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Towards an ecological approach to teacher professional development: how preservice biology teachers direct their learning routes in authentic classroom settings

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Development of preservice teacher agency: An ecological perspective

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Abstract

Teacher agency has received a great deal of attention in recent years. Current research into teacher agency based on sociocultural approaches provides insight into how agency comes about in interaction with the situation and how it develops over time. However, it still offers few concrete methods for supporting the development of agency in teachers. This study aimed first of all to use insights from ecological psychology to arrive at an integrative ecological approach to understanding and supporting teacher agency, particularly with respect to the methods and skills used needed to teach their subject. Next, we tested this approach in an empirical study with preservice biology teachers from whom data were gathered over a whole year on how their repertoire of teaching methods developed in relation to their multiple goals and possible actions (field of affordances). Our results show that all the participants developed in stages over time on the different dimensions of their subject-specific agency (content perspective, content type and educational learning process). For example, the content of the textbook was often taken as the starting point, after which the participants experimented with other variants. The participants stated at the time that they were better able to achieve their various goals. This study found that an integrative ecological approach was helpful for both understanding and developing teacher agency.

Keywords: ecological agency, teacher agency, affordances

5.1 Introduction

It is widely accepted that teachers have a central role to play in maintaining the quality of education, education reform and school development. Teachers are therefore increasingly expected to be able to independently drive their own actions and professional development. To facilitate this, it is important on the one hand to give teachers the autonomy to take decisions but they also have to be able and willing to use this autonomy in collaboration with others (Meirink, Oolbakkink-Marchand, and Admiraal, 2018). Against this background, education research has increasingly focused on teacher agency in recent years (Beijaard, 2009; Ketelaar, Beijaard, Boshuizen, and Den Brok, 2012; Eteläpelto, 2017; Priestley, Edwards, Priestley, and Miller, 2012; Toom, Pyhältö, and Rust, 2015; Orland-Barak, 2017).

Current research into teacher agency has mainly had a sociocultural orientation (for overviews see Eteläpelto, Vähäsantanen, Hökkä, and Paloniemi, 2013; Toom et al., 2015; Orland-Barak, 2017), and current approaches to teacher agency are characterised by a rejection of both complete autonomy for the teacher and complete determination by cultural and structural conditions. They have been replaced by a view which emphasises that agency is constantly formed in interaction with the environment. Teacher agency does not therefore refer to a property that a teacher possesses but to a capability that can come into being in interaction with the context (Biesta and Tedder, 2007; Eteläpelto, 2017). Following the concepts of agency developed by Emirbayer and Mische (1998), current approaches to teacher agency pay explicit attention to the time dimension. Teacher agency is always partly formed by the teacher's past experiences, is geared to future goals and always has to be accomplished in the here and now in a specific context with the time and resources available (Biesta and Tedder, 2007; Priestley et al., 2012; Eteläpelto, 2017). The following description is a definition of these characteristics of teacher agency (Priestley, Biesta and Robinson, 2015).

“(...) teachers achieve agency when they are able to choose between different options in any given situation and are able to judge which option is most desirable, in the light of the wider purposes of the practice in and through which they act. Agency is not present if there are no options for actions or if the teacher simply follows routinized patterns of habitual behaviour with no consideration of alternatives” (p. 141).

Teacher agency may concern their actions in the classroom, their relationships with colleagues in school and their actions directed at the wider environment outside school (Pappa, Moate, Ruohotie-Lyhty, and Eteläpelto, 2017). Development of teacher agency is a theme that runs through the whole career but it does need to start during teacher education (Orland-Barak, 2017). This paper focuses on the development of agency in preservice teachers in the classroom. After all, it is important first and foremost in the training context that teachers discover what options they have when they are planning their lessons and that they make progress in achieving their desired possibilities for action in the complex environment of classroom teaching. More specifically, we focus on the development of subject-specific agency in preservice biology teachers.

Current sociocultural approaches to teacher agency do give an overall picture of how agency comes into being in interaction with the situation and how it develops over time but they still offer relatively few concrete methods for supporting the development of teacher agency in the context of teacher education (Orland-Barak, 2017). Ecological approaches in psychology offer a guiding framework for this (Heft, 2012). Ecological psychology has a long tradition but has been marginalised for a long time; however, its value in both fundamental and applied research has been increasingly rediscovered in recent years (Heft, 2018; Flach and Voorhorst, 2016). In the ecological tradition, just as in the current sociocultural approaches, agency is understood to be the result of

an interaction between person and context and as something that takes place over time. However, ecological psychology elaborates how the deep structure of a context can both constrain and open up a person’s opportunities to act and how a person can discover and realise desired actions in purposeful interaction with that context. Ecological psychology has a number of research traditions that are potentially relevant for developing an ecological approach to understanding and supporting the development of teacher agency in general and the subject-specific agency of preservice teachers in particular. One research tradition, building on the work of Roger Barker, has already been developed for teaching (Doyle, 2015). However, it still lacks a synthesis of valuable insights from the other ecological research traditions and is therefore unable to translate them into an approach to understanding and supporting teacher agency.

Our research was therefore based on two questions. The first question was a theoretical one: What are the characteristics of an integrative ecological approach to understanding and supporting teacher agency? The second question concerned an explorative empirical translation and testing of this ecological approach for a specific aspect of agency with a specific target group: How does subject-specific agency develop in preservice biology teachers?

We start with a synthesis and translation of a number of research traditions within ecological psychology that aim to understand and support teacher agency in general and subject-specific agency in particular. We then go on to describe and account for the design and results of the explorative empirical study in which we used an integrative ecological approach in order to understand and support the development of subject-specific agency in preservice biology teachers. In the discussion section, we not only discuss the findings and limitations of our empirical study but we also compare the ecological approach presented here with the more prevalent sociocultural approach to agency and show how the two approaches complement each other.

5.2 An ecological approach to understanding and supporting teacher agency

5.2.1 Introduction

Ecological psychology is not a clear-cut movement in psychology but rather a designation for a number of largely complementary, psychological approaches in which the interaction between person and context, often referred to with the term ecology, is the key. The founding fathers of ecological psychology are Kurt Lewin and Egon Brunswik (Flach and Voorhorst, 2016; Heft, 2012). They in turn have inspired other psychologists who have initiated a variety of ecological approaches. Our synthesis aimed at understanding and promoting teacher agency focuses on five complementary ecological research programmes initiated by Barker (1968), Powers (1973), Gibson (1977), Simon (1996) and Vicente and Rasmussen (1990) respectively. The concept of 'affordances' has an important integrating role in this (Estany and Martínez, 2014). Box 1 presents brief definitions of the key concepts of our integrative ecological approach as applied to classroom teaching. The concepts 'affordance', 'field of affordances' and 'landscape of affordances' are borrowed from the Gibsonian tradition. The development of the landscape of affordances in a heuristic goal system comes from the work of Vicente and Rasmussen. The field of affordances as a complex heuristic goal system has been further developed in research initiated by Powers. The development of the concept of the 'class as landscape of affordances' stems from Barker's research tradition. The importance of innovating by recombining and/or adapting building blocks and the use of efficient procedures in so doing originates from the work of Simon (1996).

Each of these key concepts is briefly defined and the connections between them explained in Box 5.1, before each concept is explained in more detail. We conclude this introductory section with a discussion of what this means for understanding and promoting or developing subject-specific agency.

The key to the ecological approaches in psychology is the purposeful interaction between people and the possibilities for action offered by the environment. Purposeful possibilities for action are also referred to by the term affordances (Gibson, 1977). A chair, for example, offers the opportunity to sit down, a cup to drink, et cetera. Affordance is a relational concept which means that it not only presumes certain characteristics of the environment but also of the person operating in the environment. A chair of a certain height presumes a person of a certain height who can sit on it unaided. The whole body of affordances, organised in a heuristic goal system, that is available to a typical teacher in a typical class, is known as the landscape of affordances (Kiverstein, van Dijk

Affordance: A purposeful possibility for action that a class offers a teacher.

Landscape of affordances: The whole body of affordances, organised in a heuristic goal system, that is available to a typical teacher in a typical class.

Field of affordances: The whole body of affordances, organised in a heuristic goal system, that is relevant to a specific teacher in a specific class/specific classes.

Zone of affordable development: New possibilities for action that a teacher has not yet adopted in the existing field of affordances but which the teacher is able and willing to adopt. The teacher has efficient procedures for this and expects that the new possibilities for action will contribute to improving realisation of the goals of the existing field of affordances.

Combinatorial entrenchment: Step-by-step expansion of the field of affordances in the zone of affordable development by recombining and/or adapting existing teaching building blocks (in this case with respect to the subject-specific dimensions: (a) content perspective; (b) content type; and (c) educational learning process).

Subject-specific agency: The field of affordances of a specific teacher with respect to choices about the what and how of teaching the school subject and encompassing at least the dimensions: (a) content perspective; (b) content type; and (c) educational learning process.

Box 5.1 Key concepts of our integrative ecological approach, briefly defined as applied to class teaching

and Rietveld, 2021). For a specific teacher in a specific class, only certain affordances out of the whole landscape are relevant. This set of possibilities is known as the field of affordances (Kiverstein et al., 2021).

Both the landscape and the field of affordances contain a very large number of possibilities for action. This begs the question of how they can be represented in a clear and concise manner that encourages purposeful interaction with the environment. Vicente and Rasmussen (1990) have shown that affordances can be described for this purpose as a heuristic goal system and this can be illustrated with a very simple example. The first step of a stepladder allows you to step on to the ladder, the stepladder in turn allows you to climb up and this in turn allows you to change a light bulb for example. To describe complex landscapes and fields of affordances it is not possible to set out all of the specific possible actions but it is necessary to distinguish more abstract categories of possible actions in order to get a grip on the complexity.

Against this background, teacher agency can be defined as expanding the field of affordances within a landscape of affordances. Teachers who have a larger field of affordances at their disposal have more possibilities for action and are also able, if they so desire, to realise these possibilities in their complex contexts. If, in the context of teacher education, we wish to support teachers to expand their field of affordances, we will have to take account of the fact that these possibilities for action not only fit in the class context that every teacher has to work in (the landscape of affordances) but also has to fit in with and build on what an individual teacher wants and considers to be possible as reflected in his or her existing field of affordances. In other words, we have to bring the new possibilities for action into the zone of affordable development. We will show that the existing field of affordances can be expanded with new possibilities by recombining and making small adjustments to existing possibilities for action (Simon, 1996). This is known as combinatorial entrenchment (Wimsatt, 2014).

5.2.2 The class as a landscape of affordance

A class which is the usual environment in which teachers work, is not only a place where different teaching activities take place (Doyle, 2015). Researchers in the Barker tradition, who analyse the deep structures of contexts, have investigated the landscape of affordances that a class offers a teacher (Barker, 1968; Heft, 2012; Doyle, 2015). Although each class is different, the simple fact that a class teacher has to teach a group of students something and in order to do that requires the students' cooperation (order in the class) means that each teacher is dealing with the landscape of affordances in a heuristic goal system as summarised in Figure 5.1.

Students have to learn something in class otherwise no education is taking place. Order in class is a necessary condition for this, which means, to put it simply, that the students generally do what the teacher expects of them (top row in Figure 5.1). Besides learning and maintaining order, there are sometimes other goals that the teacher wants to achieve or is required by others to achieve. To make learning and keeping order possible, a number of conditions have to be met (middle row). Students have to be given

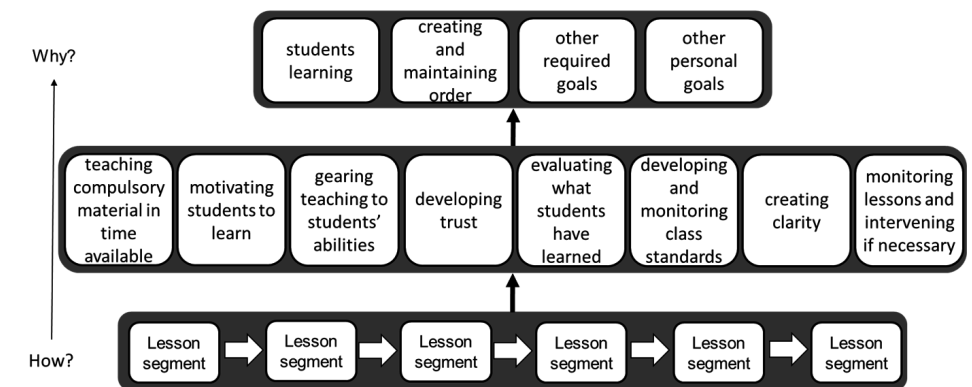


Figure 5.1 The landscape of affordances contains features that lessons have to satisfy according to many teachers (Doyle, 2015). On the bottom row are the lesson segments (lower order goals), followed by conditions for learning and maintaining order (middle order goals) which in turn are conditions for achieving the primary goals.

the opportunity to learn the compulsory material, they have to be willing and able to do this, there has to be a degree of mutual trust and the teacher has to be able to check from time to time whether the students have learned the material. In addition, agreements must be made about how people treat each other, it must be clear what is expected of the students, and the teacher must be able to monitor how the lesson is going and to intervene if required. All of these conditions have to be fulfilled at the same time for the most part through the content of the lesson that can be broken down into lesson segments (bottom row in Figure 5.1). Choices have to be made for each lesson segment about who does what, how and when and what is needed for that. Time and resources for both lesson preparation and teaching are limited.

The class is a complex landscape of affordances for teachers which allows teaching to take place but at the same time limits what teachers are able to do (Doyle, 2015). Against this background, it becomes clear why recurrent education reforms, such as guided discovery learning and differentiated teaching, have had a limited impact on teaching practice. Typically, these reforms put higher than usual cognitive demands on all of the students but this means that the ecological challenge for teachers is also increased. First, these ideals have to be converted into concrete lesson content and activities in a consecutive series of lesson segments for a particular target group and subject matter. Teachers very often lack the time, procedures and resources to design such lessons but, even if suitable tasks are to hand, this teaching style demands far more from the teachers in order to meet all of the conditions for learning and keeping order (middle row in Figure 5.1). This style of teaching requires students to be given more time to think; how then can the teacher ensure that the material required by the curriculum is covered in the time available? This challenging form of teaching also results in differences between students becoming more obvious to all of the class. How can the teacher ensure that in a class of 25-30 students all of the students remain motivated and

get the help they need? With challenging tasks it is often less clear what exactly is expected of the students. How then can the teacher ensure that clear expectations are still communicated despite this and that they can still monitor the process, make adjustments where necessary and ensure that each student stays engaged with the task?

This ecological analysis of a class as a landscape of affordances shows why many innovative approaches often have little impact on practice (Davis, Janssen, and Van Driel, 2016; Janssen, Westbroek, Doyle, and Van Driel, 2013). Teachers frequently reject a reform proposal on ecological grounds or adapt the proposal to fit in a way that turns out to be at the expense of the essence of the reform. This does not mean that proposals which try to make lessons more demanding and subject matter more relevant to all students have no chance of success, but it does mean that explicit account must be taken of the landscape of affordances of the classes in which teachers are working and the field of affordances of the individual teacher. We will now take a brief look at the field of affordances of individual teachers before discussing how reform proposals can be introduced into the zone of affordable development.

5.2.3 A field of affordances

An individual teacher develops his or her own field of affordances in interaction with the class. This field represents what the teacher deems to be important in relation to the type of possible actions to realise his or her goals. On the one hand, a field of affordances will partially reflect the landscape of affordances, as teachers are only able to teach if they are to some extent in tune with the requirements placed on them by that landscape. On the other hand, teachers have their own personal histories and ideals and they have to deal with demands placed on them by a specific school context. These influences also have repercussions for a field of affordances that represents what individual teachers consider to be desirable

and possible in their class. Just like a landscape of affordances, a field of affordances consists of a hierarchy of means and ends (Powers, 1973; Neal, Ballard, and Vancouver, 2017). At the top of the hierarchy are the goals that represent important values to a teacher and define his or her professional identity. The lower tiers contain goals that are the means by which to achieve the goals in the tier above. The bottom tier shows the lesson segments by which the teacher will try to realise the goals of the higher tiers. The field of affordances of an individual teacher functions as a filter that determines what the teacher considers to be relevant and desirable and indicates how they usually try to put this into practice. Teachers' decision-making and actions aim to reduce the gap between the observed situation and the achievable desired situation as specified in the field of affordances. The desired possible actions that are still expressed in abstract terms in the field will be specified for specific subject matter and a specific target group to the level of actions that are sufficiently concrete to be implemented.

Teachers will only be able and willing to expand their existing field of affordances by adding possible actions that are new to them if they (a) have efficient procedures by which to convert an educational ideal into relevant lesson segments given the limited time and resources available; and (b) judge that adopting these new possible actions will result in them being able to realise their existing field of affordances more effectively than when using their standard teaching methods. If both of these conditions are met, the reform proposal is said to be in the zone of affordable development.

5.2.4 Zone of affordable development

The points outlined above raise the question of how new possibilities for action can be brought into teachers' zone of affordable development in order to expand their ecological agency. A powerful approach to innovation that enables the two conditions set out above to be met has been developed in detail by Wimsatt (2014).

He calls this approach 'combinatorial entrenchment' because it involves step-by-step innovation by recombining and making small adjustments to what are for the most part existing building blocks. In this approach certain building blocks are increasingly combined with other components thereby acquiring an increasingly significant place in the field of affordances so that they become ever more deeply entrenched. This in turn opens up new development opportunities. Innovation by recombining existing building blocks not only saves time and resources because it builds on what is already there, working with tried-and-tested building blocks makes it easier for teachers to assess whether the proposed change would make a positive contribution to realising the higher goals or whether it would have an adverse effect. Finally, it is possible to develop a large repertoire with a small number of building blocks (Janssen and Van Berkel, 2015). This allows teachers to use a limited set of building blocks to discover new possibilities for action in a situation and thereby expand their field of affordances (Janssen and Van Berkel, 2015). We will illustrate the idea of combinatorial entrenchment with two examples in the field of subject-specific agency. First, we describe what we mean by subject-specific agency distinguishing three subject-specific dimensions. We will then illustrate working with building blocks with the aid of two of these dimensions.

Subject-specific agency concerns making choices about what is taught in a school subject and how. Two dimensions play an important role when teachers are making choices about what to teach: content perspective (e.g. whether they choose a medical or evolutionary perspective for biology lessons) and content type (e.g. whether the focus is on factual or conceptual knowledge). How the chosen subject matter is taught is in turn substantially dependent on choices made in relation to a third dimension: the design of the educational learning process. Building blocks can be distinguished for each of these dimensions.

Table 5.1 makes explicit the building blocks for content perspectives for biology teaching which can be used to clarify many possibilities relating to choice of subject material for biology lessons. This is illustrated with the topic of human skin. Different aspects of this subject emerge into the foreground from each building block allowing many potential tasks to be explored in a relatively short time (de Boer, Janssen, Van Driel, and Dam, 2019; Janssen and Van Berkel, 2015).

Table 5.1 Content perspectives allowing quick and efficient exploration of the curriculum potential for a biology topic, in this case human skin.

Content perspective	Generic question	Aspect/task
Structural and mechanical	How is it structured? How does it work?	What different layers can you find in the skin?
Functional	What is the function? What is its purpose?	What are the functions of the layers of the skin?
Environmental	What does it need in the environment?	Why does our skin wrinkle in the bath?
Developmental	How does it develop?	Is the skin of a baby just as old as the skin of an old man?
Evolutionary	How did it evolve?	How did our relatively hairless skin evolve? Parasites? Aquatic ape? To regulate temperature?
Medical	What can go wrong with it?	What has gone wrong in the case of various skin diseases such as psoriasis or eczema?
Technological	What can you do with it?	How deep does the needle have to penetrate the skin to make a tattoo permanent?
Ethical	What can you ethically do with it?	What is one of the most fundamental moral faults? Associating worth with skin colour.
Personal	What does it mean for you?	How does your skin define who you are?

Considering the third dimension of the educational learning process, a great variety of educational learning processes can be developed by recombining and adapting existing building blocks (Janssen and Van Berkel, 2015). An example of this process is shown in Figure 5.2, in which we show how a standard lesson plan (top row) can be converted into a lesson that starts with an interesting problem (whole task) (middle row) to create a differentiated lesson (bottom row), by reversing and selectively omitting four existing building blocks for educational learning processes.

This simple example illustrates a number of important aspects of innovation through combinatorial entrenchment. First, it makes clear that a great variety of new approaches can be realised by combining existing building blocks. It also shows that in this case

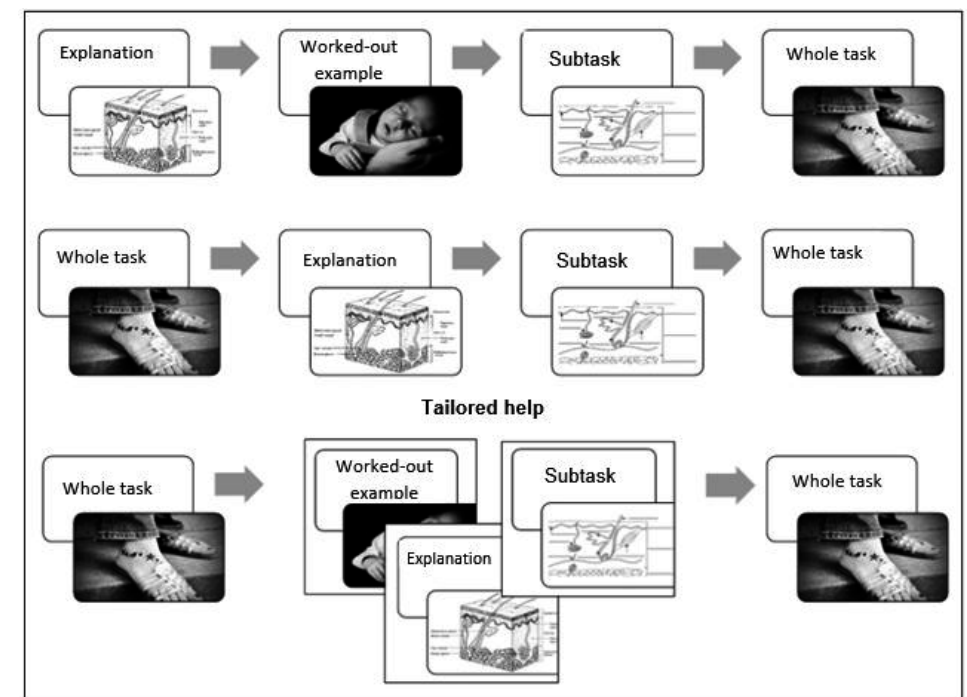


Figure 5.2 Innovation by recombining and adapting existing building blocks for an educational learning process, whereby a standard lesson plan (top row) about the skin is converted step-by-step into a differentiated lesson with the introduction of a whole task: How deep does the needle have to penetrate the skin to make a tattoo permanent?, followed by tailored help.

an interesting problem is given a more prominent position, it has become more deeply entrenched in the system. Where initially it forms the conclusion of the lesson which can sometimes be overlooked, in the subsequent steps it acquires an indispensable guiding role in the learning process and in continuing innovations. Innovation by recombining and adapting existing building blocks also provides teachers with the necessary efficient procedures to design and realise a practical new approach. Such procedures that make use of easily available and limited information are also known as fast and frugal heuristics. Finally, this example illustrates that this form of innovation potentially enables teachers to expand their field of affordances whilst achieving their existing goals just as well if not better than with their regular teaching approach. Against this background an ecological approach to subject-specific agency can be defined as the field of affordances of a specific teacher with respect to choices about what to teach in a school subject and how and containing at least the dimensions: (a) content perspective; (b) content type; and (c) educational learning process. An ecological approach to developing preservice teachers' subject-specific agency presumes step-by-step expansion of their field of affordances in the zone of affordable development by recombining and/or adapting existing building blocks relating at least to the three subject-specific dimensions.

This study comprised two parts: a theoretical part and an empirical part. The empirical part which follows applied the principles emerged from the recently presented integrative ecological approach for developing subject-specific agency outlined above to preservice biology teachers. Subject-specific agency was developed by the students as they participated in two consecutive study modules on teaching skills and methods during the one-year teacher training course at university. The participating preservice teachers did teaching placements during this year where they gave biology lessons in school. The integrative ecological approach for the development of agency described in the previous section

underpinned the organisation of both modules on teaching skills and methods. The empirical research attempted to answer the question: How does subject-specific agency develop in preservice biology teachers?

To try to answer this question we investigated how the field of affordances developed in the preservice biology teachers in terms of both building blocks on several dimensions and the heuristic goal system, looking at changes in the number of goals per participant and to what extent these were realised during the study.

5.3 Method

5.3.1 Participants and context

Twelve preservice biology teachers participated in this research. The participants constituted the whole cohort of the one-year course to obtain a master of science in teaching biology at a university in the Netherlands. Before embarking on the course, the students had already gained a master in biology or a biology-related subject. Throughout the whole training year, the students did teaching placements in a secondary school in parallel with the study modules they took at the education institute. They taught 7 hours a week at the school on average. They took two consecutive study modules on teaching skills and methods spread over the whole year and, as part of these modules, described how their subject-specific agency developed through their teaching of biology at their placement school.

5.3.2 Procedure

Teaching skills and methods concerns what is taught and how. What is taught depends in part on the content perspective and content type chosen. How this is taught is substantially dependent on the

educational learning process chosen. At the first three sessions of the first teaching skills and methods module at the beginning of the school year, building blocks for developing subject-specific agency were introduced and demonstrated for these three important dimensions: content perspective, content type, and educational learning process. The content building blocks allowed the participants to look at a biological topic from different perspectives and thereby uncover possible teaching materials and activities (see Table 5.1). The building blocks related to teaching and learning allowed them to recombine and adapt existing lesson segments to design diverse variants of an educational learning process (see Figure 5.2) (Janssen, Grossman, and Westbroek, 2015). This resulted in four types of 'whole-task-first' teaching approaches being distinguished alongside the standard lesson structure (explanation followed by subtasks and/or whole tasks). The whole-task-first approaches were: 1) a direct instruction model where a whole task is followed by the explanation; 2) a guided discovery model where, following the introduction to the whole task, the students set to work on it themselves with support from the teacher; 3) the master-apprentice model in which the teacher demonstrates how the whole task can be tackled first after which the students work on it themselves with reducing support (Janssen et al., 2015); and 4) the adaptive model where the teacher introduces the whole task but the students then decide for themselves how they want to tackle it. The students are given help to complete the whole task according to their needs. Finally, building blocks for content types were introduced borrowed from the knowledge dimension of the revised Bloom's taxonomy: factual knowledge, conceptual knowledge, procedural knowledge and metacognitive knowledge (Anderson et al., 2001). At the third session the participants constructed their field of affordances for a representative lesson plan with support from a laddering interview (Janssen et al., 2013). First, they were asked to write down on post-it notes what they do in a standard lesson and in what order (consecutive lesson segments). Next, they were asked for each

lesson segment why they thought this was important and to write this down on another post-it and then to join the two post-it notes with a line. They were repeatedly asked to say why they found each of their goals important until they reached their higher goals for which they were no longer able to give a reason. After that they were asked to indicate how satisfied they were with the achievement of the goals for all of the post-its (in the fields of affordances published here (Figures 5.3 and 5.4), a white background indicates that the participants were satisfied and a grey background that they were not yet satisfied) (see Janssen et al. (2013) for a more detailed description and explanation of this procedure).

After these introductory sessions, two routes could be distinguished: 1) all the participants attended a series of sessions on specific themes relating to teaching skills and methods and subject content; 2) the participants were invited to design their own development route by expanding their subject-specific agency step-by-step using the building blocks and building on their field of affordances. They were asked to formulate their resolution with respect to each extension of their repertoire and to draw up and explain their lesson plans. They were also asked to reflect on how each lesson had gone in practice, what they had learned from it and how this might result in a new plan. The participants had to describe their development in a subject-specific report at the end of both the first teaching skills and methods module (before the Christmas holiday) and the second module (before the summer holiday). The subject-specific reports for the two study modules contained a field of affordances; a description of their own personal development in the methods used and skills needed to teach their subject based on the subject-specific dimensions described above (building blocks for content perspective, educational learning process and content type); and elaborated lesson plans with accompanying reflections characterised by these dimensions. At the same time the participants marked each of their lessons for how satisfactory they had found it (from 0 being very low to 10 being very high)

giving a brief explanation for the mark they had given. The first report contained at least two lessons and the field of affordances produced during the third session, while the second report had to include at least three lessons and the field of affordances produced at the end of the second study module.

5.3.3 Data-gathering and analysis

To answer the second research question, the two subject-specific reports produced by each participant were described and analysed. The participants had described their own field of affordances and types of building blocks in these subject-specific reports. They had been given a demonstration in the teaching skills and methods modules on how to produce a heuristic goal system (as described in the Procedure section) and the building blocks had been introduced with examples and definitions before they had to use them to characterise their own lessons in their subject-specific reports.

The researchers first took all of the participants' characterisations of all of their lessons and put them into three separate tables in accordance with the three subject-specific dimensions (building blocks for content perspective, educational learning process and content type) (Tables 5.2, 5.3 and 5.4). Only in six situations where the participants had not characterised them did the first author do this. In these circumstances the characterisation was determined in consultation with the second author (who was also a teacher educator) and supplemented where necessary. Both researchers went through the lesson plans independently of each other and reached agreement on which type of building block for content perspective, educational learning process and content type had been used if the participants had not stated this, by looking for places where they had explicitly used the words pointing towards the dimensions.

In addition to characterising them according to the three dimensions, the participants also marked their lessons from 1 to 10

(1 very low to 10 very high). The marks that the participants had given each lesson were also put in a table (Table 5.5). The marks indicate what the participants thought about their own teaching experiments and give an idea of how satisfactory they had found their lessons. The characterisation of the three dimensions for each lesson together with the corresponding mark not only provided insight into the personal development of each participant on each of the dimensions, but also revealed similarities and differences in the development of subject-specific agency between the participants. This was revealed when we looked at whether the variation between the participants in their use of the different building blocks per dimension per lesson increased or whether they progressed to use more different building blocks thereby extending their repertoire.

Both fields of affordances of all the participants were analysed. The participants have made these fields of affordances themselves and put them in their subject-specific reports. We counted the total number of goals that each participant had in their first and second fields of affordances and also how many of these goals the participants had carried out to their own satisfaction. The participants indicated this with the aid of a colour system in the fields of affordances plus an explanation in the subject-specific reports. By counting the number of goals that the participants had made, we were able to make an absolute comparison between the number of goals in the two fields of affordances. We also counted how many goals were achieved per field of affordances per participant, enabling us to make both an absolute and a percentage comparison of the development of the participants' fields of affordances. It also allowed us to see how preservice teachers' satisfaction with their own success in reaching their goals developed over time. Where there were large differences in the total number of goals set between the two fields of affordances (whether increases or decreases), we looked at the explanation for this in the participant's subject-specific reports.

We used the two fields of affordances of each participant to map their development. The development of the fields of affordances of two of the participants are described in this paper. In Figures 5.3 and 5.4 we present the second field of affordances of these two participants, with the goals they still aimed to work on shaded grey and the goals that were new to their second field of affordance outlined in bold. We also describe how their stated goals could be traced back to their lesson plans and subsequent teaching experiments.

5.4 Results

This research examined how the subject-specific agency of preservice biology teachers developed and how this can be understood in conjunction with their fields of affordances. First, we describe the significant development routes for each subject-specific dimension of teacher agency. Next, we compare the participants' first and second fields of affordances with respect to the number of goals set and achieved. Finally, we present detailed portraits of two of the preservice teachers.

5.4.1 The first dimension of content perspective building blocks

We found that many participants continued to mainly use the content perspectives that were close to the textbook at first, usually the perspectives 'functional' and 'mechanical' (see Table 5.2 for a full summary). Only Jan took a different approach by starting with the environmental perspective. All of the participants then went on to vary their teaching by adding other content perspectives, with the medical and environmental perspectives being used the most. Jet had the most varied approach, she used four to six different perspectives in each of her lessons.

Table 5.2 Content-perspective building blocks per participant, per lesson with the number of building blocks used per lesson in brackets.

Teacher	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Lesson 7	Lesson 8
Anja	<i>a, b, c</i> (3)	<i>a, b, c, e, f</i> (5)	<i>a</i> (1)	<i>c</i> (1)	<i>c</i> (1)	<i>a, b</i> (2)	<i>a, b</i> (2)	<i>a, d</i> (2)
Stephan	<i>a</i> (1)	<i>b, c</i> (2)	<i>b, c</i> (2)	<i>c</i> (1)	<i>c</i> (1)	<i>c</i> (1)	<i>n.v.t.</i>	
Petra	<i>a, b</i> (2)	<i>a, b, c</i> (3)	<i>a, b</i> (2)	<i>a, b</i> (2)	<i>a, b</i> (2)	<i>a, b, c</i> (3)		
Vera	<i>a, b, g</i> (3)	<i>h</i> (1)	<i>a, b</i> (2)	<i>a, b</i> (2)	<i>a, b</i> (2)	<i>a, b</i> (2)		
Maaïke	<i>a, b</i> (2)	<i>a, f</i> (2)	<i>a</i> (1)	<i>a, c, d</i> (3)	<i>a, b</i> (2)	<i>a, b</i> (2)		
Martine	<i>a, b</i> (2)	<i>f</i> (1)	<i>a, b, f</i> (3)	<i>a, b, f</i> (3)	<i>a, f</i> (2)			
Patrick	<i>a, b, f</i> (3)	<i>a, b, f</i> (3)	<i>b</i> (1)	<i>a, f</i> (2)				
Sancho	<i>a, b</i> (2)	<i>a, b, c</i> (3)	<i>a, b, f</i> (3)	<i>a, b, f</i> (3)				
Bas	<i>a, f</i> (2)	<i>a, b</i> (2)	<i>b, f</i> (2)	<i>b, f</i> (2)	<i>b, f</i> (2)			
Jet	<i>a, b, f, i</i> (4)	<i>b, d, e, h, i</i> (5)	<i>a, b, c, d, e, i</i> (6)	<i>a, b, c, d, e, i</i> (6)	<i>a, b, c, d, i</i> (5)			
Jan	<i>c</i> (1)	<i>a, b</i> (2)	<i>a, b</i> (2)	<i>a, b</i> (2)	<i>a, b</i> (2)			
Tissa	<i>a, f</i> (2)	<i>a, f</i> (2)	<i>a, b, c</i> (3)	<i>a, h, i</i> (3)	<i>a, b</i> (2)			

Key: a = mechanical, b = functional, c = environmental, d = developmental, e = evolutionary, f = medical, g = technological, h = ethical, i = personal

5.4.2 The second dimension of content type building blocks

Table 5.3 shows that almost all of the participants started by using factual knowledge in their lessons and then branched out into conceptual knowledges. Stephan was the sole exception to this as he started his lesson using only conceptual knowledge. Five of the participants gradually incorporated procedural knowledge and metacognitive knowledge into their lessons. Three participants did not vary the type of knowledge they used during their course.

Table 5.3 Content type used per participant per lesson.

Teacher	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Lesson 7	Lesson 8
Anja	<i>o</i>	<i>o, p</i>	<i>r</i>	<i>p</i>	<i>o</i>	<i>o, p</i>	<i>o, p</i>	<i>o, r</i>
Stephan	<i>p</i>	<i>r</i>	<i>p</i>	<i>p</i>	<i>p</i>	<i>o, p</i>	<i>o, p, s</i>	
Petra	<i>o, p</i>	<i>o, p</i>	<i>o, s</i>	<i>o, p, s</i>	<i>o, s</i>	<i>o, p</i>		
Vera	<i>o, p</i>	<i>o, p</i>	<i>o, p, r</i>	<i>o, p, r, s</i>	<i>o, p, r, s</i>	<i>o, p, r, s</i>		
Maaïke	<i>o, p</i>	<i>o, p</i>	<i>o, p</i>	<i>o, p</i>	<i>o, p</i>	<i>o, p</i>		
Martine	<i>o, p</i>	<i>o, p</i>	<i>o, p</i>	<i>o, p</i>	<i>o, p</i>			
Patrick	<i>o, p, r</i>	<i>o, p, r</i>	<i>o, p</i>	<i>o, p</i>				
Sancho	<i>o, p</i>	<i>o, p</i>	<i>o, p</i>	<i>o, p</i>				
Bas	<i>o</i>	<i>o</i>	<i>o, p</i>	<i>o, p</i>	<i>o, p</i>			
Jet	<i>o, p, s</i>	<i>o, p, s</i>	<i>o, p, s</i>	<i>o, p, s</i>	<i>o, p, s</i>			
Jan	<i>o, p</i>	<i>p, r</i>	<i>o, p</i>	<i>o, p</i>	<i>o, p</i>			
Tissa	<i>o</i>	<i>o, s</i>	<i>o, p</i>	<i>o, p</i>	<i>o, p</i>			

Key: *o* = factual knowledge, *p* = conceptual knowledge, *r* = procedural knowledge, *s* = metacognitive knowledge

5.4.3 The third dimension of educational learning process building blocks

The fields of affordances that the participants produced in the third session of the first study module on teaching skills and methods show that all of them introduced new teaching material with an explanation. After that all of the participants attempted variants of 'whole-task-first' lessons. The direct instruction approach and the guided discovery approach were used the most, nine and ten times respectively (Table 5.4). The next most popular was the master-apprentice approach which was used by six participants and the adaptive approach was used by only one participant. Three of the preservice teachers did not vary their chosen approach at all throughout their development.

Table 5.4 Educational learning processes used per participant per lesson.

Teacher	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Lesson 7	Lesson 8
Anja	<i>j</i>	<i>m</i>	<i>j, m</i>	<i>m</i>	<i>m</i>	<i>k</i>	<i>k</i>	<i>m</i>
Stephan	<i>m</i>	<i>m</i>	<i>j</i>	<i>j</i>	<i>j</i>	<i>j</i>	<i>j</i>	
Petra	<i>j</i>	<i>j</i>	<i>j, k</i>	<i>j</i>	<i>j</i>	<i>k</i>		
Vera	<i>m</i>	<i>m</i>	<i>k, n</i>	<i>k</i>	<i>n</i>	<i>n</i>		
Maaïke	<i>j, m</i>	<i>m</i>	<i>m</i>	<i>j</i>	<i>j, m</i>	<i>j</i>		
Martine	<i>j, k</i>	<i>j, k</i>	<i>j</i>	<i>j</i>	<i>m</i>			
Patrick	<i>j</i>	<i>j</i>	<i>j</i>	<i>k</i>				
Sancho	<i>m</i>	<i>m</i>	<i>m</i>	<i>m</i>				
Bas	<i>j</i>	<i>j</i>	<i>k, m</i>	<i>k, m</i>	<i>j</i>			
Jet	<i>m</i>	<i>m</i>	<i>m</i>	<i>m</i>	<i>m</i>			
Jan	<i>j</i>	<i>m</i>	<i>j, m</i>	<i>j, m</i>	<i>j, m</i>			
Tissa	<i>j</i>	<i>j</i>	<i>j, m</i>	<i>j, m</i>	<i>j</i>			

Key: *j* = direct instruction, *k* = master-apprentice, *m* = guided discovery, *n* = adaptive

5.4.4 Marks that the participants awarded themselves

When we look at the marks that the participants awarded to themselves for the lessons they had given (Table 5.5), we are able to conclude that they were quite satisfied and gave themselves high marks. However, three participants only gave themselves a five for one lesson. The marks they gave themselves were related to whether or not they had managed to achieve the resolutions and goals they had intended for their lessons. They were also asked to explain the marks in their subject-specific report. Maaïke, for example, gave herself a five because she was not happy with the discipline in the lesson as well with her instructions and she planned to make her instructions clearer in the next lesson. Another participant, Anja, gave herself a five because she was unable to motivate her students to work on the whole task during the lesson. Her plan was to change the way she gave feedback to the students so that they would have a greater chance of experiencing success during her lessons. Patrick's marks showed a steady rise. In his notes he explained that he had achieved what he intended and he reacted positively to that with statements such as: "I give this

lesson a 7. My teaching plan was to give a structured explanation supported with clear examples. I succeeded in this. One problem was the students' motivation, they didn't seem to find the lesson interesting." Patrick's subject-specific agency did not develop along a specific dimension, but it did show progress because he partially realised his plans and used that experience to make new plans for the next lesson.

Table 5.5 Marks that the participants awarded themselves for each lesson.

Teacher	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Lesson 7	Lesson 8
Anja	8	8	5	7.5	7.5	7	6.5	8
Stephan	8	6	7	8	8	6	8	
Petra	7	5	7	8	6	7		
Vera	6	7	7.5	6.5	7.5	8		
Maaïke	5	7	7	7	6	6.5		
Martine	7	7	8.5	7	7.5			
Patrick	6	7	7	7.5				
Sancho	6.5	6	7	6.5				
Bas	6.5	7	7	7.5	6			
Jet	7	7.5	7	7	7			
Jan	6	8	7	7	8			
Tissa	7	8	7	7	8			

5.4.5 Fields of affordances

The plans that the participants formulated can be understood against the background of their first field of affordances. They were trying to achieve the goals that they had formulated in their first field of affordances in the lessons that they gave. During the course of the teaching experiments, the participants had varying degrees of success and they came up with new plans that they then tried to slot into and implement in a new teaching experiment. On that basis they formulated new goals which they adopted in their second field of affordances. The second field of affordances developed alongside the participant's development. The results show that this could happen in two ways (see Table 5.6). First, the

field of affordances stayed the same, the formulated goals remained as they were and the number of goals remained practically the same. The participants reported that they had become better at achieving their own goals. In this group of preservice teachers, we saw an increase in the number of goals achieved in the second field of affordances when compared with the first field of affordances. This was the case with Petra, Martine, Maaïke, Sancho and Tissa. A second group of preservice teachers modified their field of affordances, by adding or dropping a number of goals. We saw a big difference in the number of goals in the case of Bas, who added twenty extra goals to his second field of affordances. He explained that he wanted to expand his teaching repertoire and that he formulated new goals in order to do this. He also thought that he had achieved more of the goals he had set himself (52%) in his second field of affordances than he did in the first (33%). Vera did just the opposite, she reduced her goals from forty to thirty, explaining that she had combined some of her initial goals into a broader overarching goal.

Table 5.6 Participants' fields of affordances 1 and 2 comparing the number of goals achieved against the total number of goals in absolute figures and in percentages.

Preservice teacher	Field of affordances 1		Field of affordances 2	
	Goals achieved (total number of goals)		Goals achieved/ (total number of goals)	
Anja	13 (25)	52 %	8 (26)	31 %
Stephan	23 (31)	74 %	23 (31)	74 %
Petra	31 (45)	69 %	38 (49)	78 %
Vera	30 (40)	75 %	23 (30)	77 %
Maaïke	22 (43)	51 %	34 (49)	69 %
Martine	32 (40)	80 %	37 (40)	93 %
Patrick	not applicable	not applicable	28 (33)	85 %
Sancho	28 (36)	78 %	33 (40)	83 %
Bas	7 (21)	33 %	22 (41)	52 %
Jet	24 (28)	86 %	24 (28)	86 %
Jan	24 (32)	75 %	25 (36)	69 %
Tissa	25 (31)	81 %	29 (33)	88 %

The next two sections illustrate the development of subject-specific agency in two of the preservice teachers. We chose these two participants for two reasons. First, because they differed from each other on the type of dimension on which they developed which illustrates the breadth of growth in agency and, second, because they differed in the number of goals in their fields of affordances. The first participant is Tissa, she showed particular development of subject-specific agency on the content perspective, whereas our second participant, Vera, made excellent progress on building blocks for the educational learning process.

5.4.5.1 Tissa

In her first field of affordances Tissa stressed her resolution to enthuse the students by giving them tasks which required them to actively engage with the material and by introducing new concepts. Tissa wanted her teaching to be relevant to the world in which her students lived and to motivate them. Her teaching experiments show her attempts to give them tasks to actively work on in the lessons, which she hoped would arouse their interest and activate their prior knowledge. Tissa's plan was to give a whole-task-first lesson, using a number of content building blocks (content perspectives, see Table 5.1) to deal with the topic. Tissa's teaching experiments (Table 5.7) show that she tried whole-task-teaching in her initial lessons, combined with content perspectives other than the mechanical and functional perspectives. She showed strong development in the use of content perspectives through the period of the study (Table 5.2), applying six of the nine content perspectives offered. In her characterisation and explanation of her teaching, Tissa said the following about her use of the content perspectives during her lessons: "I try to adapt the content perspectives I use to what the class is interested in. I use the

medical perspective with year group 3 VWO¹, as this group has shown a great deal of interest in it. I use the personal perspective with year group 1 VWO, because personal perception and their amazement at all the new concepts they are offered are of big interest for this class. I do also use other content perspectives, as I let myself be guided by which perspective best suits the material. In future I'd like to try using several content perspectives at the same time to throw light on a topic from different angles." Table 5.7 shows a number of Tissa's plans and the teaching experiments she used to realise her plans, where we see that whole-task-first lessons and the use of content perspectives reappear. This resulted in her second field of affordances, to which Tissa added two goals (outlined in bold) after her teaching experiments. The goals shaded in grey are those which she felt she still needed to work on as she did not consider that she had achieved those goals during her lessons. One new goal in her field of affordances was her desire to use more content perspectives to illuminate the topic. She linked this goal with learning new concepts and learning to scientific thinking (see her second field of affordances in Figure 5.3). Both of these goals were already important in her first field of affordances. By adding this goal, she increased the likelihood of achieving her higher order goals during her lessons. In addition, she added the goal of teaching procedures to her field of affordances; this goal is only linked with clarifying the essence.

¹ Dutch secondary education is streamed by ability. VWO is for students intending to go on to university.

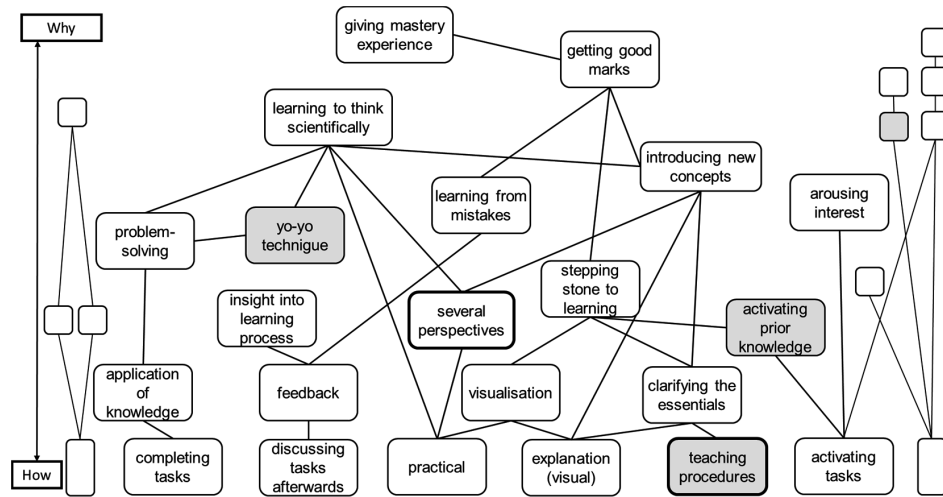


Figure 5.3 Tissa’s second field of affordances, showing that her goals (to introduce new concepts and teach scientific thinking) were supported by her newly formulated goal (to use several content perspectives).

Table 5.7 Some steps from Tissa’s teaching skills and methods learning route, summarising the plans she formulated and her subsequent teaching experiments.

Lesson 1	Plan	<i>I want to call up prior knowledge that the students may have from their own experiences, (...).I want to achieve this by having the students think about the whole task themselves and see what they already know about the 3 methods of childbirth assistance by asking questions. I want to use the medical perspective with 3 VWO, as this group has shown a lot of interest in it.</i>
	Teaching experiment	The students did a whole task about different events during the birth. After that Tissa dealt with the three phases of birth, rotation, forceps delivery, vacuum extraction and Caesarean section (medical perspective). When discussing the whole task Tissa asked questions about the 3 methods of assistance during birth. Tissa asked the students to explain what this is – thereby calling up their prior knowledge.
Lesson 2	Plan	<i>For this lesson I want to make a whole task first that is challenging and which all the students in the class can work on.</i>
	Teaching experiment	Tissa introduced the whole task on human blood groups and the students had to think about the answer themselves. After that Tissa gave a short explanation, recalling their prior knowledge. The students then worked out the problem together as a class with contributions from individual students.
Lesson 3	Plan	<i>In this lesson I want to look at whether I am giving the students enough support with the model on offer to illustrate mitosis. I want to be accessible to the students but not to jump in immediately to correct mistakes because there is more to be gained from letting them work it out for themselves in this activity. I will respond when students ask for help.</i>
	Teaching experiment	Tissa gave an explanation to the whole class so that everyone started with the same basic information. After this explanation the students started to model mitosis. Tissa gave instructions which were also written up on the board. The students used the information they had just been given. This revealed the students’ thinking processes allowing Tissa to see what mistakes they had made so she could help.

Lesson 4	<i>Plan</i>	<i>This is a rather quiet class and the students do not give much feedback. In this lesson I want to engage the class in a discussion about cloning. In future lessons I want to try to bring more content perspectives into the lesson at the same time to throw light on a topic from different angles.</i>
	<i>Teaching experiment</i>	Tissa gave a brief explanation about the cloning of animals using Dolly the sheep as an example, after which she initiated a discussion about cloning pets (including pets that have died). She then let the students discuss whether people should be allowed to clone pets (ethical perspective). Tissa hoped that this would make it easier for these students to express their opinions about this subject (personal perspective).
Lesson 5	<i>Plan</i>	<i>In this lesson I want to monitor the pairs more actively to see if they need help, even when they don't ask for help. I hope that this approach will reassure the students that it is OK to ask questions.</i>
	<i>Teaching experiment</i>	The students were given a whole task to model meiosis. They had been given their previous whole task back with feedback. The students were allowed to confer among themselves, consult their book or ask Tissa for help. Tissa tried to divide her attention around the class and offer help to all of the students without them asking for it.

5.4.5.2 Vera

In her first field of affordances Vera emphasised keeping control. Her lessons were typically highly structured and many of her goals were concerned with order or control. Vera tried out whole-task-first lessons in her teaching experiments using direct instruction or the master-apprentice approach. She felt that the guided discovery approach and the adaptive approach would make keeping order in class more difficult (see Table 5.8), but she did plan to use them. She wanted to use whole-task-first lessons to make her students more enthusiastic about biology. During the research project Vera made great progress in a number of areas including the educational learning process. Over the course of six lessons, Vera began the

first two lessons with the guided discovery approach and then added the master-apprentice and adaptive approaches in later lessons. In her characterisation and explanation of her basic approach to teaching, Vera said: "As a general principle I use direct instruction and master-apprentice in my lessons. I usually explain something to the students, (...) after that they do tasks. Sometimes I turn it the other way around but I still find guided discovery and adaptive more difficult. (.....) I thought at first that guided discovery and adaptive would make keeping order more difficult. But I've learned from experience that it does not need to." Table 5.8 shows that Vera often made plans to use whole-tasks in her lessons and hoped that this would help her to establish the level that the students were working at. She wanted to introduce more differentiation into her lessons. She then chose the type of educational learning process that best suited the level of her students. Vera let herself be informed by the class and adapted to that. Vera adapted her second field of affordances (Figure 5.4) after the teaching experiments. She took out a number of goals to do with keeping order such as checking if the students brought their books. Although keeping order was still there as a goal in her second field of affordances, specific attention for growth in this area had been pushed into the background as it had simply got easier. Vera had become clearer and more consistent in the rules that she set. Conversely, she added a number of new goals (outlined in bold), including giving feedback to students and motivating them more in the lessons. She expected that by offering them interesting contexts and whole tasks, she would find it easier to maintain discipline. She also added differentiation as a new goal to her field of affordances.

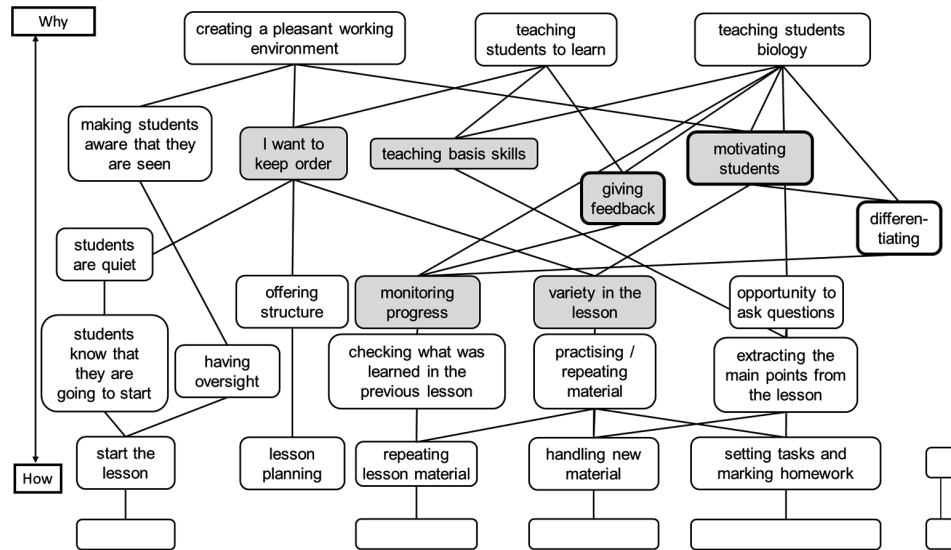


Figure 5.4 Vera's second field of affordances, emphasising control and student motivation.

Table 5.8 Some steps from Vera's teaching skills and methods learning route, summarising the plans she formulated and her subsequent teaching experiments.

Lesson 1	Plan	<i>I have difficulty giving clear instructions at the beginning of a task. I want to pay extra attention to that in this lesson.</i>
	Teaching experiment	Vera started with a brief introduction to different kinds of plants. Then she explained the task and set the students to work in pairs, offering help where it was needed. After that the task was discussed in front of the whole class.
Lesson 2	Plan	<i>I want to use a whole task in this lesson, in which the students have to find out a lot for themselves and where necessary be able to work with hints. This is intended to help me differentiate between students. I have not given this type of lesson before and I want to try it out.</i>
	Teaching experiment	Vera first explained to the students what pollination is but she then let the students find out for themselves what kinds of pollination there are and how that is reflected in the form of the flowers. After the students had done their own research, they discussed the answers (guided discovery approach).
Lesson 3	Plan	<i>I want to get to know the class better, in terms of their levels and ways of working</i>
	Teaching experiment	Vera tested the students' knowledge using mini whiteboards. Students could write their answers on these boards with a whiteboard pen. Vera asked various questions which the students had to answer on their boards. This enabled Vera to adapt her explanation to the level of the class (adaptive approach).
Lesson 4	Plan	<i>My plan is to differentiate.</i>
	Teaching experiment	Vera started the lesson with a short question to find out what the students already knew: What is the chance that two parents with brown eyes (heterozygote) have a baby with blue eyes? Vera worked out the task on the board (master-apprentice approach). Then the students were able to choose which tasks they wanted to do, depending on the knowledge they already had (adaptive approach).

Lesson 5	<i>Plan</i>	<i>I do not want to give an explanation in front of the whole class but only to those students who need it. I also want to make the tasks more challenging, by using fewer tasks from the book. In this way I hope to be more in alignment with the students' level.</i>
	<i>Teaching experiment</i>	Vera started the lesson with a teacher-guided, structured dialogue. Then she introduced a whole task. The students were then given a choice as to what form of help they needed: to do parts of the task first or to receive more explanation from Vera (adaptive approach).
Lesson 6	<i>Plan</i>	<i>I want to differentiate in the lesson and I want to know how each student is doing. I use mini whiteboards for this. (The students write the answers to questions that Vera put to the class on their boards).</i>
	<i>Teaching experiment</i>	Vera gives some tasks to the students designed to check their knowledge of the material in the chapter. They write their answers on their mini whiteboards. If necessary, she gives a brief explanation to the class. After that she discusses individual tasks with those students who need this. The other students can get on with the work (adaptive approach). Vera ends with a final checking question to the whole class.

5.5 Conclusion and discussion

Central to this paper is the theoretical development of an ecological approach to teacher agency and the testing of this in an explorative research study looking at the development of the teaching skills and methods used by preservice biology teachers.

An integrative ecological approach has been developed for understanding and supporting teacher agency based on the integration of five research traditions in ecological psychology. Agency is conceived in this context as the field of affordances that the teacher has developed in which possibilities and limitations are determined by the landscape of affordances in which the teacher is working. Teacher agency can be encouraged by gradually enlarging the field of affordances which involves first bringing new

possibilities for action into the zone of affordable development. Combinatorial entrenchment is an important mechanism for this. Our study comprised two parts: 1. integration of theory, and 2. an empirical part. The theoretical part has made a contribution to the development of an integrative ecological approach to teacher agency. We then used this integrative approach in the second empirical part of our study. Before we expand upon how the ecological approach we developed relates to the currently prevailing sociocultural approach to agency, we will first discuss the results of our empirical research.

Based on this theoretical framework, two consecutive research modules on teaching skills and methods were set up aimed at developing the subject-specific agency of preservice biology teachers. A broad repertoire of subject-specific choices about the what and how of teaching was worked out and set down in building blocks which were sorted into three dimensions: content perspective, content type and educational learning process. Where possible these building blocks were formulated in such a way that the preservice teachers were able to recognise them in their existing practice and by recombining and adapting these existing building blocks could expand their repertoire of subject-specific teaching skills and methods (combinatorial entrenchment). We started from the premise that teachers are only willing and able to try out a new combination if it helps them to achieve goals in their field of affordances (zone of affordable development) that in turn is constrained by the landscape of affordances. The preservice teachers made their field of affordances explicit in laddering interviews both at the beginning and end of the two research modules. The first field of affordances they formulated was taken as the starting point for formulating successive teaching methods plans that they tried to realise by designing and executing their lessons based on recombinations and/or adaptations of building blocks taken from one or more of the subject-specific dimensions of teacher agency.

Our results show that all of the preservice biology teachers gradually developed their subject-specific agency; however, the extent to which this happened and the dimensions on which they developed varied. We looked at their use of building blocks related to subject-specific agency, at movements in the number of goals in their fields of affordances and at how far they achieved their goals. For the content perspective dimension, it turned out that the participants started out using the content building blocks that were close to the book, such as the functional and mechanical perspectives, but later started to vary their approaches by using building blocks from other dimensions such as the medical and environmental perspectives. With respect to the content type dimension, it emerged that almost all of the teachers started with factual knowledge in their lessons and then added conceptual knowledge. Five participants also used procedural and metacognitive knowledge. For the educational learning process dimension, we found that all of the participants started by introducing new topics with an explanation, after which they all went on to try variants of whole task-first lessons. The direct instruction approach and the guided discovery approach were the most frequently used variants. The development of the participants' subject-specific agency can also be seen in the changes in the extent to which they managed to achieve the goals in their field of affordances. In general, the participants did manage to steadily improve in terms of realising the goals in their first field of affordances. Seven participants reported that they had been able to improve their achievement of the goals that they formulated for themselves. Resolutions they formulated were usually also aimed at this. However, we also observed that their teaching experiments sometimes led them to change the goals in their field of affordances. In some cases, goals had disappeared in the second field of affordances or were worded more concisely because a participant could now take the realisation of these goals more for granted and so they were no longer so prominent. New goals also appeared regularly in the second fields of affordances as a result of participants trying out new teaching methods.

This small-scale explorative study shows that an ecological approach of teacher agency offers a possible direction to support, describe and understand the development of subject-specific agency of preservice biology teachers.

We will first describe the limitations of this study and then place its merits in a broader perspective. It was a small-scale explorative study in which the development of subject-specific agency was based on detailed self-reporting by the participating preservice teachers. For a follow-up study it would be worthwhile enlarging the dataset with observations of lessons. Our research found evidence to suggest that the landscape of affordances had a significant influence on the fields of affordances formulated by the preservice teachers. A more in-depth study could examine this further. It would also be useful to describe the school context in which the teachers are working in more detail, because this could also influence the landscape and fields of affordances of groups of teachers. The results of this small-scale explorative study suggest that it would be worthwhile testing this ecological approach to the development of subject-specific agency in a quasi-experimental research study on a larger scale.

This chapter offers a new integrative ecological approach to teacher agency. As we stated in the introduction, current approaches to teacher agency, in the context of both initial teacher education and ongoing professional development, have mainly had a sociocultural orientation (Eteläpelto et al., 2013; Eteläpelto, 2017; Orland-Barak, 2017; Toom et al., 2015). The ecological approach tested and presented here does not aim to replace the prevailing sociocultural approaches but to supplement them. The most important points of agreement as well as complementary differences are discussed briefly below.

In the history of research on teacher education, a shift can be observed from behaviourist approaches in which emphasis was put on isolated behaviours, to cognitive approaches centred on knowledge, to the current dominant sociocultural approaches in

which practices take centre stage (Grossman and McDonald, 2008; Kennedy, 2016). The importance of behaviours and knowledge is recognised in sociocultural approaches but there is an assumption that they are always embedded in practices in which interactions between participants and with tools play an important role (Putnam and Borko, 2000). What the sociocultural and ecological approaches have in common is that practices are central to both.

The most important difference between the sociocultural approach and the ecological approach concerns the way in which practices are approached, Vicente and Rasmussen (1999) distinguish three perspectives in this regard: a descriptive perspective in which concrete practices are described; a normative perspective in which certain practices are prescribed and taught; and a formative perspective in which one examines which practices are possible. This can be clarified using a simple analogy. A campsite owner wants to help a guest to find her way in the local area. He could, for example, first check which routes people normally take to a specific destination (descriptive), then choose the best route and 'prescribe' this route for the guest (normative). Alternatively, he could give the guest a map so that she is able to decide on a route for herself depending on the departure point and destination that she has chosen (formative). In a sociocultural approach it is the descriptive and normative perspectives particularly that take centre stage, whereas in the ecological approach worked out in this study it is a chiefly formative perspective that has been developed. We will explain this further below and show why and how the two approaches can complement each other.

The strength of the sociocultural approach is that it offers many tools for describing concrete teaching practices, such as a teacher leading a discussion with students (McDonald, Kazemi, and Kavanagh, 2013), with an eye both for specific teacher behaviours and knowledge that teachers need and also for interactions of participants with tools and with each other (such as interactions between teacher and students and among students).

The sociocultural approach also offers many opportunities for normative elaborations. Based on these descriptions, desired concrete teaching practices can be elaborated in a specific way. The sociocultural approach also contains powerful directions for learning these concrete teaching practices, such as: giving teachers the opportunity to join a learning community, building up the complexity of practice, modelling, practice with decreasing guidance and feedback, et cetera (Grossman, Hammerness, and McDonald, 2009; McDonald et al., 2013; Putnam and Borko, 2000).

These sociocultural approaches have three important limitations however (Janssen and Van Berkel, 2015). A concrete worked-out form of a teaching practice can make teachers lose sight of what possibilities for variation actually exist. The teacher's focus, in other words, is on a specific route and the general overview of the field is lost. In addition, these approaches do not take sufficient account of the fact that a new teaching practice has to be carried out in an existing classroom setting by a particular teacher who has limited time and resources. Many new educational practices conflict with these existing requirements and possibilities with the result that teachers often do not adopt them or adapt them so much that the essence of the innovation is lost. Finally, sociocultural approaches make insufficient productive use of existing opportunities to design and implement new practices.

An ecological approach such as the one developed in this study conceptualises precisely those aspects of practices that are usually neglected in sociocultural approaches. The emphasis shifts from a descriptive and normative to a formative perspective on practices (Vicente and Rasmussen, 1999). In the context of developing teacher agency, this means that attention shifts from describing and prescribing concrete teaching practices to mapping and productively exploiting the territory which they form a part of. To that end we not only mapped the landscape of affordances for teachers but, using fields of affordances, we have also shown what possibilities for action a specific teacher considers to be relevant and desirable and reasonably achievable in combination.

Landscapes and fields of affordances do not therefore specify concrete teaching practices but offer an overview of what is possible and what factors need to be taken into account when designing and realising any number of (new) concrete teaching practices. In accordance with ecological approaches, this study does not prescribe specific teaching practices but teachers are given building blocks with which, through recombination and adaptation, they can work out new possibilities that fit into their field of affordances. In this way the field of affordances is gradually expanded from the zone of affordable development and the teacher develops his or her agency in a particular domain. Indeed, this approach gives teachers more and more options for action in a given situation, their understanding of which goals they want to achieve improves all the time, and they are increasingly able to actually realise the things they have chosen to do.

5 Against this background we can also clarify how the ecological and sociocultural approaches can complement each other. The ecological approach helps with mapping the field and offers powerful building blocks which can be selected and recombined to develop new teaching practices in the zone of affordable development. The sociocultural approach contains powerful directions for further specifying the concrete teaching practices chosen and mastering them.

In the present study we have proposed an integrative ecological approach for developing and understanding teacher agency. Next, we tested this approach for a specific school subject in actual classrooms and during initial teacher education. We hope that this contribution will also inspire others to develop and test this ecological approach to the development of agency for other domains and phases in teachers' careers.