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Teaching action-oriented knowledge on sustainability issues

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ABSTRACT

Knowledge about sustainability problems as it is typically taught does not *per se* lead to action for tackling these problems. Environmental and sustainability education researchers have argued for teaching more action-oriented knowledge. This article addresses the 'didactical work' required for teachers to do so, both in preparing and implementing lessons. The authors employ transactional didactic theory and the analytical method Practical Epistemology Analysis to open-up the black box of teaching and learning action-oriented knowledge on sustainability issues. The methodology, that has a strong focus on classroom observations, allows to empirically investigate the influence of teachers' actions on students' learning. It is here applied to a case study in higher education where it is engineering teachers' explicit ambition for their students to explore and develop a wider area of knowledge about sustainability issues. Our findings shed light on what this requires in terms of the 'scripting', 'staging', and 'performance' of lessons.

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1. Introduction

While our planet and its inhabitants are exposed to accelerating sustainability crises that require resolute action, environmental and sustainability education (ESE) practice and research face some pressing challenges. How to avoid 'eco-paralysis' (Albrecht 2011) that can be brought about by feelings of worry, anxiety, and 'ecological grief' (Ojala et al. 2021)? How to overcome the gap between knowing about sustainability problems and acting in the pursuit of tackling them (Kollmuss and Agyeman 2002)? In the face of both the devastating socio-ecological problems that demand urgent action, and the observation that (young) people increasingly suffer from the overwhelm and paralysis this brings about, appeals are made for ESE to focus on 'action competence'.

Since Jensen and Schnack (1997) influential paper on the 'Action Competence Approach', the notion has received ample attention in ESE research. Action competence involves being able, willing, and qualified to act (Jensen and Schnack 1997) and has been defined as 'someone's insightful readiness to act in a way that meets the challenges of a given situation' (Blomhøj and Jensen 2003, 126). Observing that knowledge does not *per se* lead to much-needed action, Jensen (2002, 2004) has argued that the way knowledge is typically taught in formal education

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is not sufficiently action-oriented. He distinguishes four types of knowledge through which sustainability problems can be approached and analysed: (1) knowledge about the existence and consequences of the problem ('WHAT is the problem?'), (2) knowledge about its root causes ('WHY do we have this problem?'), (3) knowledge about alternatives and visions ('WHERE do we want to go?') and (4) knowledge about strategies for change ('HOW do we change things?'). All too often, Jensen emphasises, ESE offers students a limited 'landscape of knowledge' that is not necessarily conducive to action as it reduces the focus to the existence and consequences of the problem. For education to be action-oriented, he argues, it should strive to explore and develop all four dimensions of knowledge about sustainability problems – an ambition that has 'significant consequences for planning, implementing and evaluating teaching and learning' (Jensen 2002, 329). Also Almers (2013) highlights the important role that teachers play in students' pathways towards action competence.

The latter is the focus of this article that addresses the question *how to teach* a wide and varied landscape of action-oriented knowledge. Grounded in a didactical perspective, we explicitly focus on illuminating the influence of teachers' actions on students' learning. Originally, it was emphasised that action competence should be understood *as an educational approach and ideal*, related to a Bildung perspective, rather than as a specific, pre-specified outcome that someone can fully achieve. As such, 'competence' was interpreted substantially different from how the notion is used in what Mogensen and Schnack (2010, 59) call 'individualistic-oriented Human Resource Management theory'. While the principles of such an educational ideal were elaborately described, empirical research on how to put it into practice remained scarce. In a recent 'revival' of research on the topic, within the varied interpretations of the concept (Sass et al. 2020), an alternative approach to action competence *as an educational outcome* has emerged. We witness a growing body of research literature that focusses on the effectiveness of educational interventions in view of fostering students' action competence (e.g. Olsson, Gericke, and Boeve-de Pauw 2022). Relatedly, instruments are developed for measuring action competence as a desired learning outcome such as the Self-Perceived Action Competence for Sustainability Questionnaire SPACS-Q (Olsson et al. 2020), the Action Competence in Sustainable Development Questionnaire ACiSD-Q (Sass et al. 2021), or the PACesd-Q Questionnaire to measure Professional Action Competence in Education for Sustainable Development (Sass et al. 2022). These are also applied to investigate the relation between teacher practices and (aspects of) action competence (e.g. Finnegan 2022).

Such evaluation studies are usually based on statistical research that measures and compares knowledge, values, motivation, behaviour, etc. pre- and post-intervention. They succeed in assessing the effectiveness of pedagogical efforts in terms of desirable learning outcomes, however, they are not designed to deliver detailed insight into *how* a change in knowledge, skills, values, etc. comes about through concrete practices. Thus, complementary to the existing theoretical publications and evaluation studies, we need research that creates empirically grounded insight into the learning *process*. Recently, several qualitative empirical studies contributed to knowledge about, for example, how specific education practices (Dittmer et al. 2018; Bonazzi Piasentin and Roberts 2018; Zhan, He, and Wing Mui So 2019) or the use of textbooks (Biström and Lundström 2021) can contribute to or, otherwise, limit the potential for promoting action competence. Furthermore, a review of literature on educational proposals led to the conclusion that student participation, promoting reflection on the complexity of environmental issues, facilitating critical thinking, encouraging autonomous and responsible decision-making, and involving communities in environmental education can help improve the development of action competence (Varela-Losada et al. 2016). Through such studies, general principles have been identified and described. What is still largely lacking, however, is knowledge about the 'didactical work' (Van Poeck and Östman 2020) done by teachers in order to put such principles into practice. How, for example, can we teach things such as critical thinking or reflection on complexity? What are fruitful – and perhaps also less fruitful – ways of involving communities?

Or, more generally, what *exactly* is it in specific educational practices that fosters students' action competence and how do teachers' choices and actions make that possible?

This blind spot in the currently available research literature is what is in focus in this article. We present and illustrate an approach to open-up the black-box of teaching and learning processes that can contribute to the development of action competence by creating detailed, empirically grounded knowledge about how, exactly, teachers' choices and actions – their didactical work – influence students' evolving action-oriented knowledge. This focus on 'knowledge' builds on Jensen's (2002, 2004) earlier research on the importance of a wider landscape of knowledge (see above). While agreeing with the arguments for that, it is also vital to emphasise that being able, willing, and qualified to act involves much more than only the cognitive aspect of knowledge acquisition. We will return to this consideration in the 'Discussion and conclusion' section. However, since knowledge acquisition is an omnipresent and essential aspect of education, we believe that the question how to make this more action-oriented also deserves attention in itself.

In the remainder of the article, we first present a theoretical framework (section 2) and a methodology (section 3) to empirically investigate what teachers do – both in preparing and implementing lessons – and what is the influence thereof on students' learning. Next, we illustrate this with a case study in engineering education where it was the teachers' explicit ambition for their students to explore and develop a wider area of knowledge about sustainability issues (section 4). We conclude the article with a discussion of our findings, the limitations of the presented study, and some pathways for future research (section 5).

2. Transactional didactic theory

Our object of research requires a focus on teachers' actions while preparing and performing their education practices, as well as on how teachers' decisions and interventions affect students' learning. Transactional didactic theory (see also Östman, Van Poeck, and Öhman 2019a,2019b, Van Poeck and Östman 2021, 2022) provides us with a suitable theoretical framework for that. It is inspired by philosophical pragmatism, and particularly John Dewey's writings on experiential learning and the notion of 'transaction' he developed together with Arthur Bentley.

2.1. A transactional approach to teaching and learning

Central in a transactional perspective is the focus on the interplay, i.e. the 'transaction' (Dewey and Bentley 1949), between human action and the environment in/through which it takes place. Thus, learning is understood as a dynamic interplay between, on the one hand, intrapersonal aspects (earlier acquired knowledge, skills, beliefs, values, etc.) and, on the other, interpersonal, institutional, and material aspects of the environment (Östman, Van Poeck, and Öhman 2019a). As Dewey (1938, 43–44) writes: 'An experience is always what it is because of a transaction taking place between an individual and what, at the time, constitutes his environment, whether the latter consists of persons with whom he is talking about some topic or event, the subject talked about being also a part of the situation; or the toys with which he is playing; the book he is reading […]; or the materials of an experiment he is performing. The environment, in other words, is whatever conditions interact with personal needs, desires, purposes, and capacities to create the experience which is had'. Important to notice here, is how Dewey conceptualises the 'environment' as distinguished from the totality of what he calls the 'surroundings'. Inevitably there are always only *some* aspects of the totality of objects/phenomena within the surroundings conditions that are included in persons' attentiveness. Those become an environment. While these objects/phenomena become meaningful and relevant for the actors involved, others remain unnoticed or are neglected or ignored. Hence, people's actions are not seen as

being *determined* by their surroundings. Rather, people are assumed to also actively (re)construct them through a dynamic process of 'environ*ing*' (Östman, Van Poeck, and Öhman 2019a): a process of selecting some and neglecting other objects/phenomena out of the surroundings. Thus, transactional pragmatism sees environments as being (re)constructed in action while, simultaneously and reciprocally, the environment also (re)constructs the acting person.

This process of (governing) selective attentiveness is crucial in a transactional understanding of learning and teaching. Learning something involves the ability to master the selective attentiveness necessary for putting relevant objects in the world in focus as well as to intellectually reason and bodily act in relation to the thus created environment in such a way that the pursued outcomes[1] are realised (Östman, Van Poeck, and Öhman 2019a). Teaching can then be understood as the work of governing this process (Van Poeck and Östman 2022). Any learning process involves what Wertsch (1998) calls 'privileging'. In the transactions between persons and their surroundings, only certain intrapersonal aspects and certain aspects of the environment become present and emerge as valid while others are neglected. This dynamic process of inclusion and exclusion in actions steers the meaning-making and, thus, learning in a certain direction, towards certain outcomes. Some questions, ideas, objects, etc. are acted upon as reasonable and fruitful and, thus, taken into account while others are ignored or disregarded. It is through such processes of privileging that 'environing' takes shape: persons, in transaction with the world, create an environment out of the surroundings by paying attention towards *particular* objects/phenomena in the world and neglecting others. Another aspect of privileging concerns what to *do* with the created environment. That, too, implies inclusion and exclusion as it involves choices between alternative possible doings.

2.2. The dramaturgy of teaching – scripting, staging and performance

This being said, we can describe teaching as a matter of governing privileging in connection to a purpose, which involves steering the students' attentiveness – i.e. the environing – as well as what to do with the environment in the service of what one aims to achieve. Shaping a fruitful educative environment is thus a vital aspect of the teacher's didactical work. In Dewey's (1938, 40) words: 'A primary responsibility of educators is that they not only be aware of the general principle of the shaping of actual experience by environing conditions, but that they also recognize in the concrete what surroundings are conducive to having experiences that lead to growth. Above all, they should know how to utilize the surroundings, physical and social, that exist so as to extract from them all that they have to contribute to building up experiences that are worth while'.

Aiming to incorporate attention for how an environment is created and what it does to an educative practice, our transactional theory of teaching (Östman, Van Poeck, and Öhman 2019b, Van Poeck and Östman 2022) drew inspiration from dramaturgical analysis. Dramaturgical analytical frameworks (e.g. Goffman 1956; Feldman 1995; Hajer 2005; Nahuis 2009) are built on metaphors borrowed from drama[2] and are developed with the explicit aim to study social interactions with a focus on how these are affected by the *setting* in which they occur. Recognising that settings are not static but dynamically take shape and transform as people act within and upon them, a transactional approach aims to capture what settings do with people as well as what people do with settings simultaneously and reciprocally.

As argued, we approach the practice of teaching as encompassing both the *preparatory* work of planning and designing an educative setting in advance and the actual teaching as it is performed, *in action*. Feldman's (1995), Hajer's (2005), and Nahuis' (2009) dramaturgical analyses inspired us to capture this whole process by conceptualising and analysing teaching in terms of scripting, staging, and performance (Van Poeck and Östman 2022) (see Table 1). The practice of *scripting* involves determining purposes, the roles of the characters in the play, cues for appropriate behaviour, and access conditions. The *staging* of a setting, then, refers to the

Table 1. The dramaturgy of teaching.

Scripting	Formulating purposes for the educative practice, clarifying the roles of teachers and students, explicating expectations regarding appropriate behaviour in this setting
Staging	Organising the interactions in the setting through tools, methodologies, activities, rules of the game, artefacts, etc.: • *staging the scene* of objects/phenomena that are brought to the students' attention (what to focus on and what to neglect?) • *staging tasks* for the students to actively engage with the objects of attention (what to do?)
Performance	Performing interventions within and upon the staged setting that help to guide the students' learning in the pursuit of the scripted purposes: teacher moves

deliberate organisation of interactions which takes shape through the use of particular tools, methodologies, activities, rules of the game, artefacts, etc. The *performance* is about what actors do within and upon the staged settings in the pursuit of the scripted purposes. Applied to teaching, scripting thus involves formulating purposes for the educative practice and clarifying the roles of teachers and students, including expectations regarding how these are supposed to behave in this setting. Staging an educative setting consists of two aspects: (1) staging the *scene* on which the activities take place, and (2) staging fruitful *tasks* for the students. The staged scene affects which objects/phenomena are brought to the students' attention and thus governs what to focus on and what to neglect. The staging of tasks, then, affects how the students actively engage with the objects of attention. As argued above, both are vital aspects of teaching as a work of governing privileging processes. The performance, finally, can be grasped in terms of a variety of *teacher moves* (Östman, Van Poeck, and Öhman 2019b, Lidar, Lundqvist, and Östman 2006): interventions performed by a teacher that help to guide the students' learning. These interventions can be verbal (saying something) or non-verbal (e.g. showing something, nodding, pointing at something, moving in a space). As we will elaborate below, they can steer the learning process in a certain direction or deepen it.

If we now connect the two aspects of privileging to our dramaturgical take on teaching, the work of a teacher can be described as governing the privileging through offering the students a setting consisting of a *scene* and a *task*. In transaction with this scene, the students develop a specific attentiveness and, thus, an environment. In transaction with the task, students engage in an inquiry – i.e. an investigation of/experimentation with the environment – that, if successful, results in a fruitful learning outcome. To a certain extent, the scene and task are given shape through the teacher's preparatory work of, for instance, selecting teaching content, deciding on whether and how to divide students into subgroups, or preparing exercises. However, teachers also continue to stage the setting *in the performance*. While teaching, they perform numerous *ad hoc* actions (moves) that affect the students' ongoing privileging by either influencing the students' attentiveness or their manner of acting upon the environment. Realising that the students' actions and the setting offered continuously influence one another, implies that it is vital for teachers to be prepared to adjust the scene and tasks whenever they judge it to be necessary or fruitful for steering the students privileging towards the scripted purposes. Obtaining the information needed for such judgements requires that the teacher has the opportunity to timely experience the relation between her/his actions and their consequences (Van Poeck and Östman 2022).

3. Methodology

Aiming to develop useful knowledge about how teachers' actions can help students to explore and develop a wider area of knowledge about sustainability issues, our empirical analyses need to reveal impactful interventions that contribute to this purpose. This requires a methodology that enables us to open-up the black box of what and how students learn and, in particular, how the actions of teachers influence the learning process and outcomes. Important to realise

here, is that the methodology is not aimed at evaluating predetermined learning outcomes after an intervention. As argued in the introductions, other methodological tools are available for such purposes. This article introduces an alternative, complementary methodology that is suitable to reveal what usually remains black-boxed while evaluating learning outcomes, i.e. what students may learn besides predetermined outcomes and, especially, how the learning is enabled by teachers' didactical work. Each methodology obviously has its strengths and weaknesses/blind spots. Below, we explain in detail how our methodology aims to open op the black-box of both *what* and *how* students learn. We first explain the analytical steps we follow for an in-depth analysis of qualitative empirical data and, subsequently, describe the case study through which the presented theory and methodology will be illustrated.

3.1. Analytical steps

The first step in the analysis is to identify and describe the *preparatory* work done by teachers in view of scripting and staging a setting. We scrutinise qualitative analytical data (documents, interviews, and transcripts of observations – see below 3.2) with the aim to find out what is said, be it explicitly or implicitly, about aspects of the scripting (i.e. the educational purposes teachers want to realise, the roles of teachers and students, and expectations regarding how these are supposed to behave in this setting) and staging (i.e. which objects/phenomena the students are invited to pay attention to – the scene – and how they are expected to actively engage with them – the task).

In a next step, we analyse in depth and detail how learning takes place in the actual performance of the prepared activities. This involves both an analysis of *what* is learned as well as of *how* teachers' actions steer the students' learning (see Figure 1). Therefore, we analyse transcripts of (audio/video) recorded observations with the use of Practical Epistemology Analysis (PEA – Wickman and Östman 2002). This systematic analytical method is particularly suited for delivering findings to be used within transactional didactic theory (Shilling 2018; Östman and Öhman 2022). PEA analyses meaning-making. More precisely, it is used to investigate meaning as something that is literally *made*, that is dynamically created and transformed in and by action. PEA's key analytical concepts are 'gap', 'encounter', 'relation', and 'stand fast'. The analysis starts with identifying *gaps* that occur when people encounter a new situation. While gaps arise in every *encounter*, they are often bridged immediately. Sometimes, however, the gap is too big to bridge automatically and makes it impossible for people to simply proceed with their activity. A disruption of routine modes of thinking and acting arises which becomes visible in

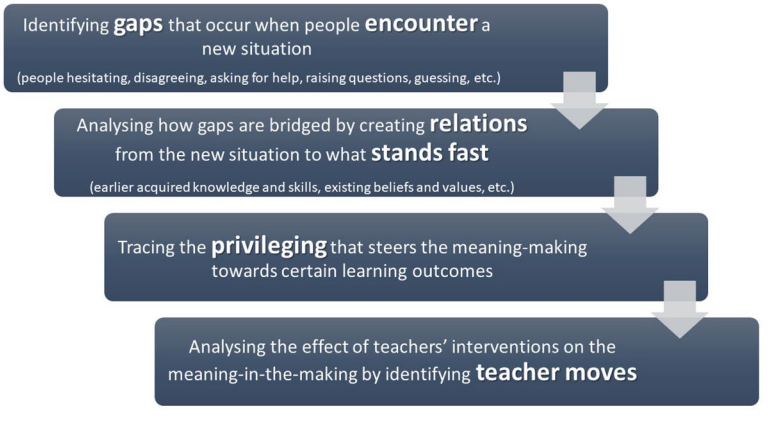

Figure 1. An analysis with Practical Epistemology Analysis (PEA) in combination with Teacher Move Analysis (TMA).

people starting to hesitate, disagree, ask for help, guess, etc. Then we can observe a gap that lingers. Before they can proceed, people experiencing such a gap need to create *relations* from the new situation they encounter to previous experiences that *stand fast* for them: earlier acquired knowledge and skills, existing beliefs and values, etc. It is through the thus created relations – in transactions between persons and their social and physical environment – that meaning is made. The outcomes of PEA – i.e. empirical findings on the making of meaning – can subsequently be connected to transactional didactic theory since the identification of lingering gaps and the analysis of relations created to bridge the gaps allow us to trace the privileging that steers the meaning-making towards certain learning outcomes. Learning is seen to have happened if a gap is successfully bridged by creating fruitful relations to what stands fast. We can observe this when the participants are able to proceed without further disruption.

Revealing the impact of teachers' actions is done through a Teacher Move Analysis (TMA). As indicated, these are – verbal or non-verbal – interventions of a teacher that help to guide the students' learning. Important to emphasise is that TMA is a *functional* analysis. It focuses on the function that a move has in an on-going privileging process and is aimed at identifying its *effect* on the meaning-in-the-making, instead of, for example, interpreting the teacher's intention with a move. Different types of teacher moves have been identified (Östman, Van Poeck, and Öhman 2019b), for example:

- *adding moves* that influence the students' learning by adding an object/phenomenon to be used in an on-going inquiry;
- *directing moves* that affect the direction of the students' learning by either affirming the pathway of inquiry (i.e. *confirming moves*) or changing it (i.e. *reorienting moves*);
- *deepening moves* that affect the direction of the students' learning by deepening the inquiry: here we can distinguish moves with a generating and judging function:
- *generating moves* can, for instance, influence the students' learning by raising the conversation to a higher level with the aid of more general terms (*generalising moves*) or help the students to be more specific in their claims and insights (*specifying moves*);
- *judging moves* can, for example, stimulate the students to develop their thinking/argument by judging it in relation to an alternative option (*comparative moves*) or to inquire whether the idea/claim still holds when circumstances change (*testing moves*).

By investigating – *in situ* – how learning takes place in the performance of concrete practices, we can thus identify and describe the influence of teachers' work in two ways. First, the PEA reveals how the teacher's preparatory work of scripting and staging a setting has an observable influence on the encounters taking place, the gaps that emerge, and the relations that are created in order to bridge these. Second, it reveals the observable impact of the teacher's interventions in the performance (i.e. the teacher moves) on the making of meaning and, thus, on the learning outcomes.

3.2. Case study

In the next section, we illustrate the above explained analytical approach with a case study of a project-based course scheduled in the 3rd Bachelor year of an electro-mechanical engineering programme in a Belgian university. The course is selected because it is 'information-rich' (Patton 2002) in relation to our research objectives: the teachers have the explicit ambition to offer their students a wider area of knowledge about sustainability issues and it is possible to access data that allow us to gain insight into both the preparation and the performance of the teaching.

In this project-based course, the students work together in groups of four and have to design and produce a technical installation (scale model) that is assumed to tackle sustainability problems: e.g. a wind turbine, or a solar water heater. In addition, they are given an assignment in

which they have to situate their technical design in a broader societal context by making an analysis of the so-called 'socio-technical system' in which their installation is embedded (e.g. the energy or housing system in the examples above) from a 'Multi-Level Perspective' on sustainability transitions (see below for more information). They have to describe this in a (group) paper of maximum 6.000 words and present it during a seminar where they also discuss each other's work. We focus our analysis mainly on the paper assignment and seminars, where it is the explicit intention to provide a wide variety of (more than only technical) knowledge, and therefore we do not go into details on how the students are taught about the design of the technical installation.

The dataset consists of documents (e.g. the course description, the description of the assignment for the students, and the papers resulting from it), the transcript (14 pages) of an audio-recorded interview with the teacher-in-charge of the course, the recording of a focus group with the team of six teachers responsible for supervising the students in the paper assignment and facilitating the seminars we analysed (2h42min), and the recordings of observed presentations and discussions of the papers of three groups of four students in a seminar facilitated by the teacher-in-charge of the course (3h14min). All data are collected with the informed consent of the participants and following the Belgian guidelines for research ethics[3]. Verbatim transcriptions are made.

4. Findings

In what follows, we apply the above elaborated analytical approach to our case study. We first present our analysis of the teachers' preparatory work in view of scripting and staging a setting (step 1) and subsequently the analysis of what is learned and how teachers' actions steer the students' learning in the performance (step 2).

4.1. Preparing the teaching practice

4.1.1. Scripting

As stated, scripting is about determining educational objectives, which and how many teachers teach a course or lesson, which students take the course, whether guest lecturers are involved, how the students are expected to behave, etc.

As indicated, the teachers of the project-based engineering course have the explicit ambition to make their students explore and develop a wider area of knowledge about sustainability issues. The group of students taking the course varies between 60 and 100 per year. They are expected to attend the seminars and to prepare and actively participate in them (see further below). Sustainability takes central stage in the course. The students have to design and produce a technical installation (scale model) that in one way or another contributes to tackling sustainability problems such as climate change:

> 'It is actually a course where the students have to synthesise the knowledge they have acquired up to that point and apply it in a design. They have to show that they can design an installation – not something new but a sort of installation that actually already exists. They must be able to make a wind turbine, a solar water heater, et cetera by applying existing knowledge. That was the original assignment in the project-based course. In the context of our goal to integrate sustainability into the project, we only chose technologies that fit within a sustainable system […]. And then add a bit of introduction for our students to get to know sustainability'. (interview teacher)

With this 'introduction to sustainability', it is the explicit intention of the teachers to provide their students with a broader view of a sustainable society, and thus more diverse knowledge, than is typically the case in their education programme. Usually, the interviewed teacher explains, their students mainly learn natural sciences based knowledge on the existence, causes, and

consequences of sustainability problems (i.e. WHAT is the problem and WHY do we have it?) and technical knowledge about specific, technological solutions. In the course specifications, one of the recently added competencies to be achieved in this course is described as 'basic knowledge of the United Nations Sustainable Development Goals' (i.e. WHERE do we want to go?). In the interview, the teacher-in-charge links this to the objective of providing students with more than just technical knowledge by paying attention to decision- and policy-making processes in international institutions as possible strategies for change (i.e. HOW do we change things?):

> 'That is a frame of reference that I think is important for them to have. […] Because that is a framework for making decisions and in which a lot of policy is also framed. So […] it structures the problem in its broad sense, and more than just in the technical sense'. (interview teacher)

In addition to the technical design task, the students are also given an assignment (see below) in which they have to situate their technical design in a broader societal context from the perspective of a transition to a more sustainable society. The educational objectives of this assignment also reflect the ambition to provide students with more diverse knowledge on WHY we have sustainability problems and HOW we can change things. For example:

> 'The students…
>
> - … have insight in and are able to illustrate how the transition to a sustainable society requires choices that cannot be made on the basis of solely (natural) scientific and technical arguments
> - … have insight in and are able to illustrate how (sustainable) technologies are embedded in socio-technical systems and how a sustainability transition depends on systemic changes
> - … can explain and illustrate in a nuanced way and with insight into the multi-level nature of sustainability transitions how (new) technologies can contribute to the transition to a more sustainable society
> - … approach sustainability problems and possible solutions from different perspectives and weigh them against each other in order to take a stand' (document: assignment)

The course is taught by six teachers, professors in electro-mechanical engineering, assisted by a number of assistants. To bring in non-technical knowledge about the SDGs, the broader societal context and the transition to a more sustainable society, the students get a guest lecture from a professor from the Political Sciences department.

4.1.2. Staging

Staging, as explained, has to do with designing a learning environment (scene) and staging tasks for the students. The teachers' work here consists of selecting learning content and teaching materials, choosing/furnishing a classroom, giving assignments, determining whether students will work in groups and how to divide them, planning and monitoring the time that can be spent on activities, etc.

The teachers developed an assignment in which the students have to analyse the socio-technical societal system in which their technical design fits with the help of a framework from the field of sustainability transition studies[4]:

> 'In addition to the technical design, in your case a wind turbine, you will also be given an assignment to frame this technology - and your role as an engineer in its development - in a broader societal context from the perspective of a transition to a more sustainable society. The assignment for your group is: make an analysis of the energy system in Flanders using the Multi-Level Perspective (MLP). Describe the results of the analysis in a group paper of maximum 6.000 words'. (document: assignment)

The students are provided with specific content and teaching materials. For example, sustainability transitions and the MLP are explained in the document in which the assignment is

described and the students receive a 'glossary' with definitions of the central concepts. An excerpt illustrates how this assignment should help the students to gain knowledge on WHY we have sustainability problems, WHERE we may want to go, and HOW we can change things:

> 'How can we analyse how the world works, how it has evolved historically and how change is taking place? Broadly speaking, that is what the Multi-Level Perspective (MLP) is trying to do. Formulated a little more correctly: how does a socio-technical system work, how has it developed historically, and how can we understand profound changes (also known as transitions) in a socio-technical system? The MLP shows that socio-technical systems (with the energy, mobility, and agri-food systems as typical examples) can be analysed as an interplay between a dominant regime, challenging niches and a contextual landscape'. (document: assignment)

In the guest lecture, the students receive more in-depth explanations and illustrations from a professor who works with the MLP in his research. They are also provided with four academic papers about the MLP as recommended readings. Furthermore, the students are instructed to collect specific information themselves:

> 'It is important that you have already collected and reviewed information before the first seminar. Search for 7 publications each (so 7 per student - 28 in total for a group of 4) that discuss one or more aspects of the socio-technical energy system. Please include one scientific article and 6 other publications ('publication' can be interpreted broadly, e.g. newspaper articles, blog articles, statistics, NGO reports, videos…). Read these beforehand, write down the references and list 6 keywords for each publication that describe the content. Submit this information (references + keywords) […] and bring the publications with you to the seminar'. (document: assignment)

The student groups are intensively supervised by one of the professors in completing the assignment:

> 'Sustainability transitions and the MLP will be explained in detail in the guest lecture on [date]. You will also be guided in this assignment during a seminar [date]) and receive targeted feedback (per group) on a draft version of the paper [date] '. (document: assignment)

They receive a detailed step-by-step plan for carrying out the analysis:

> 'The MLP analysis for this assignment is based on four research questions. Use it to build the paper. We have included some sub-questions for each part of the analysis. The answers to that will paint a comprehensive picture of the energy system. […]
>
> - Question 1: What are the characteristics of the current energy system regime? […]
> - Question 2: What are the main niches and their characteristics? […]
> - Question 3: What are important landscape elements for the energy system? […]
> - Question 4: Do you see signs of a transition to a more sustainable energy system? What are your expectations? […]' (document: assignment)

Again, they are thus encouraged to engage with WHY we have sustainability problems (question 1 and 3), WHERE we may want to go (question 2), and HOW we can change things (question 4). The assignment explicitly asks not only to pay attention to technical, scientific information, but also to other kinds of information:

> 'Use a combination of quantitative data (figures, statistics, tables…) and qualitative (descriptive) information. Focus not only on the 'hard' technological and infrastructural aspects but also on 'softer' socio-cultural aspects, social values, cultural preferences, etc. (see Glossary)' (document: assignment)

Also the sub-questions in the step-by-step plan invite the students to pay attention to various types of knowledge and information. Some questions are focused on uncovering the effects of problems (WHAT), for example: 'What are the major problems the regime is grappling with?' Other questions gauge for (root) causes (WHY) and do this, in accordance with the course's

ambitions, by paying attention to both technical and non-technical aspects, for example: 'Which technologies dominate?'; 'What infrastructure does the regime support?'; 'What about consumers and their preferences?'; 'Which social values and cultural preferences give direction to the regime?'; and 'What are the main policy measures?' Still other questions focus on ways in which societal change is brought about and strategies that can be used to achieve this (HOW), for example: 'What are [niches] building on, what are the driving forces behind them? E.g. actors active in it, new business models, emerging consumer markets, changing social values, science that supports them…?'; or 'What are important societal trends that put pressure on the regime: political, economic, technological, ecological, cultural? […] Are those trends/events stimulating niches? If so, for which niches and in what way?' Finally, there are also questions that encourage students to pay attention to alternative visions for the future (WHERE), for example: 'In what different ways do these niches try to form an alternative to the regime and how?'; and 'What are your expectations with regard to a transition to a more sustainable system? What could such a new, more sustainable regime look like? What changes do you expect? Why?'

Analysis of the papers written by the students shows that, indeed, attention is paid to more than purely technical knowledge about sustainability transitions. Although the students place a lot of emphasis on technological niches (e.g. precision agriculture, GMOs, vertical farming, AI, 3 D-printed food, purifying wastewater using nanotechnology, desalination of seawater, hydrogen, CCU, Thorium power plants) compared to social niches (e.g. car-sharing, energy cooperatives, group purchasing, short food supply chain), we observe that they also have an eye for topics such as the unequal distribution of wealth, international cooperation, awareness, the role of the media, citizen movements, etc.

These papers can be considered, besides an educational activity/end in itself, as a preparation for a subsequent activity that we will further analyse below when we focus on teachers' actions in the performance. After writing their papers, the students have to present their analyses to fellow students and discuss these with each other during seminars. For this, seminar groups are formed by bringing together three groups of students who collaborated on three different papers, i.e. who studied different socio-technical systems. In this way, they can read and hear about various technologies and societal systems through each other's work. The students have to read the other papers in advance and prepare questions for their fellow students. Each seminar is supervised by one of the teachers. The students get 20 minutes time for the presentation, followed by more than half an hour of discussion and a short break between the groups.

4.2. Performing the teaching practice

We observed a seminar in which three groups of students present their paper and discuss it with each other. The papers deal with analyses of the energy system, the water system, and the agri-food system in line with the students' technical designs (respectively a wind turbine, an urban garden installation, and an energy-efficient cold store for a food distribution centre). Each discussion starts with questions that the students in the other groups have prepared after reading the paper.

In what follows, we analyse three excerpts of the observation with the help of Practical Epistemology Analysis and Teacher Move Analysis[5]. Each of them reveals a different way in which the teacher's intervention in the performance affects the students' learning, which we summarise in Table 2 at the end of this section.

4.2.1. Excerpt 1: a sustainable future for mobility?

The excerpt starts with a question from Student B to her/his fellow students that introduces a gap which, as we will see, is not immediately bridged. Both the gap (question) and the subsequently constructed relations focus strongly on technical aspects of the topic discussed. The 'future of mobility' (WHERE do we want to go?) is linked to technological solutions (HOW do we change things?), namely the electric car and hydrogen:

1. *Student B: How do you see the future of mobility? Do you think that electric cars will be the solution, I mean with batteries, or do you rather look at hydrogen or how do you see that exactly? …*
2. *Student F: Yes, if I can speak for a moment. In my opinion, electric cars have the major disadvantage that battery production is itself very polluting because it uses precious metals, yes, rare metals such as cobalt that is mined in Africa. So yes, the production is one thing but also the recycling of batteries, to my knowledge there is no solution for that yet. If that were the case, it would of course be better in terms of CO_2 emissions. And for electric hydrogen cars you mentioned that H_2 has a low energy intensity [Student D nods]. So it can be generated with sustainable electricity, but then the storage. And then I think of the condensation and the cooling of H_2, which is very energy-consuming, so that the added value is ultimately somewhat cancelled out.*
3. *Student B: Yes, that's the big problem with hydrogen anyway. You have that cycle efficiency of electricity-hydrogen-electricity. In the conversion of electricity to hydrogen we have an efficiency of about 75. If you then look at the storage thereof, i.e. pressurisation and so on, cooling, we speak of 20% loss and then in the next conversion from hydrogen to electricity we lose another 55%. So that is certainly the big disadvantage and in my view also the main reason why that hydrogen technology has not yet broken through. The efficiency is just too low. And okay, there is a lot of research going on, for example into fuel cells that become more efficient and so on, but there you also have the disadvantage, in those fuel cells, okay, most of them use platinum, very expensive, scarce, yeah, is it then a sustainable solution? But I think in that regard there is simply no ideal way to generate energy right now. Wind turbines have disadvantages, tidal power plants have disadvantages. I think there is no ideal solution at the moment. And I see that Student K or Student T want to speak, so I will stop here then.*
4. *Student K: Uh, yeah, it was actually to go into what you just said. I think that it is actually difficult for the entire energy system to find THE sustainable solution, including in terms of mobility, and that we should therefore weigh up all the options against each other and then look at what we can do and, above all, experiment until there might be a new, even better solution. But I think it is especially very difficult to be able to achieve that, to find THE sustainable solution.*

Student F suggests a number of disadvantages of the proposed technologies. In PEA terms, s/he creates relationships between what Student B introduced and what s/he already knows: the polluting production of batteries, the lack of technological solutions for recycling rare materials contained in it, and the low energy intensity of hydrogen. Student B agrees and brings in additional knowledge that confirms the reasoning (privileging) initiated by Student F. S/he arrives at the conclusion that there is no ideal, sustainable solution at the moment. Student K also agrees. The encounters we observe are encounters between the different students, each bringing a lot of previously acquired knowledge into the conversation. In spite of this, however, the gap is not bridged. The discussion continues as follows:

1. ***Teacher: [name Student T]?***
2. *Student T: Uh yes, maybe to give a possibility for a more sustainable energy system it might be an option to look at better public transport infrastructure [Student D nods]. I am thinking, for example, of trains that also run on electricity. And then perhaps also to look at how to internationalise that a bit more. For example, for people who travel abroad, that they may then be able to take the train a little more easily than, for example, an emitting plane.*

With this intervention, Student T, building on Student K's remark that we should experiment with 'new, even better solutions', brings a new element into the discussion: the possibility of making the energy system more sustainable by using public transport. This is in line with one of the objectives that the lecturers have in mind, namely that 'the students have insight in and

are able to illustrate how (sustainable) technologies are embedded in socio-technical systems and how a sustainability transition depends on systemic changes' (see 4.1.1). It also reflects a broader view of sustainability than solely a focus on new technological niches as ways for HOW to change things by also taking into account aspects such as infrastructures and consumer preferences: elements that the students had to pay attention to in their description of the current regime (see 4.1.2). The teacher wants to respond to this, but sees that Student D wants to do the same and gives the floor to her/him:

1. ***Teacher: [name Student T]… [to Student D] Oh sorry, just respond***
2. *Student D: No no, I thought, [name of Student B] we had read something about hydrogen and vehicles, that it might also be more interesting with larger vehicles such as buses and so on. So that's why I find it interesting that you actually start talking about public transport, because hydrogen could possibly be a solution there, for example. But that is of course the part of the niche, so [name of Student B] knows more about that, but I just want to add that.*

Here we see that this student takes into account (includes in the privileging) what Student T has just brought in ('I find it interesting') and is building on that by relating the possibilities of public transport back to hydrogen technology. S/he does this by referring to something they read in preparation of their group work (paper). In this way, Student B, who 'knows more about this', is also involved in the discussion:

1. *Student B: Yes, of course, if we look at, for example, who is interested in hydrogen, then, in Belgium, [name bus company] is doing pilot projects, [name supermarket chain] also has many vehicles and their forklift trucks, for example, they already have a few hydrogen-powered ones. So I think public transport can also be made more sustainable. Not only the passenger car because, in my opinion, everything such as carpooling and so on should be promoted even more, even if people may not like to do that, but I think that is THE direction to go more sustainable. It is not only technology that needs to change, but also thoughts and practices.*
2. *Student X: Yes, I think so too.*

Through the relationships s/he establishes, the students find a way out of the gap in which they were stuck: public transport can be made more sustainable and this is seen as 'the direction to go more sustainable'. The student explicitly articulates here a broader-than-technological view on WHERE to go and HOW to change things, just as the teachers had in mind (see 4.1.1): according to her/him it is also about 'thoughts and practices' that need to change. The teacher, who has not yet made any substantive input, intervenes with what we call a 'generalising move':

1. ***Teacher: Yes, I now hear a number of people say that we should actually reorganise as a society…?***
2. *Student B: In a way, I think it certainly is. If we look at the past, there were no cars, then a few, and now, yes, if you look at the streets the only thing you will see are cars with one person in it. I think that should be different if we want to create a sustainable system.*

Through this intervention, the students come to a conclusion about WHERE to go and HOW to change things on a more general level, namely that we must, 'in a way', 'reorganise as a society'. The mere focus on technological solution strategies at the start of the conversation evolves throughout the discussion to also paying attention to other aspects. We see that this is made possible by several factors. Students make use of knowledge and insights they have acquired during (the research work for) writing their paper (see line 8 above: 'we had read something') where, as argued (see 4.1.2) they pay a lot of attention to technological niches and solution strategies, but also address non-technological aspects. We also observe in the seminars that they learn from each other, by building on (in PEA terms: creating relations with) the input

of others (line 3, 4, 6, 8, 9). This ties in with the scripting of this course, in which the students are expected to make an active contribution during the seminars and discussions (see 4.1.1). It is also made possible by providing sufficient time in the staging of this seminar activity (see 4.1.2) to give the discussions a certain depth and by asking the students to read the papers of the other groups beforehand. The rather reserved attitude of the teacher, who first lets students have their say before intervening her/himself (line 5, 7), also contributes to this. While the gap was not immediately overcome in the beginning, we see that they eventually discover opportunities for making the mobility system more sustainable. Thanks to the specific way of preparing the lessons and assignments (see 4.1), the teacher does in this case not have to intervene that much at the time of this discussion (the performance). S/he can limit her/himself to the generalising move (line 11) as the scripting and staging 'have done their job' as intended. In what follows, however, we see that this is not always the case and that a teacher, in the performance, regularly has to intervene, remediate, and make adjustments in the actual implementation of the prepared lessons/activities either by redirecting the students' attention to other areas of knowledge (see 4.2.2 Excerpt 2) or by bringing in – *ad hoc*, in the moment itself – specific knowledge her/himself (see 4.2.3 Excerpt 3).

4.2.2. Excerpt 2: Land for food production

Here, students discuss the challenge of producing enough food for a growing population. Student F states that technological progress will be essential for HOW to change things, to which Student L responds by suggesting that different types of food production require different amounts of land:

1. *Student F: In any case, we are going to have to produce more densely and with far fewer resources, as has already been said for the water system. Flanders does not have that much water. More people will have to be fed with less and that will require technological advances and perhaps those technological advances will allow a new way of farming to emerge in large vertical farming or precision agriculture. That that type of farmer will increase more and that the classic type of farmer will decrease more.*
2. *Student L: I would still like to add that if you grow a beef, a lot of the crops you grow go to animal feed. While if a switch is made to poultry, and more simply direct vegetable food, a larger part of the agriculture on that land will be used directly, without an intermediate step, so that less will be farmed in order to be able to feed the same number of people.*

The teacher builds on this input from Student L by linking the issue of limited land s/he mentioned to the societal choice about what we should use the limited amount of available land for, thus addressing the areas of knowledge WHERE we want to go and HOW to change things:

1. ***Teacher: Yes, Student L, you mention something. We only have a limited amount of land that we can use. We are going to have to choose. Wouldn't we use our land more for agriculture and less for habitation, for example?***
2. *Student L: Yes, I also think, we have cited the example of vertical agriculture because we actually have a very big problem that there are certainly a lot of buildings and urbanisation in Flanders, so I think maybe if we could elaborate on that that will also offer a solution to that problem.*

After this response from Student L, who does not question the choice to use a lot of land for buildings in Flanders and proposes, again, a technical solution with 'vertical agriculture', the teacher intervenes again. We see in line 5 below that the reaction of the student (line 4) does not go in the direction s/he intended with her/his intervention (line 3). S/he repeats her/his reorienting move that focuses the students' attention on the possibility of alternative policy choices – and thus diverts it away from the focus on technological innovation (line 6, 7):

1. ***Teacher: Isn't it easier to clear land? Get the houses off that land. Because in the past we simply parcelled out agricultural land into residential areas. Shouldn't we just start doing that in reverse?***
2. *Student M: I do think that what they are doing, or were doing now, is the 'concrete stop'[6]. That can offer a solution. Maybe people who live there now are not taking them out of their homes. That seems a bit drastic to me. But it certainly prevents parcelling on land that can be used as agricultural land.*
3. *Student L: Yes, I think so too. I think it will be very difficult to get people who already live there out of there. But even further parcelling, yes, will only cause even more problems, not only on our level [the agri-food system], but also, for example, for the second presentation with water. Even more parcelling will ensure that even less water can penetrate into our soil. So yes, I think that with the concrete stop there would already be an important step for us.*

The responses of Student M and Student L reveal that they are now indeed also considering policy measures ('the concrete stop') and thus more varied knowledge about strategies for HOW to make change: the focus is shifting from purely technological solutions to policy measures as well.

4.2.3. Excerpt 3: Thorium nuclear power plants

In the example above, we see how the teacher's moves allow the students to use knowledge that they have already acquired beforehand, perhaps through the research work for their paper. They are already aware of the government decision to stop using open space as building land and some possible advantages and disadvantages of it. However, this is not always the case. In the excerpt below, we analyse an example in which the teacher not only intervenes with 'reorienting moves' but also has to perform 'adding moves' in order to provide the necessary knowledge *ad hoc*, as the conversation takes place.

We observed a discussion starting with a question from the teacher about Thorium nuclear power plants that are described by this group of students as a niche that could possibly play a role in making the energy system more sustainable. The teacher thus raises a gap for the students to bridge: is this the direction WHERE we want to go?

1. ***Teacher: To what extent is that [Thorium nuclear power stations] a sustainable solution?***
2. *Student B: Yes, if you look at CO_2 emissions, for example, it's not that bad. And then you also have the big problem with the nuclear power plants that we currently have: the nuclear waste. That is much less with Thorium. Some sources even claim that that is simply used up in the plant itself, so that you are not left with any nuclear waste. So in that respect it is a big difference in our opinion compared to nuclear power plants. For the time being, the nuclear power plant is in my opinion one of the most sustainable solutions, except for the problem of waste. Because if we look at, for example, wind turbines, then you are still left with the composite blades and all the sources I read say that almost everything just goes to the landfill. That is also not really sustainable, and then you also have the problem of electricity storage.*
3. *Student D: So [name of Student B], may I add something to that? You say, you have the problem of waste, but Uranium, there is also a limited supply of Uranium, for example and I don't know exactly how that is in the case of Thorium, but I also think, an important reason that it is not in the sustainable system, it's also that your stock is finite, isn't it.*
4. *Student B: Thorium is also very present in the Earth's crust.*
5. *Student D: Yes? Okay, that is possible.*

Student B argues that these power stations are indeed a sustainable solution, according to her/him but Student D does not automatically accept this (line 3). S/he wonders whether the raw material, Thorium, is sufficiently available. The gap lingers. Student B answers the in the affirmative, after which the discussion seems to be closed for Student D (line 5). Then, however, the teacher intervenes with a reorienting move (line 6):

1. ***Teacher: But do you know in which regions?***
2. *Student B: Uh… I'm going to have to be honest there that I don't know that right away. The only thing I have read is that it is present in large quantities on earth.*
3. ***Teacher: Yes.***
4. *Student B: But, yes, good point: Do we want to depend on the import of Thorium? That is of course a discussion in itself, I think.*

This intervention redirects the students' attention from the mere availability of Thorium stocks to their geographic location. Student B indicates on the one hand that this is indeed something that deserves attention ('good point'), but at the same time that s/he has no knowledge of this geographic issue (line 9). The gap lingers and the teacher performs an adding move:

1. ***Teacher: Yes, hence my question. I will answer you: it is mainly, uh, in large mountain ranges. And there is a very large mountain range in China. So coincidentally, most of the Thorium is in China. Bit of bad luck, huh. And there is also a bit in Africa, where there is also a lot of Uranium. And, who has the most economic impact there at the moment? Ts, China. [laughs] Anyway, that's geopolitics isn't it. But that's why my question was how sustainable is that. If you look, it's a finite fuel, too. It's not forever.***
2. *[Student D nods]*

'Geopolitics' thus becomes something that is taken into account (i.e. that is included in the ongoing privileging) as relevant knowledge about alternatives and visions (WHERE do we want to go?). In the remainder of the discussion, the teacher makes other adding moves (line 13, 15) that, for example, bring the antisocial nature of mining – and thus also social aspects of the effects of sustainability problems (WHAT is the problem?) – to the students' attention:

1. *Student D: And besides, you also have transport, well, transport that is not sustainable, huh.*
2. ***Teacher: And the mining that is not sustainable.***
3. *Student D: Yes! I even read that it is very polluting.*
4. ***Teacher: Yes, and also very antisocial huh. All the mining we have on Earth is done by people in a weak situation.***
5. *Student D: Yes…*

The reorienting moves and adding moves of the teacher in this performance thus make it possible to provide the students with more diverse knowledge (domains) and to stimulate them to further explore these various aspects. As such, they contribute to the scripted purpose of the teachers of this course (see 4.1.1) and were – like the reorienting moves in Excerpt 2 – a remediating intervention to (re-)stage the desired scene and task during the performance.

The identified teacher moves in the analysed excerpts are summarised in Table 2.

5. Discussion and conclusion

Our analysis presented above reveals that the teachers of the studied course succeeded in providing their students with a wide landscape of action-oriented knowledge as described by Jensen (2002, 2004): knowledge about the effects and root causes of sustainability problems

Table 2. Overview of identified teacher moves, definitions, and examples.

Identified move	Definition	Example
Generalising move	Type of 'deepening move' that influences students' learning by adding an object/phenomenon to be used in an on-going inquiry	'Yes, I now hear a number of people say that we should actually reorganise as a society…?'
Reorienting move	Type of 'directing move' that affect the direction of students' learning by changing the pathway of inquiry	'But do you know in which regions [Thorium is available in the Earth's crust]?'
Adding move	Move that influences students' learning by adding an object/phenomenon to be used in an on-going inquiry	'And the mining that is not sustainable'.

as well as about alternative visions for the future and strategies to bring about change. Furthermore, also *within* each of these four domains, the students were invited and encouraged to explore various types of knowledge. They acquired knowledge about ecological but also about social and economic effects of sustainability problems. They addressed a wide range of root causes: political, cultural, economic, etc. The strategies for change brought to their attention involved both technological and non-technological strategies. And also with regard to visions for the future, they were urged, as future engineers, to explore not only innovative technologies but also alternative policies, new consumer preferences, etc.

We also showed how doing so required specific didactical work, both in the preparation of lessons and in their implementation. Our analytical approach, focused on investigating the dramaturgy of teaching and its influence on students' evolving meaning-making and learning, thus allowed us to progress insight into *how to teach* a wide and varied landscape of action-oriented knowledge – the key question of this article. The combination of PEA and TMA made it possible, as explained above, to reveal in detail how exactly teachers' choices and actions have an observable influence on what and how students learn, i.e. on the encounters taking place, the gaps that emerge, and the relations that are created in order to bridge these and, thus, on 'the making of meaning' and, hence, learning outcomes. As argued above, we did not evaluate whether and to what extent the students achieved predetermined learning outcomes, neither do we make claims about, for example, long-term internalisation of knowledge. Rather, we approached learning as evolving meaning-making that results in (starting to) master a relevant, selective attentiveness and functional ways of reasoning and acting (see Östman, Van Poeck, and Öhman 2019a for an in-depth explanation). By doing so, and especially by focusing on the didactical work of teaching, the presented approach makes it possible to complement the existing research on action competence in ESE such as theoretical accounts of the concept (Jensen and Schnack 1997; Mogensen and Schnack 2010) and the growing body of literature on measuring action competence in terms of prespecified outcomes (Olsson et al. 2020; Sass et al. 2021, 2022) and studying the effectiveness of educational practices in achieving this (Olsson, Gericke, and Boeve-de Pauw 2022; Finnegan 2022). It does so by offering researchers theoretical and analytical tools to open-up the black box of teaching and learning action competence – something that, as of yet, largely remains a blind spot in ESE research.

By analysing both the teachers' preparatory work of scripting and staging a setting, and their interventions in the performance (i.e. their teacher moves), we were able to identify some crucial elements that, in this studied case, made it possible for the students to broaden their landscape of action-oriented knowledge. In the preparatory scripting and staging, decisive aspects were both related to the content offered and to the organisation of the setting. As to the former, the choice for providing the students with a framework that helps understanding how societal transformation can take shape (i.e. the Multi-Level Perspective in sustainability transitions) contributed to acquiring knowledge about alternatives and visions and about strategies for change – two areas of knowledge that often get too little attention (Jensen 2002, 2004)[7]. As to the organisation of the course's setting, several aspects proved to be important. Asking the students to engage in depth and detail with the offered content by

writing the papers not only allowed them to gain action-oriented knowledge on the specific sustainability problems and socio-technical system addressed by their subgroup, but also to be prepared for the subsequent seminars. They were well-equipped for a classroom discussion with peers through the preparatory readings and analyses for their own papers, but also through the task of reading the other papers in advance and preparing questions for their fellow students. As our PEA, and in particular the relations created across the input of different students (see Appendix), reveals, this brought about important opportunities to learn from each other and to widen their scope of knowledge beyond the specificity of their own assignment. This was also strengthened by the choice to assemble the seminar groups so that subgroups of students with different paper assignments were able to interact. A crucial element was also that plenty of time was taken for the discussions. This created increased opportunities for the students to learn from each other, and for the teacher to carefully govern the students' attentiveness and activities during the seminar. As such, our analysis of the performance revealed how crucial it was to stage a setting in which a teacher was continuously present during the students' discussions. We noted that well-considered scripting and staging in the preparation of lessons is very important. As illustrated by Excerpt 1, it can lead to letting students explore and develop a rich and diverse range of knowledge. However, Excerpts 2 and 3 also show the vital importance of interventions by the teacher in the actual implementation of the lesson, *ad hoc* during the performance. We observed that the added value of remediating the staging in order to realise the scripted purposes requires continuous attentiveness to assess whether the on-going learning process evolves towards the formulated purposes (see reorienting and generalising moves), as well as substantial familiarity with the subject content (see adding moves). This could only be realised thanks to the availability of a sufficient number of well-prepared teachers, which made it possible for them to supervise all the discussions in the seminars instead of letting the students discuss among themselves, trusting that the preparatory scripting and staging would automatically 'do their job'. To make this possible, education policy faces the challenge to overcome obstacles related to shortage of teachers and insufficient time for intensive supervision of small groups of students, especially in (Belgian) higher education (Deleye, Van Poeck, and Block 2019).

Our findings show that teaching action-oriented knowledge brings about didactical challenges for teachers. It involves the ability to shape students' experiences through the environment offered to them (Dewey 1938 – see above 2.2) and, thus, requires a great deal of pedagogical content knowledge (Brandt et al. 2022). Larsen (1998, 22), cited by Jensen (2002, 329), also points to the importance of mastering subject content knowledge for teachers who work in dialogue with students as active partners. The professional experienced teacher, he argues, must be 'in natural control of the substance […] That means that the content substance is controlled at a level such that it becomes an integral part of the teacher's personality, so [they do] not need to use attention and resources on the professional side but can concentrate all [their] energy on choreographing the educational process'. Our case study shows in particular how didactic knowledge and subject content knowledge cannot be approached separately but, in practice, emerge as being very entangled and, thus, should be approached as such in training and capacity building of (university) teachers. The context of sustainability problems that are often very complex and multi-faceted makes this particularly demanding and may require collaboration across disciplines and subjects, as we also observed in the studied course where the engineering teachers were inspired and assisted by colleagues with a social sciences background.

To end this article, let us reflect on the limitations of the presented case study and formulate some related pathways for future research on how to teach action competence in ESE. First, it is important to realise that, as indicated, we conducted this case study mainly with the aim to illustrate and assess the presented analytical approach. As such, it is largely explorative and does not claim to provide a full answer to the question how to teach action-oriented knowledge, nor does it offer a systematic insight into the black-box of teaching and learning processes involved. Making this possible will require large-scale follow-up research that applies the analytical approach

to multiple, diverse settings and identifies patterns as to what enables or constrains fruitful learning in view of action competence and what this requires in terms of teachers' didactical work and capabilities. Particularly interesting in this respect is a comparative perspective that sheds light on similarities and differences between, for example, higher and compulsory education, or between diverse disciplines and multi-disciplinary settings. Another limitation is that, in this article, we focused on how to teach action-oriented *knowledge*. It is obvious, however, that action competence cannot be reduced to this cognitive dimension. As Almers (2013) has shown, the pathway to action competence, also involves aspects such as emotions that create a desire to change conditions, a core of deeply emotionally invested values and contrasting perspectives, action permeation, feeling confident and competent with what one can contribute, trust and faith from and in adults, and qualities like outsidership and belongingness. Action-oriented ESE can thus not be limited to teaching knowledge but also requires attention for other capabilities and needs. Therefore, we should move beyond a solely cognitive approach by including also ethical, political, practical, aesthetical, and existential dimensions. This has been argued repeatedly in relation to ESE in general (e.g. Van Poeck, Östman, and Öhman 2019) but it requires further, empirically grounded research in order to deepen our insight into how teachers can actually make that happen also in relation to fostering action competence. Our hope is that this article will inspire much-needed follow-up research on how to teach action competence in ESE and that the presented analytical approach can facilitate future empirical work on the topic.

Notes

1. We want to emphasise that these pursued outcomes should not be understood as being limited to prespecified ways of thinking or acting (e.g. factual knowledge, a correct way of understanding something). On the contrary, they can be as 'open-ended' as for example forming a personal opinion about something, creatively creating new practices, etc. Even in the latter case, however, teaching requires careful and well-considered planning and steering in the pursuit of helping the students achieve these aims.
2. Connecting didactic theory to dramaturgical frameworks in fact aligns well with the etymology of the word didactics (Didaktik) which stems from the Classical Greek group of words connected to 'didaskein' (didaktikos, didaskalia, didache, etc.) which means 'teaching', 'showing something', but also 'playing out a drama' (Hoppman 2007).
3. Following Ghent University's 'ethics decision tree', our study did not meet the criteria for being 'ethically sensitive' (e.g. no work with human body materials, animals, medical data, potentially harmful research activities, minors) and therefore did not require ethics approval by an ethics committee.
4. They developed this assignment in the context of an education innovation project at their university and were thereby largely inspired by an assignment developed by Thomas Block and Erik Paredis at Ghent University's Centre for Sustainable Development (Block, Paredis, and Van Poeck 2019).
5. Here we present and discuss excerpts of the conversations. In order to offer transparency about the analysis and illustrate it in detail, the Appendix presents a table on the PEA and TMA that includes an overview of the identified gaps and created relations, the effect on privileging as well as the identified teacher moves.
6. This is a decision from the government to stop using open space as building land by 2040.
7. Student evaluations in the university where we conducted our study, reveal that Jensen's observation in the early 2000s to a certain extent still holds true – although there are obviously also counter-examples. At the end of the Bachelor programmes, 76,1% of the students indicates that their education has "encouraged them to think about societal challenges" while only 56,9% states that it "taught them to think about ecologically sustainable and/or socially just solutions for problems". 19,6% (strongly) disagreed with the latter statement. After the Master programmes, respectively 70,1% and 54,1% agreed with the two statements. (source: https://ugiprd.ugent.be/)

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Appendix

Excerpt 1: A sustainable future for mobility?

Conversation	Gap - relations	Privileging	Teacher moves
Student B: How do you see the future of mobility? Do you think that electric cars will be the solution, I mean with batteries, or do you rather look at hydrogen or how do you see that exactly? …	Gap: How do you see the future of mobility? - electric cars the solution? - or rather hydrogen?		
Student F: Yes, if I can speak for a moment. In my opinion, electric cars have the major disadvantage that battery production is itself very polluting because it uses precious metals, yes, rare metals such as cobalt that is mined in Africa. So yes, the production is one thing but also the recycling of batteries, to my knowledge there is no solution for that yet. If that were the case, it would of course be better in terms of CO_2 emissions. And for electric hydrogen cars you mentioned that H_2 has a low energy intensity [Student D nods]. So it can be generated with sustainable electricity, but then the storage. And then I think of the condensation and the cooling of H_2, which is very energy-consuming, so that the added value is ultimately somewhat cancelled out.	[electric cars the solution? - or rather hydrogen?] - battery production is very polluting - no solution for recycling [electric cars the solution? - or rather hydrogen?] - H_2 has a low energy intensity - the added value is ultimately somewhat cancelled out	Inclusion of polluting battery production and recycling problems as disadvantages of electric cars Inclusion of low energy intensity as a disadvantage of hydrogen • Gap not bridged	
Student B: Yes, that's the big problem with hydrogen anyway. You have that cycle efficiency of electricity-hydrogen-electricity. In the conversion of electricity to hydrogen we have an efficiency of about 75. If you then look at the storage thereof, i.e. pressurisation and so on, cooling, we speak of 20% loss and then in the next conversion from hydrogen to electricity we lose another 55%. So that is certainly the big disadvantage and in my view also the main reason why that hydrogen technology has not yet broken through. The efficiency is just too low. And okay, there is a lot of research going on, for example into fuel cells that become more efficient and so on, but there you also have the disadvantage, in those fuel cells, okay, most of them use platinum, very expensive, scarce, yeah, is it then a sustainable solution? But I think in that regard there is simply no ideal way to generate energy right now. Wind turbines have disadvantages, tidal power plants have disadvantages. I think there is no ideal solution at the moment. And I see that Student K or Student T want to speak, so I will stop here then.	[H_2 has a low energy intensity] - that's the big problem with hydrogen - also the main reason why that hydrogen technology has not yet broken through [How do you see the future of mobility? - electric cars the solution? - or rather hydrogen?] - there is simply no ideal way to generate energy right now - there is no ideal solution at the moment	Confirmation of inclusion of low energy intensity as a disadvantage of hydrogen Inclusion of lack of ideal solution at the moment (lingering gap becomes explicit) • Gap not bridged	
Student K: Uh, yeah, it was actually to go into what you just said. I think that it is actually difficult for the entire energy system to find THE sustainable solution, including in terms of mobility, and that we should therefore weigh up all the options against each other and then look at what we can do and, above all, experiment until there might be a new, even better solution. But I think it is especially very difficult to be able to achieve that, to find THE sustainable solution.	[there is no ideal solution at the moment] - it is actually difficult for the entire energy system to find THE sustainable solution [there is no ideal solution at the moment] - we should weigh up all the options against each other and then look at what we can do [there is no ideal solution at the moment] – we should experiment until there might be a new, even better solution	Confirmation of inclusion of lack of ideal solution at the moment Inclusion of need to make choices Inclusion of need to experiment to find new, better solutions • Gap not bridged	

(*Continued*)

Conversation	Gap - relations	Privileging	Teacher moves
Teacher: [name Student T]?			
Student T: Uh yes, maybe to give a possibility for a more sustainable energy system it might be an option to look at better public transport infrastructure [Student D nods]. I am thinking, for example, of trains that also run on electricity. And then perhaps also to look at how to internationalise that a bit more. For example, for people who travel abroad, that they may then be able to take the train a little more easily than, for example, an emitting plane.	[we should experiment until there might be a new, even better solution] - yes [we should experiment until there might be a new, even better solution] - it might be an option to look at better public transport infrastructure	Confirmation of inclusion of need to experiment to find new, better solutions Inclusion of public transport as a possible option for a more sustainable system	
Teacher: [name Student T]… [to Student D] Oh sorry, just respond			
Student D: No no, I thought, [name of Student B] we had read something about hydrogen and vehicles, that it might also be more interesting with larger vehicles such as buses and so on. So that's why I find it interesting that you actually start talking about public transport, because hydrogen could possibly be a solution there, for example. But that is of course the part of the niche, so [name of Student B] knows more about that, but I just want to add that.	[it might be an option to look at better public transport infrastructure] - hydrogen might also be more interesting with larger vehicles such as buses - interesting that you actually start talking about public transport - hydrogen could possibly be a solution there	Confirmation of inclusion of public transport as a possible option for a more sustainable system Diminishing the importance of low energy intensity as a disadvantage of hydrogen by including the distinction between cars and larger vehicles	
Student B: Yes, of course, if we look at, for example, who is interested in hydrogen, then, in Belgium, [name bus company] is doing pilot projects, [name supermarket chain] also has many vehicles and their forklift trucks, for example, they already have a few hydrogen-powered ones. So I think public transport can also be made more sustainable. Not only the passenger car because, in my opinion, everything such as carpooling and so on should be promoted even more, even if people may not like to do that, but I think that is THE direction to go more sustainable. It is not only technology that needs to change, but also thoughts and practices.	[hydrogen might also be more interesting with larger vehicles such as buses] - yes, of course [it might be an option to look at better public transport infrastructure] - I think public transport can also be made more sustainable [How do you see the future of mobility?] - it is not only technology that needs to change, but also thoughts and practices - that is THE direction to go more sustainable	Confirmation of diminishing the importance of low energy intensity as a disadvantage of hydrogen by including the distinction between passenger cars and larger vehicles Confirmation of the inclusion of public transport as a possible option for a more sustainable system Inclusion of importance of thoughts and practices – not just technology – as important for sustainability Inclusion of the possibility of 'the direction' to a more sustainable system	
Student X: Yes, I think so too.			
Teacher: Yes, I now hear a number of people say that we should actually reorganise as a society…?			Generalising move
Student B: In a way, I think it certainly is. If we look at the past, there were no cars, then a few, and now, yes, if you look at the streets the only thing you will see are cars with one person in it. I think that should be different if we want to create a sustainable system.	[reorganise as a society] - in a way it certainly is - if we want to create a sustainable system	Inclusion of the need to reorganise society	

Excerpt 2: Land for food production

Conversation	Gap - relations	Privileging	Teacher moves
Student F: In any case, we are going to have to produce more densely and with far fewer resources, as has already been said for the water system. Flanders does not have that much water. More people will have to be fed with less and that will require technological advances and perhaps those technological advances will allow a new way of farming to emerge in large vertical farming or precision agriculture. That that type of farmer will increase more and that the classic type of farmer will decrease more.	we are going to have to produce more densely and with far fewer resources - more people will have to be fed with less - that will require technological advances	Inclusion of need to feed more people with fewer resources Inclusion of technological progress in response to resource constraints	
Student L: I would still like to add that if you grow a beef, a lot of the crops you grow go to animal feed. While if a switch is made to poultry, and more simply direct vegetable food, a larger part of the agriculture on that land will be used directly, without an intermediate step, so that less will be farmed in order to be able to feed the same number of people.	[more people will have to be fed with less] - if you grow a beef, a lot of the crops go to animal feed - while if a switch is made to poultry and direct vegetable food, less will be farmed in order to be able to feed the same number of people	Confirmation of inclusion of the need to feed more people with fewer resources and further clarification through inclusion of the problem of limited land Diminishing the importance of technological progress as (only) response to limited resources through inclusion of distinction between production of beef – poultry and plant-based food	
Teacher: Yes, Student L, you get something out of that. We only have a limited amount of land that we can use. We are going to have to choose. Wouldn't we use our land more for agriculture and less for habitation, for example?	[agriculture on that land] - we only have a limited amount of land that we can use - we are going to have to choose - use our land more for agriculture and less for habitation, for example	Confirmation of inclusion of problem of limited land Confirmation diminishing the importance of technological progress as the (only) answer to limited resources through inclusion of the need to make choices Inclusion of problem of habitation	Reorienting move
Student L: Yes, I also think, we have cited the example of vertical agriculture because we actually have a very big problem that there are certainly a lot of buildings and urbanisation in Flanders, so I think maybe if we could elaborate on that that will also offer a solution to that problem.	[we only have a limited amount of land that we can use - we are going to have to choose] - there are certainly a lot of buildings and urbanisation in Flanders - vertical agriculture - will also offer a solution to that problem	Confirmation of inclusion of problem of limited land Confirmation of inclusion problem of habitation Reaffirmation of inclusion of technological progress in response to resource constraints	
Teacher: Isn't it easier to clear land? Get the houses off that land. Because in the past we simply parcelled out agricultural land into residential areas. Shouldn't we just start doing that in reverse?	[vertical agriculture - will also offer a solution to that problem] - isn't it easier to clear land? - get the houses off that land	Questioning inclusion of technological progress in response to resource constraints Reaffirmation of inclusion problem of habitation Inclusion of the option to get houses off the land	Reorienting move
Student M: I do think that what they are doing, or were doing now, is the concrete stop. That can offer a solution. Maybe now people who live there are not taking them out of their homes. That seems a bit drastic to me. But it certainly prevents parcelling on land that can be used as agricultural land.	[isn't it easier to clear land?] - the concrete stop can offer a solution [get the houses off that land] - not taking people out of their homes - a bit drastic - concrete stop prevents parcelling on land that can be used as agricultural land	Confirmation of inclusion problem of habitation Inclusion of concrete stop policy measure as a possible solution Questioning the inclusion of the option to get houses off the land by inclusion of preventing further parcelling	
Student L: Yes, I think so too. I think it will be very difficult to get people who already live there out of there. But even further parcelling, yes, will only cause even more problems, not only on our level, but also, for example, for the second presentation with water. Even more parcelling will ensure that even less water can penetrate into our soil. So yes, I think that with the concrete stop there would already be an important step for us.	[not taking people out of their homes - a bit drastic] - I think so too - very difficult to get people who already live there out of there - the concrete stop would already be an important step [parcelling] - will only cause even more problems - also for water - more parcelling will ensure that even less water can penetrate into our soil	Confirmation of inclusion of concrete stop as a possible solution Inclusion of concrete stop policy measure as also important in the solution of water problems	

Excerpt 3: Thorium nuclear power plants

Conversation	Gap - relations	Privileging	Teacher moves
Teacher: To what extent is that [Thorium nuclear power stations] a sustainable solution?	Gap: Is Thorium nuclear power stations a sustainable solution?		
Student B: Yes, if you look at CO_2 emissions, for example, it's not that bad. And then you also have the big problem with the nuclear power plants that we currently have: the nuclear waste. That is much less with Thorium. Some sources even claim that that is simply used up in the plant itself, so that you are not left with any nuclear waste. So in that respect it is a big difference in our opinion compared to nuclear power plants. For the time being, the nuclear power plant is in my opinion one of the most sustainable solutions, except for the problem of waste. Because if we look at, for example, wind turbines, then you are still left with the composite blades and all the sources I read say that almost everything just goes to the landfill. That is also not really sustainable, and then you also have the problem of electricity storage.	[Is Thorium nuclear power stations a sustainable solution?] - yes - CO_2 emission is not that bad [Is Thorium nuclear power stations a sustainable solution?] - nuclear waste - much less with Thorium - some sources even claim that you are not left with any nuclear waste - for the time being one of the most sustainable solutions [Is Thorium nuclear power stations a sustainable solution?] - with wind turbines you still have the composite blades - goes to the landfill - that is also not really sustainable [Is Thorium nuclear power stations a sustainable solution?] - with wind turbines - you also have the problem of electricity storage	Inclusion of lower CO_2 emissions as an argument for why Thorium nuclear power plants are a sustainable solution Inclusion of less or no nuclear waste as an argument for why Thorium nuclear power plants are a sustainable solution Inclusion of composite blades as an argument for why wind energy is not really sustainable either Inclusion of storage as a problem in wind energy	
Student D: So [name of Student B], may I add something to that? You say, you have the problem of waste, but Uranium, there is also a limited supply of Uranium, for example and I don't know exactly how that is in the case of Thorium, but I also think, an important reason that it is not in the sustainable system, it's also that your stock is finite, isn't it.	[the big problem with the nuclear power stations that we currently have: the nuclear waste] - there is also a limited supply of Uranium - I don't know exactly how that is in the case of Thorium (gap) - but I think - an important reason that it is not in the sustainable system is that your stock is finite	Inclusion of finite stocks as a *possible* (gap) argument why Thorium nuclear power plants are not a sustainable solution	
Student B: Thorium is also very present in the Earth's crust.	[I don't know exactly how that is in the case of Thorium] - Thorium is very present in the Earth's crust	Exclusion finite supplies as an argument for why Thorium nuclear power plants are not a sustainable solution	
Student D: Yes? Okay, that is possible.	[Thorium is also very present in the Earth's crust] - okay, that is possible	• Gap is bridged	
Teacher: But do you know in which regions?	Gap: [Thorium is also very present in the Earth's crust] - but do you know in which regions?		Reorienting move
Student B: Uh… I'm going to have to be honest there that I don't know that right away. The only thing I have read is that it is present in large quantities on earth.	[but do you know in which regions?] - I don't know that right away	• Gap is not bridged	
Teacher: Yes.			
Student B: But, yes, good point: Do we want to depend on the import of Thorium? That is of course a discussion in itself, I think.	[but do you know in which regions?] - yes, good point: Do we want to depend on the import of Thorium?	Inclusion of geographic location of Thorium stocks as a relevant element to take into account	

(*Continued*)

Conversation	Gap - relations	Privileging	Teacher moves
Teacher: Yes, hence my question. I will answer you: it is mainly, uh, in large mountain ranges. And there is a very large mountain range in China. So coincidentally, most of the Thorium is in China. Bit of bad luck, huh. And there is also a bit in Africa, where there is also a lot of Uranium. And, who has the most economic impact there at the moment? Ts, China. [laughs] Anyway, that's geopolitics isn't it. But that's why my question was how sustainable is that. If you look, it's a finite fuel, too. It's not forever.	[yes, good point: Do we want to depend on the import of Thorium?] - hence my question [I don't know that right away] - I will answer you: it is mainly in large mountain ranges - most of the Thorium is in China - bit of bad luck - also a bit in Africa - who has the most economic impact there at the moment? China - that's geopolitics - that's why my question was how sustainable is that - it's a finite fuel, too	Confirmation of inclusion of geographic location of Thorium stocks as a relevant element to take into account Inclusion of geopolitics as a relevant element to take into account Inclusion of China's economic impact as a negative element Re-inclusion of finite stocks as an argument for why Thorium nuclear power plants are not a sustainable solution	Adding move
[Student D nods]	[it's a finite fuel, too] - nods	Confirmation of inclusion of finite stocks as an argument for why Thorium nuclear power plants are not a sustainable solution	
Student D: And besides, you also have transport, well, transport that is not sustainable, huh.	[it's a finite fuel, too] - also transport that is not sustainable	Inclusion of unsustainable transport as an argument for why Thorium nuclear power plants are not a sustainable solution	
Teacher: And the mining that is not sustainable.	[also transport that is not sustainable] - and the mining that is not sustainable	Inclusion of unsustainable mining as an argument for why Thorium nuclear power plants are not a sustainable solution	Adding move
Student D: Yes! I even read that it is very polluting.	[and the mining that is not sustainable] - Yes! - it is very polluting	Confirmation of inclusion of unsustainable mining as an argument for why Thorium nuclear power plants are not a sustainable solution	
Teacher: Yes, and also very antisocial huh. All the mining we have on Earth is done by people in a weak situation.	[it is very polluting] - and also very antisocial - all the mining is done by people in a weak situation	Inclusion of anti-social mining as an argument for why Thorium nuclear power plants are not a sustainable solution	Adding move
Student D: Yes…	[and also very antisocial] - yes	Confirmation of inclusion of anti-social mining as an argument for why Thorium nuclear power plants are not a sustainable solution	