the development of new kinds of materials or tools, which can be multimedia in nature and may be created and controlled by both teachers, experts or learners (Davies et al., 2013; Mueller & Toutain, 2015). ICT can support learning in different ways: it can be used to stimulate engagement in learning (e.g. being used as tool to construct knowledge), to connect to real-world contexts (access to databases, experts, etc.), to support collaboration in groups, and to stimulate feedback and interaction (Roschelle et al., 2000). Because of the increased use of ICT – both in education as well as society at large - it is also important that digital skills of learners are addressed, such as awareness of social processes online, being able to judge sources of information and the validity and credibility of information, awareness of privacy and security of information, et cetera (ref).

Educational ecosystems contain both in-school as well as out-of-school spaces and the links between both types of spaces are important for transfer to take place (Zitter & Boeve, 2012). Out-of-school contexts are expected to stimulate their motivation to learn (Vennix, den Brok, & Taconis, 2017), the development of professional identity of learners, their creative thinking and problem solving abilities and their boundary crossing competencies (Davies et al., 2013; Oonk, 2016). According to Zitter and Boeve (2012), out-of-school contexts may play a different role in the ecosystem, either forming an addition to the in-school context (for example in the case of site visits or excursions) or forming the major part of the learning context (for example in the case of internships). Learning in out-of-school contexts may take place in different contexts, such as workplaces (Zitter & Boeve, 2012), museums (Holmes, 2011; Andre, Durksen, & Volman, 2017; Bamberger, 2009), field trips (Rebar, 2012), and outreach activities (Vennix et al., 2017; Zaragoza & Fraser, 2017).

Learning spaces are increasingly flexible and open, in order to allow for a variety of learning activities, hands-on activities and various learning settings – including group work – to take place (Barrett et al., 2015; Davies et al., 2013; Mueller & Toutain, 2015). This means that management and control of the learning spaces also may be in the hands of learners themselves (Mueller & Toutain, 2015).

Evaluating educational ecosystems

Educational ecosystems are in many ways different from traditional classroom contexts or learning environments, as they focus on different goals, involve different and multiple actors, entail different learning and teaching activities, involve different locations, the use of ICT and stimulate learning at different timeframes or timescales. As such, to investigate the working, effectiveness and implementation of these complex ecosystems, evaluation and research have to take different aspects into account. I will first briefly mention and elaborate these new demands. In the last part of this inaugural lecture, I will highlight some recent and ongoing projects that my chair group, Education and Learning Sciences, is being involved in, to show where my intentions with respect to research on learning in educational ecosystems lie.

There are several demands for research on educational ecosystems:

- Evaluation *needs to collect data at different levels:* individual graduates or students, groups of students, units of learning such as courses or curricula, organisations and networks of groups, or organisations. This means characteristics and variables at all of these levels have to be measured, and combined into analyses.
- Evaluation *needs to take into account different timescales:* moment-to-moment interaction and learning during activities, series of activities – often organised into learning scenarios or courses, but ideally also learning lines that span a curriculum (or beyond – see for example Wesselink et al., 2017). I feel that especially linking different timescales will provide some new insights and will be an innovation in research that is much needed.
- Evaluation needs to *involve the use of common data collection instruments* such as surveys or questionnaires, interviews or observations, *but also less common instruments or the availability* of ICT to collect and analyse data, for example emails, eye-tracking data, LMS data or learning analytics, and even physical indicators such as light, sound, air quality, et cetera. Typically, mixed methods will have to be used to map variables and their associations.
- Evaluation *may engage different types of actors in the collection, analysis and even reporting of results*, as is common in citizen science research. But in the educational context, this may include students analysing and collecting data on their own learning, using apps; teachers evaluating their own learning environments; or other actors involved such as employees of companies investigating their own roles or learning context.
- All of the aforementioned issues, *require the use of multiple and complex analysis methods*, that often go beyond the traditional statistics or qualitative analysis. Think of analyses such as multilevel analysis – including growth-curve analysis – structural equation modelling, agent based modelling, person-based analyses, simulation, sequence analysis or orbital decomposition. I will explain some of these terms briefly below.
- Evaluation needs to *link variables to a variety of criterion or outcome variables*. Not only cognitive or psychomotor skills and knowledge have to be investigated, but also affective outcomes, metacognitive outcomes – including reflection – and the development of professional identity. It is highly likely that such analyses will show that different factors and variables in the ecosystem will be associated with different outcome variables (Creemers & Kyriakides, 2008).
- Evaluation needs to *include different learning contexts and the links between them*. Next to classroom and institutional contexts, this means out-of-school contexts, outreach activities, and hybrid learning contexts, innovation spaces or other maker spaces, incubators, and so on.

The *multilevel nature* of the ecosystem requires some extra explanation.
Many educational studies collect learning outcome and student perception data from entire courses and from multiple courses within programmes. As such, data-points are not independent, but data are hierarchical in nature, with students nested in groups, groups nested under teachers or courses, and teachers or courses nested in programmes. It can be argued (and it has been shown many times) that the perceptions of students in the same context or activity are likely to be more similar compared with those of students or teachers in different courses or programmes (Hox, 2002; Snijders & Bosker, 1999). However, traditional analyses of variance or regression analyses do not take this into account, leading to inaccurate and often overestimated associations between variables (Dorman, 2009; Lüdtke, Trautwein, Kunter & Baumert, 2006). In addition, variables that are measured also can exist at different levels or exert different effects at different levels; for example, type of course is a characteristic of all students in a course, while student gender is an individual student-level variable. Studies have shown that effects of variables are indeed often overestimated with traditional analysis methods, that effects of variables can show different patterns at different levels of analysis – sometimes even reversing in direction from positive to negative – and can even have effects at different levels – boys for example having more negative perceptions of teachers in certain domains than girls, and this divide being further widened by the number of boys present in a learning context.

Another development of special interest is the study of environments at *different timescales*. More and more studies involve collecting longitudinal data and use multilevel analyses of variance to investigate developments in perceptions of the learning environment, via so-called growth curve analyses (e.g. Davis, Chang, Andrzejewski, & Poirier, 2014). For certain variables, such as teacher interpersonal behaviour for example, researchers have studied and reported developments in perceptions during the teaching career or during the course of the year (Wubbels, Brekelmans, den Brok, & van Tartwijk, 2006; Mainhard, Brekelmans, den Brok, & Wubbels, 2011). These studies showed that different dimensions of educational ecosystems or aspects of teaching can develop differently. The degree of interpersonal control by a teacher, for example, shows a linear declining trend over the course of a year, but an increasing and stabilizing trend over the career of a teacher. The degree of communion or interpersonal proximity, on the other hand, shows a curvilinear trend, both over the course of a year and over the course of a career, beginning with a gradual incline, followed by a gradual decline. These are examples of studies that have concentrated on more stable and long-term perceptions. However, little is known about how perceptions are formed or developed, and how specific events or experiences lead to certain perceptions.

Moment-to-moment data are more often collected in a different fashion in the educational context, for example, via speech/text analysis (Song & McNary, 2016), Qualitative Comparative Analysis (Nijssen, Hillebrand, de Jong & Kemp, 2012), observation systems using joy-stick coding (Pennings, van Tartwijk, Wubbels, Claessens, van der Want, & Brekelmans, 2014) or eye-trackers (Van den Bogert, Van Bruggen, Kostons, & Jochems, 2014; Wolff, Jarodzka, van den Bogert, & Boshuizen, 2016, McIntyre, Mainhard, & Klassen, 2017). Current developments in ICT, such as learning management systems or other systems that generate so-called big data, allow different types of datasets to be collected. To analyse such data and to link them to the more long-term perception data brings new methodological challenges, such as sequential analyses (Furtak, Araceli Ruiz-Primo, & Bakeman, 2017), probabilistic analyses, among others. They also require new ways to report and interpret data, such as via visualisations (e.g., Mainhard, Pennings, Wubbels, & Brekelmans, 2012) and simulations. In this respect, it might be fruitful for educational researchers to connect with scholars from other domains, such as statisticians, mathematicians, software engineers and psychologists, and to open themselves for new frameworks. At this university, I hope to collaborate in this respect with the colleagues from Information systems (INF, Tekinerdogan) and Open and online education (Wild). A nice example for complex analysis is the advancement of Dynamic Systems Theory and chaos theory. These theories specifically aim to search for patterns in seemingly chaotic data, link trends at different time frames, and allow for other than linear relationships between variables. To analyse moment-to-moment interactions in courses and to link these to perceptions of courses, state-space grids (Pennings & Mainhard, 2016; Pennings et al., 2014) and time-line charts (Pennings, Brekelmans, Wubbels, van der Want, Claessens, & van Tartwijk, 2014) can be used. These methods show how developments occur over time (on a plane or linear graph) and how they can be related to more-general perceptions. Pennings, for example, found that a teacher with an uncertain–aggressive profile, compared with a teacher with a tolerant–authoritative profile, showed much more variation in behaviour on a state-space grid in real-time interactions with students. Yet another method is orbital decomposition (Guastello, Peressini, & Bond, 2011; Pincus, Ortega, & Metten, 2010), in which text or other data are analysed for recurring patterns of events in time series data. Such analyses can show if certain events reoccur in seemingly chaotic data and, if so, how much time elapses between these reoccurrences.

An interesting development in my view also is the use of more *person-centred approaches* to analysis rather than variable-centred approaches. In person-centred approaches, the idea is to distinguish between different groups of respondents (e.g. types of students), for example based on how they perceive certain aspects of the learning context or based on how they perform on outcome variables, such as different types of motivations or learning behaviours. This way, typologies or profiles can be constructed. If such typologies can be enriched with more qualitative descriptions and labels, this could enhance their recognisability or help people to reflect on them or become more aware (Rickards, den Brok, & Fisher, 2005). Also the interpretation of, for example, the effects of certain ecosystem variables together on individuals can be interpreted with more ease. More recently, structural equation modeling has been combined with profile analyses, leading to latent profile analysis (Schenke, Ruzek, Lam, Karabenick, & Eccles, 2017; Seidel, 2006). Latent profile analysis is more precise for constructing typologies because measurement errors and background characteristics of respondents can be taken into account during the analyses.

More and more complex models with direct and mediating effects are being used and also, for longitudinal data, these models are being tested. For example, in a cross-lagged panel design, variables are measured at different points in time. Thus, the effect of a variable (e.g. perceived complexity of an assignment) on another variable (e.g. student perception of own competence on a certain skill) can be investigated and, at the same time, compared with the reciprocal effects of, in this example, the perceived skill level on perceived complexity of assignments. As a result of such analyses, research is getting more precise in what and how factors affect the perceptions of students and teachers of learning contexts, to what degree and via what mechanisms.

The use and availability of different learning spaces also means that the *effect of such spaces and their characteristics on learning can be investigated*. This means that researchers more and more include physical factors, such as tools and materials involved, classroom spaces and school building characteristics (Cleveland & Fisher, 2014; Fisher, 2016; Imms, Cleveland & Fisher, 2016; Mäkelä & Helfenstein, 2016; Nidzan Che Ahmad, Osman, & Halim, 2013; Zandvliet & Broekhuizen, 2017), next to psychosocial factors. Moving beyond the traditional borders of the classroom context will require new types of data collection as well, such as real-time observations of space use and positioning of respondents, as well as physical measurement of aspects such as sound, light and air quality. To map transitions between in-class and out-of-class environments, still other data collection methods might be needed, such as analysis of email, tweets, contributions to online discussions (Song & McNary, 2011) or network surveys (Heldens, Bakx, & den Brok, 2016). These again could lead to the use of different types of analysis tools, such as word cloud instruments, network analysis software and text analysis software.

To allow for the development of innovative teaching and learning contexts at the university, it is important that *innovations are not only stimulated, but also properly* *investigated*. Many innovations are now only marginally evaluated, meaning we are often unaware or unsure of their impact, sustainability and relevance. One of the important 'new' tasks of ELS is to conduct and support research on educational innovations, especially at WUR. Second, good practices should be *shared*, within but especially beyond institutional boarders. In many cases, learning will transcend institutional boarders, but many of the current problems faced by institutions are also similar. Nice examples of networks are the 4TU Centre for Engineering Education (see: https://www.4tu.nl/cee/en/research-innovation/#/), of which I will become chair effectively this year, and Groen Kennisnet (see: https://www.groenkennisnet.nl/nl/groenkennisnet.htm). Characteristic of these networks is the combination of innovation fund/support, professional development and exchange. This means joint or individual innovation days, web resources displaying innovations and their effects, active contribution to BKO and SKO development, et cetera.

Existing and future research: the role of the Education and Learning Sciences group

In the previous parts of this lecture, I have highlighted the need for new types of graduates in the life-science domain, factors that motivate changes in educational learning contexts, characteristics and elements of educational ecosystems, and the need for more and different research on these ecosystems. In this section I will highlight some specific projects and developments in which I myself, and ELS as a chair group, are getting involved in.

We are initiating, and have started, a series of projects that focus on the development of new competencies required from life-science graduates and the ways in which education and educational ecosystems can contribute to the development of these competencies. Two projects focus on boundary crossing competencies. Boundary crossing is the competence to work together with others outside one's own scientific domain, institute, culture or context, and is regarded as one of the major competencies needed by future university graduates in order to respond better to emerging global challenges. Boundary crossing is also at the forefront of the new educational vision of Wageningen University.
A first project is a post-doc project in which Carla Oonk studies boundary crossing together with Judith Gulikers, Cassandra Tho and myself at the level of courses or learning experiences. Her post-doc study aims at mapping which boundaries students face in various learning contexts; what students do to face, explicate and overcome the boundaries; how capable students feel to work across boundaries; what support students expect and experience to enable and strengthen boundary learning;

to what extent students perceive boundary crossing in their courses is (or might be) of added value for the final outcome of a learning experience; and what teachers do to support students in their boundary learning. Two courses will be investigated, namely the Academic Master Cluster courses *Academic Consultancy Training* and the *European Workshop*. Data will be collected via student questionnaires, observations of educational activities, focus group interviews with students, teacher interviews and analyses of end products students have to create in the courses.
A second project focuses on boundary crossing at the level of the entire university and learning lines. Recently, together with the dean of education Arnold Bregt, ELS was involved in the application of a NWO Comenius leadership grant, which was obtained to further develop boundary crossing at the level of the university.
At Wageningen University, there is a need to address boundary crossing more explicitly and structurally throughout the diverse curricula, both at the bachelor and master level. A comprehensive overview of existing practices is needed, as is (scientific) insight in to how boundary crossing competence develops in students and is best supported by teachers and educational ecosystems. The proposed project aims at mapping existing boundary crossing practices in the bachelors, at developing a conceptual foundation for the development of boundary crossing competence, and at further improving and implementing boundary crossing experiences. The project will be conducted together with educational researchers, programme directors, lecturers, study programme managers and policy staff.

Another set of projects will focus on the development of other relevant competencies that graduates need to obtain, namely entrepreneurship and creativity, and the ways in which the learning environment and teachers can help to support this development. The post-doc project of Lisa Ploum, which she will conduct together with Thomas Lans and myself, will focus on the development of entrepreneurial skills. The proposed post-doc project aims at collecting micro-timescale level or moment-to-moment data from students in the entrepreneurship education track on the development of their entrepreneurial competencies, by developing an online tool. This tool, on the one hand, supports students in self-assessment and making decisions on their learning and enlarging their involvement, and, on the other hand, provides research data om development of competencies in relation to characteristics of the leaning context or learning activities. Data from the tool will be linked to student performance measures (for example achievement or progress data) and will be analysed using advanced techniques and theoretical insights from Dynamic Systems Theory, agent based modelling and multilevel growth-curve analyses.
The NWO funded teacher PhD project of Robert Ovbiagbonhia focuses on the development of innovation skills of students. The first results of his study show that there is some attention for innovative thinking and design skills in programmes of

universities of applied science, but that this attention is more incidental than structural, and that there is a need to focus more on learning activities and learning lines to develop this competence more explicitly. In the current phase of the project the design, implementation and evaluation of interventions to stimulate students' innovation skills are central. The first impressions from the data show that students develop their innovation competencies and are satisfied with the developed interventions.

In a series of projects we will study the innovation of WUR education via projects in the so-called Wageningen University educational innovation fund. First of all, in the upcoming two years ELS will be engaged in a large-scale evaluation of innovation fund projects at WUR. Funded innovation projects at the course level of the past three years will be studied in-depth, to see what kind of mechanisms in these projects lead to successful implementation in practice. The first part of this study will be quantitative and will incorporate the design of a framework for studying course innovations. This framework will be used to analyse innovation fund proposals as well as project reports, evaluation documents and other available information. In the second phase, we will study a selection of innovation projects more qualitatively and in-depth. The project connects well to work of the 4TU Centre for Engineering Education, in which WUR is involved.

Second, ELS will be involved in the evaluation of several specific innovation projects conducted at WUR. An example of an interesting project is a project on the use of virtual and augmented reality in courses of the Plant Sciences master, where students are engaged in virtual excursions and can interactively develop certain farms or geographic areas. The project is coordinated by Blair van Pelt and Rogier Schulte and from ELS Luuk Huijgen and myself will be involved. Another example is the evaluation of a writing skills learning line in an innovation project coordinated by Jet Vervoort and colleagues, also of the Plant Sciences programme. This project will be conducted by Judith Gulikers, amongst others. A third project is yet another learning line project from the Food Chemistry group, in which a PhD student will be working with myself and Julia Diederen in evaluating skills learning lines.

Three recently started PhD projects by WUR and international colleagues also focus on higher education educational contexts. The PhD project by Mohsen Nameghi, supervised by Harm Biemans, Piety Runhaar and myself, focuses on student collaboration in WUR courses and the role that personality and personality types play in collaboration and its outcomes. The project is of interest, because there is much research on collaborative learning that has focused on collaborative learning activities, learning networks and learning outcomes, but hardly any research on individual factors in collaboration, such as personality. The PhD project by Megawanti Megawanti, supervised by Renate Wesselink, Harm Biemans and myself focuses on access and equity in higher education and will compare two life-science universities, WUR and an Indonesian university. Access and equity are relevant and contemporary themes, both at the level of policy as well as research; current discussions in the Netherlands for example focus on restricting access in times of student growth, the quality and use of English language in bachelors and masters, and dealing with diversity in student populations. A third project is the PhD project by Casper Zelissen, supervised by Jaap Molenaar and Hilde Tobi from Biometris and by myself, in which he studies how formative assessment may help in better understanding and retainment of mathematical knowledge by university students as well as increasing students' attitude towards (learning) mathematics. In this respect, he will look in particular at the role that ICT may play in such formative assessment and feedback processes.

The domain of teacher education is also a good example of modern higher education. In teacher education, flexibility, personal learning paths, and the use of ICT are at the forefront of developments. Teacher education currently faces the challenge of educating more and a wider variety of different types of teachers, while there are only few candidates, a large teacher shortage and many other career options available for students. Also, many trained teachers prematurely leave the profession.

One of the reasons for this is the challenge of classroom management skills (den Brok, Wubbels, & van Tartwijk, 2017), and teacher education constantly looks for new ways to enhance this development. The NWO funded teacher PhD project of Hanneke Theelen investigates the potential role of virtual internships in teacher education, as well as the role of 360 degrees videos and classroom simulation in the development of classroom management skills. First findings of this project show that classroom simulations via 360 degrees videos and virtual internships can reduce student teachers' anxiety, increase their self-efficacy and also lead to more theoretically supported reflection and knowledge. Another NWO funded teacher PhD project by Thom Adams will study the development of classroom management competencies during the school internship phase of teacher education, and the factors that affect this development.

Of course, with these projects mentioned, I do not do justice to the complete range of expertise and projects of ELS, they merely are an overview of some recently started projects that fit nicely into the topic of this inaugural lecture. ELS is involved in many other interesting projects as well, focusing on topics such as sustainability education, career development, competence based education, skills education, human resource management and school organisation, vocational education, formative assessment, and so on.

Words of thanks

The development of new projects and plans brings me to my own development, and in this respect to words of thanks, as many have helped me to arrive at the point where I currently am.

First of all, I would like to thank rector magnificus Arthur Mol and the university board for appointing me as professor in the Education and Learning Sciences and as chair of the ELS chair group at Wageningen University and for showing confidence in me. In this respect, I would also like to thank the management of the Social Sciences Group, Jack van der Vorst, Martijn Hackmann and John ten Bohmer for the support and mentoring they have given me during the first months and are still giving me to this day as new chair. In addition, I would like to thank my 'new best friends' Arnold Bregt – dean of education - and Erik Heijmans – head of the educational support centre – for the fact that I already am fully incorporated into the educational innovations at WUR and engaged in all kinds of joint activities. All of you have helped me feel welcome and appreciated right from the start, and I could not have wished for a better start.

I would like to thank Martin Mulder, my predecessor at Wageningen, for establishing and consolidating such a nice, high quality, productive and friendly chair group, in which people, on the one hand, really work as a collective and, on the other hand, fully develop their own expertise and competencies. To my new colleagues at the chair group: thank you for receiving me with open arms. I feel blessed to work with all of you and I am proud of what you all achieve in education, research and innovation. In a short period of time we have already started many new projects, have formulated a joint vision for the chair group and further plans for the future. A special word of thanks goes to Harm Biemans, for contacting me and persuading me to come to Wageningen, and for taking care of the group in-between two professors; to Carla Oonk, for coordinating education at the chair group; to Jolanda, my right hand in matters of finance and personnel, and of course to the secretaries Nicolette Tauecchio, Marissa van den Berg and Laura de Wit, not in the last place for assisting in the organisation of all the activities today. To all chair group members that I have not mentioned in this lecture or word of thanks: my appreciation goes to all of you as well, and not explicitly mentioning you is more a matter of coincidence than anything else.

I also have to express my thanks to my former colleagues at the Eindhoven School of Education, to whom I rather suddenly announced I was leaving for Wageningen in June last year. Douwe Beijaard, Ruurd Taconis, Birgit Pepin and Connie Cantrijn, members of the management team of ESoE at that time: thank you for the warm and intensive way in which we worked together, and for the way in which you helped to smoothen my transition to Wageningen. Thank you for allowing me to help finish the PhD students that I am still supervising: Bram, Annemieke, Nan, Leandra and Rens. And sorry to the PhD students that I had to leave behind: but I am sure that you are still in good hands, given the good supervisors available at ESoE! Thank you to the other ESoE colleagues, with some of whom I keep on collaborating in projects to this day and in the near future. A special thanks also to Lex Lemmens, Lilian Halsema, rector magnificus Frank Baaijens and previous rector magnificus Hans van Duijn for all the opportunities that were given to me to be involved in educational innovation at the university level, and that have surely helped me to be at the fortunate position I am currently at WUR.

At Wageningen, I am fortunate to work with many interesting colleagues, also at other departments. This for example concerns Emiel van Puffelen and Marijke van Oppen at the Wageningen part of the 4TU.CEE, Steijn Heukels, Erik Heijmans, Eva Verschoor and others at ESC, Ulrike Wild at Open and Online education, and Jaap Moolenaar, Hilde Tobi and Casper Zelissen at Biometris. Also, I am happy to work together with inspiring co-chairs at the section business sciences of which ELS is part:

Alfons Oude Lansink, Hans van Trijp, Bedir Terkinerdogan, Wilfred Dolfsma, and Jacqueline Bloemhof. I hope that within the section we can also engage in future joint research projects and educational activities. Obviously, this invitation also extends to other chair groups and educational programmes, some of which we already have longstanding collaborations with, such as the section Communication, Philosophy and Technology[5].

Of course, I thank my parents, sister, and family-in-law for their support and for believing in me. Without you, I would not have gone into science, education and the combination thereof. Thanks to my friends, for providing me with the necessary distraction and friendship. After serious business, it is sometimes good to visit a festival, have a beer, camp in caves, and what not more!
The biggest sacrifice, however, is made by my family. Tim and Bas, sorry that dad is often away or working at nights, to 'be boss of the 7th floor of the high rise building'. But do know that I am very proud of both of you, and that it is a great privilege to see you grow and become beautiful and wise young adults. To my wife Wendy: thank you for being so patient with me, for always listening to my stories and worries, for the fact that you basically take a much larger load of the work at home in order for me to flourish at work. It is often too much that I demand of you and the kids in this respect, and it may seem as if it is never enough. I feel very blessed with you and love you deeply.

Ik heb gezegd.

[5] *A nice example is the Journal of Agricultural Education and Extension, published by Taylor & Francis.*

References

Akkerman, S.F. & Bakker, A. (2011). Boundary crossing and boundary objects. *Review of Educational Research, 81*, 132-169.

Andre, L., Durksen, T., & Volman, M. L. (2017). Museums as avenues of learning for children: A decade of research. *Learning Environments Research, 20*, 47-76.

Bamberger, Y., & Tal, T. (2009). The learning environment of natural history museums: Multiple ways to capture students' views. *Learning Environments Research, 12*, 115-129.

Barnett, R. (1995). *The Limits of Competence: Knowledge, Higher Education and Society*. Berkshire, UK: McGraw-Hill/Open University Press.

Barrett, T. W., Pizzico, M. C., Levy, B., Nagel, R. L., Linsey, J. S., Grau Talley, K., Forest, C. G., & Newstetter, W. C. (2015). *A review of university maker spaces*. Paper presented at the 122nd American Society for Engineering Education Conference & Exposition (paper ID #13209). Seattle: ASEE. Retrieved July 17, 2018 from https://smartech.gatech.edu/bitstream/handle/1853/53813/a_review_of_university_maker_spaces.pdf.

Beijaard, D., Meijer, P. C., & Verloop, N. (2004). Reconsidering research on teachers' professional identity. *Teaching and Teacher Education, 20*, 107-128.

den Brok, P., Bergen, T., Stahl, R. J., & Brekelmans, M. (2004). Students' perceptions of teacher control behaviours. Learning and Instruction, 14, 425–443.

den Brok, P., Wubbels, T. & van Tartwijk, J.W.F. (2017). Exploring beginning teachers' attrition in the Netherlands. *Teachers and Teaching: Theory and Practice, 23 (8), 881-895*.

Carvalho, L., & Goodyear, P. (2017). Design, learning networks and service innovation. *Design Studies*, 1-27. https://doi.org/10.1016/j.destud.2017.09.003

Chapin, F.S., Zavaleta, E.S., Eviner, V.T., Naylor, R.L., Vitousek, P.M., Reynolds, H.L., Hooper, D.U., Lavorel, S., Sala, O.E., Hobbie, S.E., et al. (2000). Consequences of changing biodiversity. *Nature, 405*, 234–242.

Cleveland, B., & Fisher, K. (2013). The evaluation of physical learning environments: A critical review of the literature. *Learning Environments Research, 17*, 1-28.

Creemers, B.P.M., & L. Kyriakides (2008). *The dynamics of educational effectiveness: A contribution to policy, practice and theory in contemporary schools*. London: Routledge.

Conole, G. & Dyke, M. (2004). Understanding and using technological affordances: a response to Boyle and Cook. *ALT-J: Research in Learning Technology, 12* (3), 301-308.

Davies, D., Jindal-Snape, D., Collier, C., Digby, R., Hay, P., & Howe, A. (2013). Creative learning environments in education: a systematic literature review. *Thinking Skills and Creativity, 8*, 80-91.

Davis, H., Chang, M. L., Andrzejewski, C. E., & Poirier, R. R. (2014). Examining relational engagement across the transition to high schools in three US high schools reformed to improve relationship quality. *Learning Environments Research, 17*, 263-286.

Deci, E. L., & Ryan, R. M. (2000). The "What" and "Why" of goal pursuits: human needs and the self-determination of behaviour. *Psychological Inquiry, 11* (4), 227-268.

Dorman, J. P. (2009). Statistical tests conducted with school environment data: The effect of teachers being clustered within schools. *Learning Environments Research, 12*(2), 85-99.

Flynn, W. J., & Vredevoogd, J. (2010). The future of learning: 12 views on emerging trends in higher education. *Planning for Higher Education, January-March 2010*, 5-10.

Fisher, K. (Ed.). (2016). *The translational design of schools: An evidence-based approach to aligning pedagogy and learning environments*. (Advances in Learning Environments Research series). Rotterdam: Sense Publishers.

Fraser, B.J. (1994). Classroom and school climate. In Gabel, D. (Ed.), *Handbook of Research on Science Teaching and Learning* (pp. 493-541). Macmillan, New York.

Fraser, B. J. (2014). Classroom learning environments: Historical and contemporary perspectives. In N. Lederman & S. Abell (Eds.), Handbook of research on science education Volume II (pp. 104-119). New York: Routledge.

Fox, M. (2018). *Wicked problems*. Retrieved July 17, 2018 from: http://mofox.com/what-i-do/wicked-problems/

Furtak, E. M., Araceli Ruiz-Primo, M., & Bakeman, R. (2017). Exploring the utility of sequential analysis in studying informal formative assessment practices. *Educational Measurement, 36* (1), 28-38.

Gardiner, W.L. (1989). Forecasting, Planning and the future of information society. In Goumain, P. (Ed.), *High Technology Workplace: Integrating Technology, Management and Design for the Productive Work Environments* (pp. 27-39). New York: Van Nostrand Reinhold.

Gomez-Puente, S. (2014). *Design-based learning: exploring an educational approach for engineering education. Doctoral dissertation*. Eindhoven: Eindhoven School of Education/TUe.

Gomez Punte, S.M., van Eijck, M., & Jochems, W. (2015) Professional development for design-based learning in engineering education: a case study. *European Journal of Engineering Education, 40* (1), 14-31.

Grabinger, R. S., & Dunlap, J. C. (1995). Rich environments for active learning: a definition. *ALT-J Research in Learning Technology, 3* (2), 5-34.

Gresnigt, R., Taconis, R., van Keulen, H., Gravemeijer, K., & Baartman, L. (2014). Promoting science and technology in primary education: a review of integrated curricula. *Studies in Science Education, 50*(1), 47-84.

Griethuijsen, R.A.L.F. van (2015). *Relationships between students' interest in science, views of science and science teaching in upper primary and lower secondary education*. Doctoral dissertation. Eindhoven: Eindhoven School of Education/TUe.

Groen Onderwijs (2016). *Ontwikkelagenda groen onderwijs 2016-2025: investeren in een vitaal onderwijssysteem voor een krachtige groene sector*. Retrieved, July 10, 2018 from: http://groenonderwijs.nl/publicaties/.

Guastello, S. J., Peressini, A. F., & Bond, R. W. (2011). Orbital decomposition for ill-behaved event-sequences: Transients and superordinate structures. *Nonlinear Dynamics, Psychology, and Life Sciences, 15*, 465-476.

Gulikers, J., & Baartman, J. (2017). *Doelgericht professionaliseren: formatieve toetspraktijken met effect! Wat doet de docent in de klas?* Eindrapportage overzichtsstudie NRO. Wageningen: ECS. Retrieved August 28, 2018 from: https://www.nro.nl/wp-content/uploads/2015/09/Inhoudelijke-eindrapport_NRO-PPO-405-15-722_DEF.pdf

Heldens, H. (2017). *Teacher educator collaboration: activities, networks and dynamics. Doctoral dissertation*. Eindhoven: Eindhoven School of Education/TUe.

Heldens, H., Bakx, A., & Brok, P. den (2016). Teacher educators' collaboration in subject departments: Collaborative activities and social relations. *Educational Research and Evaluation, 21*, 515-536.

Herrington, J., & Oliver, R. (2000). An instructional design framework for authentic learning environments. *Educational Technology Research and Development, 48* (3), 23-48.

Holmes, J. A. (2011). Informal learning: Student achievement and motivation in science through museum-based learning. *Learning Environments Research, 14*, 263-277.

Hox, J. J. (2002). *Multilevel analysis: techniques and applications*. Mahwah, NJ: Lawrence Erlbaum Associates.

Hubers, Mireille D., Moolenaar, Nienke M., Schildkamp, Kim, Daly, Alan J., Handelzalts, Adam & Pieters, Jules M. (2018). Share and succeed - the development of knowledge sharing and brokerage in data teams' network structures. *Research Papers in Education*, 33 (2), 216-238.

Imms, W., Cleveland, B., & Fisher, K. (Eds.). (2016). *Evaluating learning environments: Snapshots of emerging issues, methods and knowledge* (Advances in Learning Environments Research series). Rotterdam: Sense Publishers.

Lüdtke, O., Trautwein, U., Kunter, M., & Baumert, J. (2006). Reliability and agreement of student ratings of the classroom environment – A reanalysis of TIMSS data. *Learning Environments Research, 9*, 215-230.

Mainhard, M. T., Brekelmans, M., Brok, P. den, & Wubbels, Th. (2011). The development of the classroom social climate during the first months of the school year. *Contemporary Educational Psychology, 36*, 190-200.

Mainhard, M. T., Pennings, H. J., Wubbels, Th., & Brekelmans, M. (2012). Mapping control and affiliation in teacher–student interaction with state space grids. *Teaching and Teacher Education, 28*(7), 1027-1037.

Mäkelä, T., & Helfenstein, S. (2016). Developing a conceptual framework for participatory design of psychosocial and physical learning environments. *Learning Environments Research, 19*, 411-440.

McCrindle, M., & Wolfinger, E. (2010). *The ABC of XYZ: understanding the global generations*.
Sydney: The University of New South Wales Press.

McIntyre, N. A., Mainhard, M. T., & Klassen, R. M. (2017). Are you looking to teach? Cultural, temporal and dynamic insights into expert teacher gaze. *Learning and Instruction, 49*, 41-53.

Mueller, S., & Toutain, O. (2015). *The outward looking school and its ecosystem: entrepreneurship 360*. Thematic paper for the OECD. Dijon: Burgundy School of Business / OECD. Retrieved, July 10, 2018 from: http://www.oecd.org/cfe/leed/Outward-Looking-School-and-Ecosystem.pdf.

Mulder, M. (2017). A five-component future competence (5CFC) model. *Journal of Agricultural Education and Extension, 23* (2), 99-102.

Nidzam Che Ahmad, C., Osman, K., & Halim, L. (2013). Physical and psychosocial aspects of the learning environment in the science laboratory and their relationship to teacher satisfaction. *Learning Environments Research, 16*, 367-385.

Nijssen, E.J., Hillebrand, B., de Jong, J.P.J., & Kemp, R.G.M. (2012). Strategic value assessment and explorative learning opportunities with customers. *Journal of Product Innovation Management, 29* (S1), 11.

Oonk, C. (2016). *Learning and teaching in the regional learning environment: enabling student and teachers to cross boundaries in multi-stakeholder practices*. Doctoral dissertation. Wageningen: Wageningen University.

Oonk, C., & Gulikers, J. (2018). *Boundary crossing: leren van en met de ander, studenten opleiden tot bruggenbouwers*. Canon Beroepsonderwijs. 's-Hertogenbosch: ECBO. Retrieved July 17, 2018 from: http://www.canonberoepsonderwijs.nl/Boundary-crossing-leren--met-en-van-de-ander.

Oonk, C., Gulikers, J., & Mulder, M. (2017). Educating boundary crossing planners: evidence for student learning in the multi-stakeholder regional learning environment. *Journal of Planning Education and Research*, 1-14. Published online: DOI:10.1177/0739456X17737598

Pennings, H. J. M., Brekelmans, M., Wubbels, Th., van der Want, A. C., Claessens, L. C. A., & van Tartwijk, J. (2014). A nonlinear dynamical systems approach to real-time teacher behavior–Differences between teachers. *Nonlinear Dynamics, Psychology, and Life Sciences*, 18 (1), 23-45.

Pennings, H. J. M., & Mainhard, T. (2016). Analyzing teacher-student interactions with state space grids. In M. Koopmans & D. Stamovlasis (Eds.), *Complex dynamical systems in education – Concepts, methods and applications* (pp. 233-271). New York: Springer International Publishing.

Pennings, H. J. M., van Tartwijk, J., Wubbels, Th., Claessens, L. C. A., van der Want, A. C., & Brekelmans, M. (2014). Real-time teacher-student interactions–A dynamic systems approach. *Teaching and Teacher Education, 37*, 183-193.

Pincus, D., Ortega, D.L., & Metten, A.M. (2010). Orbital decomposition for multiple time series comparisons. In S. J. Guastello & R. A. M. Gregson (Eds.), *Nonlinear dynamical systems analysis for the behavioral sciences using real data*. Boca Raton, FL: CRC Press/Taylor & Francis.

Rebar, B. M. (2012). Teachers' sources of knowledge for field trip practices. *Learning Environments Research, 15*, 81-102.

Rickards, T., Brok, P. den, & Fisher, D. L. (2005). The Australian science teacher: A typology of teacher-student interpersonal behaviour in Australian science classes. *Learning Environments Research, 8*, 267-287.

Roschelle, J., Pea, R., Hoadley, C., Gordin, D., & Means, B. (2000). Changing how and what children learn in school with computer-based technologies. *The Future of Children, 10* (2), 76-101.

Schenke, K., Ruzek, E., Lam, A. C., Karabenick, S., & Eccles, J. (2017). Heterogeneity of student perceptions of the classroom climate: A latent profile approach. *Learning Environments Research, 20*, 289-306.

Seidel, T. (2006). The role of student characteristics in studying micro teaching learning environments. *Learning Environments Research, 9*, 253-271.

Sluijsmans, D. M. A., Dochy, F., & Moerkerke, G. (1998). Creating a learning environment by using self-peer- and co-assessment. *Learning Environments Research, 1*, 293–319.

Snijders, T. A. B., & Bosker, R. J. (1999). *Multilevel analysis*. London: Sage.

Snowden, D. J., & Boone, M. E. (2007). A leader's framework for decision making. *Harvard Business Review, November 2007* (R0711C), 1-9.

Song, L., & McNary, S. (2011). Understanding students' online interaction: Analysis of discussion board postings. *Journal of Interactive Online Learning, 10* (1), 1–14.

Spelt, E., Biemans, H.J.A., Tobi, H., Luning, P., & Mulder, M. (2010). Teaching and learning in interdisciplinary higher education: a systematic review. *Educational Psychology Review, 21*, 365-378.

Stets, J. E., & Burke, P. J. (2014). The development of identity theory. *Advances in Group Processes*, 31, 57-97.

Tassone, V., O'Mahoney, C., McKenna, E., Eppink, H.J., & Wals, A.E. (2018). (Re) designing higher education curricula in times of systemic dysfunction: a responsible research and innovation perspective. *Higher Education, 76* (2), 337-352.

Trudgill, S. (2007). Tansley, A.G. 1935: The use and abuse of vegetational concepts and terms. Ecology 16, 284 307. *Progress in Physical Geography 31*, 517–522.

van den Bogert, N., van Bruggen, J., Kostons, D., & Jochems, W. M. G. (2014). First steps into understanding teachers' visual perception of classroom events. *Teaching and Teacher Education, 37* (1), 208-216.

Vennix, J., Brok, P. den, & Taconis, R. (2017). Perceptions of STEM-based outreach learning activities in secondary education. *Learning Environments Research, 20*, 21-46.

Vermunt, J.D, & Verloop, N. (1999). Congruence and friction between learning and teaching. *Learning and Instruction, 9*, 257-280.

Voogt, J., Sligte, H., Beemt, A. van den, Braak, J. van, & Aesaert, K. (2016). *E-didactiek: welke applicaties gebruiken leraren en waarom?* Amsterdam: Kohnstamm Instituut.

Wageningen University and Research (2017a). V*ision for education Wageningen University and Research, the next step*. Retrieved July 10, 2018 from: https://www.wur.nl/upload_mm/1/a/7/60d669b6-f604-4e84-98d0-7cfbe29643eb_WU%20Vision%20for%20Education%202017.pdf.

Wageningen University and Research (2017b). Jaarverslag 2017 Wageningen University and Research. Retrieved, July 10, 2018 from: https://www.wur.nl/upload_mm/f/2/2/7a463b04-4598-4f10-84f7-c7621aa31cfd_Jaarverslag%20WUR%202017%20Totaal.pdf.

Wals, A. E. J. (2010). *Message in a bottle: learning our way out of unsustainability*. Inaugural lecture. Wageningen: Wageningen University & Research.

Wals, A. E. J. (2015). *Beyond unreasonable doubt: education and learning for socio-ecological sustainability in the Anthropocene*. Inaugural lecture. Wageningen: Wageningen University and Research.

Wenger, E., Trayner, B., & De Laat, M. (2011). *Promoting and assessing value creation in communities and networks: a conceptual framework*. Ruud de Moor Centrum Rapporten, nr 18. Heerlen: Open University/Ruud de Moor Centrum.

Wesselink, R., Biemans, H.J.A., Gulikers, J., & Mulder, M. (2017). Models and Principles for Designing Competence-Based Curricula, Teaching, Learning and Assessment. In: Mulder, M. (Ed.), *Competence-based Vocational and Professional Education*. Bridging the Worlds of Work and Education. Cham, Switzerland: Springer.

Westra, R., Boersma, K., Savelsbergh, E., & Waarlo, A. (2006). Visies op ecosystemen in onderwijs en onderzoek. *Tijdschrift voor Didactiek der β-wetenschappen, 23* (1/2), 18-39.

Willis, A.J. (1994). Arthur Roy Clapham. 24 May 1904-18 December 1990. *Biographical Memoirs of Fellows of the Royal Society 39*, 72–80.

Wolff, C.E., Jarodzka, H., van den Bogert, N., & Boshuizen, E. (2016). Teacher vision: Expert and novice teachers' perception of problematic classroom management scenes. *Instructional Science, 44*, 243-265.

Wubbels, Th., Brekelmans, M., Brok, P. den, & van Tartwijk, J. (2006). An interpersonal perspective on classroom management in secondary classrooms in the Netherlands. In. C. Evertson & C. S. Weinstein (Eds.), *Handbook of classroom management: research, practice and contemporary issues* (pp.1161-1191). New York: Lawrence Erlbaum Associates.

Youngworks (2016). *Bètamentality 2011-2016: jongeren boeien voor bèta en techniek*. Retrieved, July 10, 2018 from: http://www.betamentality.nl//docs/Publicaties/betamentality-2011-2016.pdf.

Zandvliet, D., & Broekhuizen, A. (2017). Spaces for learning: Development and validation of the school physical and campus environment survey. *Learning Environments Research, 20*, 175-187.

Zaragoza, J. M., & Fraser, B. J. (2017). Field-study science classrooms as positive and enjoyable learning environments. *Learning Environments Research, 20* (1), 1-20.

Zimmerman, B.J. (2000). Attainment of self-regulation: A social cognitive perspective. In M. Boekaerts, P.R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 13-39). San Diego, CA: Academic Press.

Zitter, I., & Hoeve, A. (2012). *Hybrid learning environments: merging learning and work processes to facilitate knowledge integration and transitions*. OECD Education Working Papers. Retrieved July 17, 2018 from: https://doi.org/10.1787/5k97785xwdvf-en.

Prof.dr Perry den Brok

Societal challenges and developments in technology drive the need for life-science graduates with both strong disciplinary expertise as well as competencies such as interdisciplinary collaboration, creativity, and critical thinking, and qualities such as social involvement, empathy and caring. This means that learning contexts need to support the development of these requirements. In this inaugural lecture characteristics of learning ecosystems, modern educational contexts that help support this development, will be discussed, including the new roles demanded from university teaching staff. The lecture also discusses examples of projects started by the chair group Education and Learning Sciences aimed at evaluating the educational ecosystem at Wageningen University and Research.

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