European Journal of Physics

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OPEN ACCESS
IOP Publishing
European Journal of Physics
Eur. J. Phys. **43** (2022) 025705 (13pp)
https://doi.org/10.1088/1361-6404/ac3493

Active and passive transductions—definitions and implications for learning

Kim Svensson[1,*], Jennie Lundqvist[2], Esmeralda Campos[3] and Urban Eriksson[1]

[1] Lund University Physics Education Research (LUPER) group, Department of Physics, Lund University, SE 221 00 Lund, Sweden
[2] UiT The Arctic University of Norway, iEarth, N-9037 Tromsø, Norway
[3] Tecnologico de Monterrey, Writing Lab, Institute for the Future of Education, Ave. Eugenio Garza Sada 2501, Monterrey, N.L., 64849, Mexico

E-mail: Kim.Svensson@fysik.lu.se

Received 14 August 2021, revised 5 October 2021
Accepted for publication 28 October 2021
Published 21 February 2022

Abstract

To move between different *semiotic systems*, such as graphs and formulas, is a necessary step in learning physics or solving problems. In s*ocial semiotics*, this movement of *semiotic material* is called a *transduction* and during a transduction a student must *unpack*, *filter*, and *highlight* different aspects of the concept or problem. Unpacking, filtering, and highlighting have been shown to be important to the meaning-making process and transductions should be seen as indicators of meaning-making and learning. However, in this paper we argue that not all transductions performed by students requires unpacking, filtering, or highlighting, and hence the definition of transduction needs to be refined in its description. We introduce the ideas of *passive* and *active* transductions that separates transductions that may lead to meaning-making from transductions that may not. This separation is done through shown engagement with the semiotic material of the transduction. We connect shown engagement with the semiotic material to the already established *anatomy of disciplinary discernment* to create a useful tool when evaluating student engagement and discernment. In the paper, we showcase examples of passive and active transductions and provide a short description of how to identify them in different learning situations.

*Author to whom any correspondence should be addressed.

Keywords: transduction, social semiotics, disciplinary discernment

(Some figures may appear in colour only in the online journal)

1. Introduction

This theoretical paper aims to advance the description of *transduction* as used in s*ocial semiotics* in physics educational practices and research. Since a full review of social semiotics and transductions is beyond the scope of this paper, we refer the reader to [1–3] for more detailed descriptions, and move straight to the details relevant for this paper.

The act of performing transductions [1–5] have been shown to play an important role in the meaning-making process and is defined by Jeff Bezemer (page 169) [6] as:

The movement of semiotic material from one mode to another,

where the concept of 'mode' has been substituted by *semiotic system* within the social semiotics framework. A semiotic system is a qualitatively different way of representing the *semiotic material*, for example, a formula or text used to represent the semiotic material of 'force'. In the transduction from text to formula, we lose the verbal description of the concept but gain the possibility to discern a symbolic relationship between the different parts. In equation (1) we perform a transduction between 'formula' and 'text' while attempting to preserve the semiotic material of 'force'.

$$\bar{F} = m\bar{a} \leftrightarrow \begin{cases} \text{Force is equal to mass times acceleration.} \\ \text{A heavy object experiences less} \\ \text{acceleration compared to a lighter object} \\ \text{when experiencing the same force.} \end{cases} \tag{1}$$

Another example of a typical transduction is the act of moving semiotic material from the semiotic system of 'text' to 'image', or some other visual semiotic system. In figure 1 we see an example of such a transduction. In the transduction, we see that a number of implicit questions has been answered, such as: what color is the ball? How large is it? By answering these questions, the person performing the transduction engages with the semiotic material of 'a ball' because they have to consider how to represent the semiotic material in a new semiotic system.

1.1. Transductions with engagement: unpacking, filtering, and highlighting

During the transduction process, many questions emerge that must be answered. This process involves *unpacking, filtering*, and *highlighting* different aspects [3]—What aspects do we keep, how do we represent them, what do we throw away? In equation (1), we must decide how to represent 'force' as a mathematical symbol, $\bar{F}$. Do we write the whole vector: $\bar{F} = (F_x, F_y, F_z)$ or do we forego the vector notation completely?

In [5, 7] Svensson *et al* uses programming to perform the transduction and shows how programming requires these steps when it is employed in a learning environment. Unpacking [8] has previously been shown to help students to discern disciplinary relevant aspects [9] from representations that may have been difficult to discern without discussions with peers or an instructor.

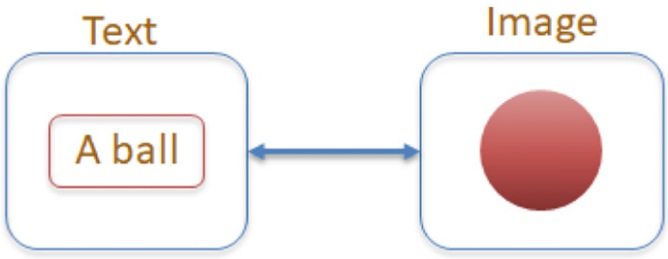


Figure 1. A transduction is performed between the semiotic systems 'text' and 'image'.

Using the previous research of Eriksson *et al* [10], we are able to connect transductions with the anatomy of disciplinary discernment (ADD), see figures 6 and 7. The connection between transductions and ADD provides us with a more detailed description of students' engagement and disciplinary discernment in the learning situation.

1.2. Transductions without engagement

The processes of unpacking, filtering, and highlighting different aspects, requires engagement with the semiotic material. The semiotic material must be studied and its parts must be understood and put back together in a new representation. However, in this paper we present transductions where students seemingly do *not* engage with the semiotic material, showcasing that a performed transduction does not necessarily mean that the student performs the unpacking, filtering, or highlighting steps. We therefore suggest a division of transductions into two classes: *active and passive transductions*. In the following sections we discuss how these can be defined and used to analyze and improve the learning situation.

2. Active and passive transductions

Below follows the definitions of the two types of transductions that we have identified:

Active transduction : *the student shows engagement with the semiotic material during the transduction*.

Passive transduction : *the student does not shows engagement with the semiotic material during the transduction*.

Where we view *engagement* as: *students play an active role in the unpacking, filtering, or highlighting of aspect in the transduction*, such as asking what $\bar{F}$ means to unpack it, or using different colors for different aspects in a function and its corresponding graph to highlight the connection between them.

A student does not engage with the semiotic material if no unpacking, filtering, or highlighting takes place. If a lecturer says:

'Write down 'F' equals 'm' 'a','

and the student writes it down, the student has not engaged with the semiotic material, but merely copied it over from one semiotic system–'speech'–to another–'formula'. Using the old definition [11], this is technically a transduction; however, we cannot couple it to any

Example 1: active transduction

1	**Fredrik**	We have the formula for heat. [Gustaf nods]. The 'Q' equals to, what is it, '$mc\Delta T$'?
2	**Gustaf**	yeah.
3	**Fredrik**	Should I write it down…I can write it down
4	**Kim**	Yes, please do. [Fredrik draws a 'Q']
5	**Fredrik**	we have 'm' 'c' 'ΔT' [Fredrik draws the symbols as he speaks]
6		[Fredrik writes 'mass' and draws an arrow from the word 'mass' to the 'm' in the formula.]
7	**Fredrik**	'c' is the…. [Draws an arrow pointing to 'c'] what is this called?
8	**Gustaf**	Heat capacity…
9	**Fredrik**	It's called heat capacity…specific heat capacity, yeah.
10		[Fredrik writes heat capacity at the arrow point to 'c']
11	**Fredrik**	And 'ΔT' is the, well, change in temperature.
12		[Fredrik draws an arrow pointing to 'ΔT']

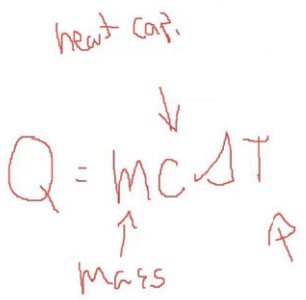


Figure 2. Fredrik writes down the formula for thermal energy, $Q = mC_v\Delta T$, but also modifies it by adding arrows and words to explain it. Fredrik unpacks the representation and highlights different aspects. This is an example of an active transduction performed by a student.

unpacking, filtering, or highlighting, nor can we say that the student discerns or explores any aspect during the transduction, which leads us to revise and refine the definition into the sub-definitions above.

The terms *passive* and *active* should not be interpreted as value-judgment of students individual learning situation, but only as neutral descriptive terms of the situation. Thus, a passive transduction should not be seen as a negative outcome of a learning situation, but as an indicator that this specific transduction does not provide any information for use in assessing the learning situation or outcome.

Example 2: passive transduction

1		[Fredrik is looking up the formula on a formula sheet]
2		[Fredrik begins to write down the formula $\Delta U = nC_v\Delta T$]
3	**Fredrik**	I am just copying the formula.
4		[Fredrik adds: $= f/2nR\Delta T$]
5	**Gustaf**	Yeah, sure
6		[Fredrik adds: $= f/2Nk\Delta T$]
7	**Kim**	And what does that formula say?

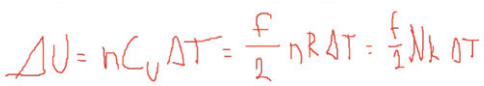


Figure 3. Fredrik copies the formula, but without engaging the semiotic material. This is an example of a passive transduction.

2.1. Data collection

The four examples presented in this paper come from three different studies performed by the authors. Examples 1 and 2 come from the project '*constructing semiotic resources using social semiotics and variation theory for use in physics education*'that is lead by Kim Svensson of the LUPER group at Lund University. Examples 1, 2, and 3 are all from physics students discussing or solving physics problems. Example 3 is from Campos *et al* [12], where physics students explored and solved problems in relation to electromagnetic fields. Example 4 comes from a geoscience education research study by Lundqvist *et al* [13], where students are tasked with discussing and representing geological time.

2.2. Informed consent

The students in examples 1, 2, and 4 were all volunteers for the research and have signed consent forms that comply with the general data protection regulation (GDPR, Regulation (EU) 2016/679). The data collection for examples 1, 2, and 4 took place at Lund University in Sweden by authors Kim Svensson and Jennie Lundqvist, no ethics committee was required. All names in examples 1, 2, and 4, are fictitious and cannot be traced back to the students. The data collection for example 3 took place in Tecnologico de Monterrey in Mexico with volunteers who signed informed consent to participate in the research. All volunteers answered the questions anonymously.

2.3. Examples

Below follows a number of examples that have been chosen to showcase different active and passive transductions.

Example 3: passive transduction

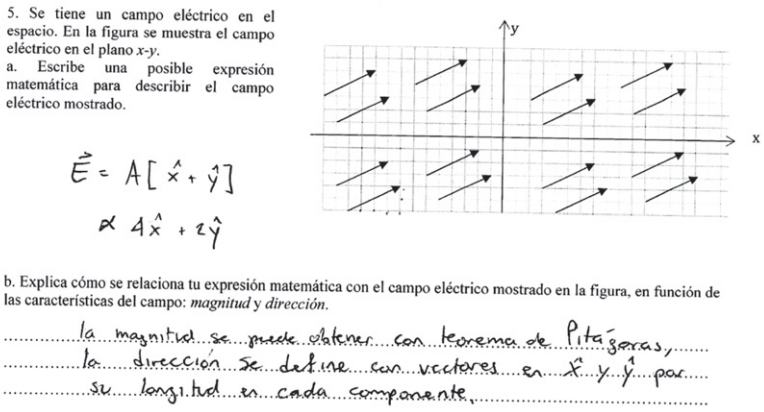
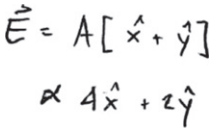


Figure 4. The task given to the students in Spanish.

Translated into English:
5. There is an electric field in space. The figure shows a part of the electric field in the x–y plane.
a. Write a possible mathematical expression to describe the electric field shown.
b. Explain how your mathematical expression relates to the electric field shown in the figure, in terms of the features of the field: magnitude and direction.

The student answered:

a.



b. 'The magnitude can be obtained using the Pythagorean theorem, the direction is defined with vectors x and y and by the length of each component.'

In examples 1 and 2, the transductions are primarily performed by the student Fredrik in regards to an exercise about heat and thermal energy. In example 1, Fredrik performs an active transduction from 'speech' to 'formula' and during the transduction he adds arrows and words to unpack it, as seen above in the transcription and in figure 1. Fredrik engages with the semiotic material and makes choices during the transduction. He chooses what to unpack and what to highlight based on what he finds relevant to the situation. Kim, one of the authors of this paper, is the interviewer in examples 1 and 2.

However, in the transcript in example 2, the same student performs a passive transduction, where he does not engage with the semiotic material during the transduction process. It was

Example 4: active transduction

1	**Hutton**	It is quite simple, the paper we received in the beginning of [the first course]
2	**Interviewer**	How do you visualize it in your mind /.../ when you talk about geological time how does it look inside your mind?
3		/.../
4	**Lyell**	It is true that Silur and those in the beginning are blue /.../ we see yes, we see color, we see time as color.
5	**Agassiz**	You can, then, it's not something that is completely wrong
6	**Lyell**	Color
7	**Hutton**	I think there are three pieces of red
8		[Hutton is quiet for a while and is occupied with drawing figure 5, when the drawing is finished, he exclaims]
9	**Hutton**	This is what it looks like
10	**Interviewer**	Is this how you visualize it (points at figure 5)
11	**Hutton**	Yes, this is what it looks like in my room

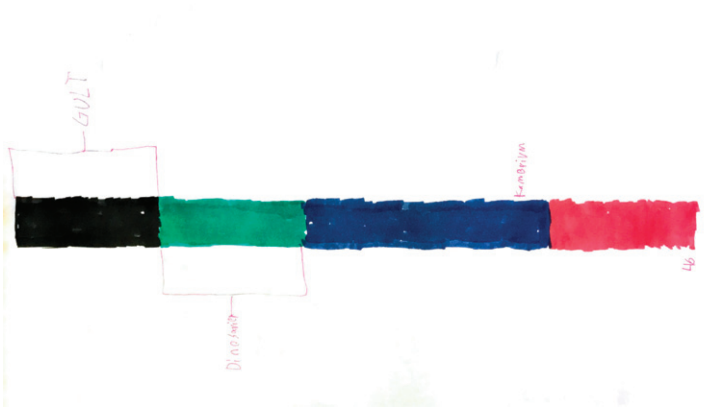


Figure 5. A linear representation of geological time in the form of a vertical column with sharp distinct borders between the colored fields that represents different parts of Earth's history. The representation has been rotated 90 degrees.

not until Fredrik or Gustaf were prompted, on line 7, to describe the formula that they began to engage with the semiotic material of the representation; a short moment after the transduction was complete. In figure 3 we see the result of the passive transduction.

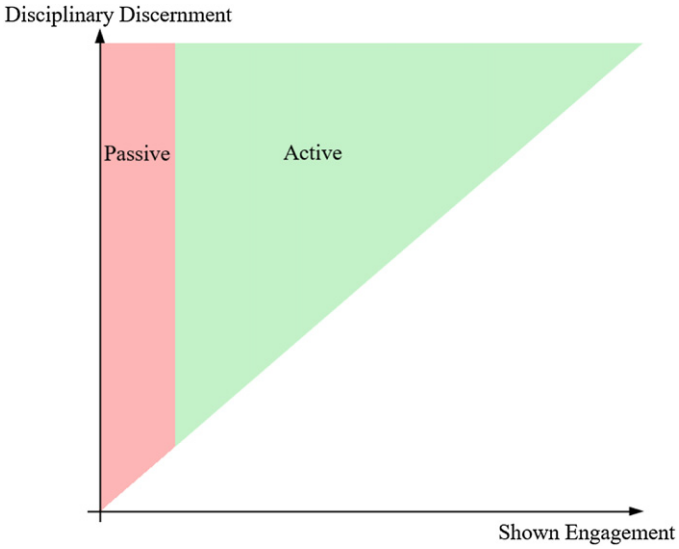


Figure 6. A student must be able to discern what the representation affords before the student may engage with the semiotic material. The larger the engagement is, the higher up the disciplinary discernment hierarchy the student must be. However, the reverse is not true, a student may display low engagement and high disciplinary discernment.

In example 4 we see an active transduction where Hutton engages with the semiotic material of geologic time. The data comes from semi-structured interview with first year geoscience students at a Swedish university [13].

In the excerpt above Hutton begin the active transduction by moving the initial mental image of geologic time into speech in line 2 and into a drawing in line 4. This is an example of an active transduction but with a low engagement. In the drawing we can see some attempts of unpacking through the notations of dinosaurs, Cambrian and the number 46 but there is no further explanation. When the drawing is finished there is no further interaction or exploration of the image but rather a finalizing statement that concludes that this is how it is.

2.4. Identifying passive and active transductions

As seen in example 3, it is not trivial to identify if a transduction is active or passive. The first step is to define what semiotic material is in focus in the transduction. In example 3, the semiotic material is the electric field, however, the transduction in example 3 may be performed with no shown engagement with the electric field at all, only with the vector field representation.

In example 1, Fredrik is actively showing how the mathematical formula is related to physical quantities such as mass, specific heat capacity and temperature. Fredrik thus engages with the semiotic material, by unpacking it, and performs an active transduction.

If a student engages with the intended semiotic material during the transduction, it is an active transduction, else it is a passive transduction.

2.5. Connection to disciplinary discernment

Eriksson *et al* 2014 [10] introduces the ADD and it provides a hierarchy of student discernment of disciplinary relevant aspects. Discernment is also identified as a necessary condition of

learning [14] and we apply this notion to our active and passive transductions. We suggest that the shown engagement may be used to help determine the disciplinary discernment level, but we refer back to Eriksson *et al* 2014 for a deeper description of these levels and how to identify them. See figure 6 for a graphical representation of this. Figure 6 presents how passive and active transductions can relate with either low or high disciplinary discernment level. Also, the passive or active transductions can be seen as a continuum, where students can transition from passive to active transductions and vice versa, while increasing (or reducing) their disciplinary discernment level. The students disciplinary discernment level determines their potential for engagement with the semiotic material. Without any discernment, the student may not engage with the semiotic material at all.

3. Conclusion

A transduction does not necessarily mean that a student unpacks, filters, or highlights different aspects of the semiotic material. In situations, the process may be just more akin to copying, or writing things down that someone says, without any disciplinary reflection. In this paper we introduce two new categories of transductions: active and passive transductions that aims to separate the two cases. In the case of the active transduction, the student engages with the semiotic material and performs one or several of the actions: unpack, filter, or highlight on the semiotic material, hence show signs of learning, according to social semiotics. In the case of the passive transduction, the student writes down, or copies, what is presented to them (moves from one semiotic system to another) without any engagement with, or disciplinary reflection on, the semiotic material.

Other theories have also identified the distinction between active and passive transductions as important. For example, the theory of registers of semiotic representations identifies 'transitional auxiliary representations' as the changes of representations that do not imply cognitive activity [15]. We highlight that 'conversions' in the theory of registers of semiotic representations are directly related to active transductions, because they both imply cognitive activity, such as unpacking, filtering and highlighting. Whereas, 'transitional auxiliary representations' may be related to passive transductions, because students do not engage with the semiotic material, when the transitional auxiliary representations are used. In example 3, the student was able to move between different representation systems without recognizing the characteristics of the electric field, probably due to the fact that students are familiar with the conversions between vector diagrams and algebraic equations; in this way, the familiarity with the representation systems would act as the transitional auxiliary representation.

It is important to acknowledge the relevance of the context in which each theory developed. On the one hand, the theory of registers of semiotic representations comes from the didactics of mathematics and claims that cognitive activity in mathematics depends on the transformation of representations (treatments and conversions) [15]. In this context it is necessary to distinguish conversions as the changes of representation that denote cognitive activity, and transitional auxiliary representations as those that do not. On the other hand, social semiotics describes a wide range of processes that happen when learners engage with semiotic material in the physics education context. Therefore, transductions describe a wide range of processes, and it has become relevant to identify active and passive transductions in relation to disciplinary discernment and the processes of unpacking, filtering and highlighting.

4. Implications

Merely identifying that transductions, according to [11], are performed by the student is not enough to infer that they involve any unpacking, filtering, or highlighting parts of a transduction leading to meaning-making. To obtain a better description of the situation, a researcher must also identify if this transduction is active or passive.

From previous studies [16–18] we know that student engagement with the semiotic material is important for learning and practitioners should aim to create learning situations where active transductions are taking place instead of passive transductions. A practitioner should ask the question: 'are the students only writing down what I am saying, or are they engaging with the semiotic material?' and modify their teaching methods to avoid passive transductions taking place.

To avoid passive transductions, we suggest that practitioners adopt active learning [19, 20] techniques and employ the variation theory of learning [14, 21, 22] to ensure greater engagement with the semiotic material by the students.

4.1. Plotting the engagement

The examples presented in section 2.3 can be placed within the graph presented in figure 6. By plotting where the transductions are located in the 'disciplinary discernment' and 'representational engagement' plane we obtain a better view of how fluent the students are in their usage of representations. For example, if all transductions are in the upper right corner of the plot, the material may appear too easy for the students since they do not need to engage with the semiotic material at all when they are performing the transduction. However, if they are all in the bottom left corner, the material may be on a too high a level and the students can not engage with the semiotic material because they cannot discern what is important and what is not important. In figure 7 we see the examples plotted and identify areas of the plot that may be important for the planning and execution of the learning situation.

4.2. Designing assessments

In example 3, the student believes that they have done what is asked of them. However, if the exercise can be solved by the student without them showing any engagement with the semiotic material, the exercise is not a good way to assess student understanding of the physical concept. If the student solves the problem using passive transductions, we cannot say anything about their disciplinary discernment of the physical concept, as shown in figure 6.

It is important to identify exercises that may be solved using only passive transductions to acknowledge their limitations when designing assessments. Assessments should thus focus on making the student engage, and show this engagement, with the semiotic material to be useful during the assessment process. However, a student may still engage with the semiotic material when solving the exercise, but if they do not show it, we cannot say that they do, nor their level of understanding. As such, when assessing students, one must construct tasks and problems that allows for many transductions. See e.g., [23–25] for some activities that have shown potential of engaging students meaning-making. We also highlight the work by Trevor Volkwyn [3, 26, 27] on which the definitions of active and passive transductions are based, for a better understanding of how to induce transductions during the meaning-making process of students.

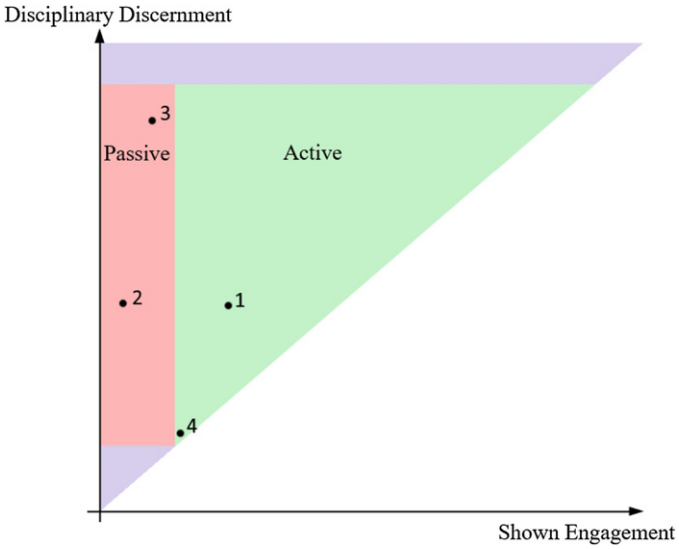


Figure 7. The examples (1–4) plotted in the diagram. The disciplinary discernment level has been estimated based on other interactions with the students in question. The top purple area indicates an area where the student is unable to progress and the bottom pink area indicates an area where the students are unable to engage with the semiotic material.

4.3. Interventions and passive transductions

In example 2, the student Fredrik performs a passive transduction and he, and Gustaf, only begins to engage with the semiotic material after they are prompted by Kim, the interviewer. The passive transduction provided an opening for a well timed intervention. Thus, teachers may use passive transductions as indicators that they may want to perform an intervention to get the students to engage with the semiotic material.

4.4. Future research

Future research that incorporates or expands upon the ideas presented in this paper could include looking at the construction of tasks and representations to allow for active transductions. This will be incorporated into an analysis done by one of the authors in an ongoing project where the data presented in examples 1 and 2 will be used.

Requiring students to perform active transductions on all tasks they perform may be taxing and mentally exhausting. A mix of passive and active transductions may be a desired were the active transductions are directed toward what a lecturer wants to assess, but that other transductions may be kept passive to not overwhelm the student. This could be connected to, and explored by, cognitive load theory as '…*extraneous cognitive load* […] *caused by task-related aspects*…' [28].

5. Summary

In this paper we have refined the definition of transductions in social semiotics to include passive and active transductions. Passive and active transductions capture the students' shown engagement with the semiotic material of the concept in question.

Active transductions signals that students are higher up in the disciplinary discernment hierarchy. Usually, the more the student engages with the semiotic material, the further up the hierarchy they are. Passive transductions signals that the student does not engage with the semiotic material. There are several reasons why a student may not engage with the semiotic material; they do not discern the semiotic material itself and cannot engage with it, or they have no need to engage with the semiotic material because it is second nature to them, or they are disinterested in the exercise, or they do not have to engage with the semiotic material to solve the problem.

A passive transduction provides no information about the students' disciplinary discernment. An assessment should be designed to encourage the student to perform active transductions so that their disciplinary discernment may be observed. By using interventions at opportune moments, students may be encouraged to turn a passive transduction into an active one.

We have applied the ideas of passive and active transductions to physics education research and geoscience education research. However, the ideas presented here and the concept of transduction can, and should, be applied to any type of educational setting where representations are used in the meaning-making process.

Acknowledgment

We wish to thank Dr Elias Euler for his valuable comments on the application and usefulness of the ideas presented in this paper.

ORCID iDs

Kim Svensson https://orcid.org/0000-0002-7985-8872
Jennie Lundqvist https://orcid.org/0000-0002-0744-841X
Esmeralda Campos https://orcid.org/0000-0002-3097-3933
Urban Eriksson https://orcid.org/0000-0001-6638-1246

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