Research synthesis

Four interesting concepts in physics education

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<table>
<tr><td>Concept 1:</td><td>Threshold concepts</td></tr>
<tr><td>Definition:</td><td>Threshold concepts are objects of learning that act like portals, are transformative and enable students to think about something in a new way. (Meyer, 2010; Meyer & Land, 2006)</td></tr>
<tr><td>MTP course:</td><td>Integration Seminar (Chapter 1, 2 and 11)</td></tr>
<tr><td>Question(s):</td><td>• What are the threshold concepts in physics, especially mechanics, and how do they transform the learner?
• How can we better help students when teaching those threshold concepts?</td></tr>
<tr><td>Literature:</td><td>General
• The idea of threshold concepts (Land, Meyer, J.H.F, & Smith, 2008; Meyer, 2010; Meyer & Land, 2006)
• Threshold concepts question the “intended learning outcome” model (Meyer, 2010)
• Understanding of threshold concepts in their disciplines by teachers (O’Brian, 2008)
• Troublesome Knowledge: Blaming students vs. focus the teaching on the area of difficulty (Perkins, 2006)
• Threshold concepts in economics (Davies & Mangan, 2007)
• Threshold concepts in mathematics – the Plateau Principle (Easdown, 2007)
Physics
• The struggle of solving problems without numbers (Lasry, Guillemette, & Mazur, 2014)
• Thresholds in Electrical Engineering (Flanagan, Taylor, & Meyer, 2010)
• Threshold concepts in physics (Bar, Brosh, & Sneider, 2016; Prusty & Russell, 2011; Psycharis, 2016)</td></tr>
<tr><td>Summary:</td><td>Learning is not a linear sequence. Some concepts are more critical than others as they can keep a learner from accessing the next higher level. Those threshold concepts, once mastered, transform the way of thinking (Meyer, 2010). Some research has been done regarding threshold concepts in physics: Psycharis (Psycharis, 2016) mentions previous work of Meyer (Meyer, 2003) and list some threshold concepts in physics. While Prusty and Russell (Prusty & Russell, 2011) attribute the high failure rate in mechanics courses to the presence of threshold concepts, Bar et al. (Bar et al., 2016) link the threshold concept of weight, mass and gravity to the alternative conceptions the students have developed prior to their courses .</td></tr>
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Concept 2:	**The role of alternative student conceptions (misconceptions) on learning physics**
Definition:	Alternative conceptions (or misconceptions, pre-conceptions, and intuitive conceptions) are conceptions acquired through interaction with the natural world without formal education.
MTP courses:	CKID, Fostering Creativity
Question(s):	• Do we harm the students' understanding of physics (and force them into a surface approach) by trying to remove their misconceptions instead of working with them? • Is there a better way to use a constructivist approach to work with the students' initial concepts? • The interaction with "misconceptions" is well studied in mechanics, what is their role in other domains of physics?
Literature review:	• Different approaches of experts and novices to misconceptions (Brault Foisy, Potvin, Riopel, & Masson, 2015; Buteler & Coleoni, 2014) • Instability of pre-conceptions (Bransford, Brown, & Pellegrino, 2000; Lasry et al., 2014) • Helping students to overcome alternative conceptions, building on alternative conceptions (Buteler & Coleoni, 2014; Lin & Singh, 2015; Smith III, Disessa, & Roschelle, 1994) • Encouraging divergent thinking – Textbooks inhibit students' creative thinking (Klieger & Sherman, 2015)
Summary:	Alternative conceptions have been acquired through interaction with the natural world without any formal education. They successfully explain everyday phenomena but often interfere with formal physics education, forming a threshold that keeps the students from acquiring a deep understanding. Traditionally, they are considered misconceptions that ought to be removed and replaced. However, more recent research (Buteler & Coleoni, 2014; Klieger & Sherman, 2015; Lin & Singh, 2015; Smith III et al., 1994) suggest that it might be more beneficial take a constructivist approach and work with those initial conceptions, re-branding them as "alternative conceptions".

Concept 3:	**Conceptions of learning science (Deep vs. Surface)**
Definition:	Deep learning emphasizes the pursuit of meaning and understanding for its own sake while surface learning concentrates on reproducing information without particular interest in its meaning (Knapper, 2010). Deep learning is transformative and leads to a structural shift of thought, feelings, and actions. (Transformative Learning Centre 2004, as cited by (Kitchenham, 2008))
MTP courses:	CKID, Integration Seminar (Chapter 1, 2, 3, 4 and 10, 13)
Question(s):	• What encourages students to adopt the deep approach to learning science? • How can we create conditions that foster deep learning
Literature:	General: • Initial concept of surface vs. deep learning (Marton & Säljiö, 1976a, 1976b) • Mezirow's transformative learning ((Kitchenham, 2008) • Effect of the examination system on learning approaches (pushing students to use the surface-approach) (Watkins & Hattie, 1981). • The influence of the teaching on the students learning approaches (Kember & Gow, 1994; Lindblom-Ylänne, 2010; Ramsden & Entwistle, 1981). • Influence of the perception of the learning environment (Entwistle, 2010) • The role of meta-learning (Biggs, 1985) Science: • Deep (forward inference) vs. surface (backwards inference) approach to physics problem solving (M. T. Chi, Feltovich, & Glaser, 1981; M. T. H. Chi, Glaser, & Rees, 1981; Eryılmaz Toksoy & Akdeniz, 2015; Larkin, McDermott, Simon, & Simon, 1979, 1980, A. Priest, 1986b, 1986a; A. G. Priest & Lindsay, 1992; Wilson, 2014) • Understanding or Memorization (Mazur, 1997) • Engineering students trying to memorize (3000!) homework problems (Woods, 1987) • View of physics (isolated factual knowledge vs. a whole) (Hammer, 1997; Wieman, 2010) • Successful science education transforms how students think (Wieman, 2010) • Traditional classroom teaching is ineffective (or even has a negative effect as shown by the FCI-Scores). (Hake, 1998; Wieman, 2010) • Ideas to help students understand, for example: reducing the cognitive load (Wieman, 2010)
Summary:	While experts in physics employ a deep approach to solving problems and learning, students often use a surface approach (M. T. Chi et al., 1981; M. T. H. Chi et al., 1981; Eryılmaz Toksoy & Akdeniz, 2015; Hammer, 1997; Larkin et al., 1979; A. Priest, 1986b, 1986a; A. G. Priest & Lindsay, 1992; Wilson, 2014), resulting in an insurmountable barrier (a threshold?). More effort (time spent memorizing) does not lead to better understanding and mastery. As the choice of deep vs. surface approach, in general, can be influenced by the learning context and traditional classroom teaching has been shown to be ineffective (Hake, 1998; Mazur, 1997; Wieman, 2010; Woods, 1987), more research should be done on how to concretely help students adopt a deep approach when learning physics, for example by reducing their cognitive load, addressing beliefs, stimulating and guiding thinking and use of technology (Wieman, 2010).

Concept 4:	**Influence of motivation on learning**
Definition:	Motivation plays a key role in the learning process, leading to either deep learning (through intrinsic motivation (Christensen Hughes & Mighty, 2010)), surface learning (through extrinsic motivation (Christensen Hughes & Mighty, 2010)) or work avoidance (Seifert, 2004).
MTP courses:	Motivation for Learning, CKID, Integration Seminar (Chapters 1, 4 and 14)
Question(s):	• What is the role of motivation in the learning process? • What type of motivation encourages students to adopt the deep learning approach? • How can teachers create a motivating learning environment?
Literature review:	• Behaviourism (Skinner, Pavlov, and others) • Attribution Theory (Greene, 1985; Seifert, 2004; Weiner, 1985) • ARCS Model (David, 2014) • Self-Worth (Seifert, 2004) • Achievement Theory / Learning goal orientation (Ames & Archer, 1988; Seifert, 2004; Taing, Smith, Singla, Johnson, & Chang, 2013) • Goal Setting Theory (Locke & Latham, 2002) • Expectancy-Value Theory (Reported in (Weiner, 1985)) • Motivation and learning physics (Bransford et al., 2000) • Influence of motivation on learning (Pintrich, 2003) • Self-efficacy (Bandura, 2012; Caprara et al., 2008; Seifert, 2004) • Trait-Self efficacy (Yeo and Neal (2006) reported in (Bandura, 2012)) • Social Cognition Theory (Bandura, 2012) • Perceptual Control Theory (Powers (1973) reported in (Bandura, 2012)) • Empowerment, self-direction, and choice (Candy, 1991; Conger & Kanungo, 1988) • Flow Theory (M. Csikszentmihalyi reported in (krist2366, 2014))
Summary:	Various theories describe student motivation and its influence on the learning process. The theories explain what types of motivation (intrinsic) lead to deep learning and what types (extrinsic) will favour the surface approach. Also, the possible negative role of motivation (work avoidance to preserve self-worth) is understood. Further on, much research has been done to study how a teacher can, for example by providing choice, create a motivating learning environment for the students.

Reflection

My interest in all four topics (Threshold concepts, alternative student conceptions, conceptions of learning science, and the influence of motivation on learning) comes from the troublesome fact that the pass rate of the first physics course (NYA Mechanics) at our College is significantly lower than the other physics and science courses. The course seems to be a major obstacle for science students. It turns out that this phenomenon is not limited to our school, but observed in Colleges and Universities across North America.

Initially, I thought of the four concepts as separate areas that influence student learning in that course. However, it now appears to me that they might be intimately linked together: Is the interference of alternative concepts a particular threshold of the mechanics course, a course that deals with many topics of which we acquire an intuitive understanding during childhood? Is overcoming the belief that science is a surface-discipline a mayor threshold? Is the labelling of the alternative conceptions as misconceptions and the attempt of many teachers to "remove" them the cause for students ending up with a surface understanding? How can we motivate the students to "get through" the thresholds of this course and adopt a deep learning approach?

While first, I was mostly interested in the role of alternative conceptions, now I intend to focus more on threshold concepts, an idea I just learned about and that promises to play a major role in explaining the low pass rate in the mechanics course.

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