Creating Responsive Learning Environments to Develop Students' Reflective Capacity

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Abstract: In today's society, rapidly changing conditions and expectations mean that students need to learn how to make reflective judgments, and there is a clear need to better understand how to create learning environments that scaffold student learning to make these judgments. Here, we explore the design of a learning environment that integrates an computerized scoring system into a large scale course to provide students with formative assessment of their cognitive complexity level. We discuss important aspects to consider when framing and integrating this technology and how the deployment allows for formative assessment practices in large scale courses found in today's education.

Keywords: Cognitive ability, higher education, learning environment, metacognition, scaffolding.

Introduction

In today's rapidly changing world, it is not enough for *higher education institutions* (HEIs) to only equip students with discipline specific knowledge and skills (McAleese et al., 2013). HEIs should support students in becoming *lifelong learners* that can both adapt to and actively shape the society of the future (Schuetze, Slowey, Schue, & Slowey, 2015). Therefore, it is important to

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create learning environments where students are empowered to take control of their own learning and engage in *self-regulated learning*, while at the same time receiving the necessary support to move forward (Pintrich & Zusho, 2007). Students need to learn how to face complex challenges and make judgments that take into account a multitude of dimensions, often with incomplete and conflicting positions (Barnett, 2004). These types of *ill-structured* or *wicked problems* (Brown, Harris, & Russell, 2010) require students to make *reflective judgments*. As King and Kitchener (2004) put it: "Reflective judgments are initiated when an individual recognizes that there is controversy or doubt about a problem that cannot be answered by formal logic alone, and involve careful consideration of one's beliefs in light of supporting evidence" (p. 6).

Students' capacity to make reflective judgments is closely linked to their level of *cognitive* and *epistemological complexity*, which can be conceptualized using *cognitive developmental models* that describe the progression through different stages from early childhood, through late adolescence and into adulthood (Hofer & Pintrich, 1997). For HEIs to help students increase their capacity for and quality of reflective judgments and become self-regulated learners, there is a clear need to better understand how to create *learning environments* that explicitly support the development of students' underlying cognitive and epistemological complexity and are conducive for growth into what Magolda and others call a *self-authoring epistemology* (Magolda & King, 2004). Within this field of research, two key aspects of the learning environment have been identified: the application of cognitive developmental models and *formative assessments* (Clark, 2012; Nicol & Macfarlane-Dick, 2006).

One way to create these kinds of learning environments is to integrate *Lectical Assessment*s into courses to provide students with the necessary individual formative assessment and support (Dawson, 2002; Dawson, Commons, & Wilson, 2005). The Lectical Assessment System (LAS) is a domain independent system for measuring cognitive complexity on Fischer's (1980) skill scale (Stein & Dawson, 2011) and is based on intensive studies of the pathways through which individuals build understanding and skill in specific knowledge areas (Dawson & Wilson, 2004). The scalability of Lectical Assessments has been limited due to the amount of training required to certify scorers and the human labour involved in scoring. However, the recent release of the *Computerized Lectical Assessment System* (CLAS) has altered this situation (https://lecticalive.org/demo/). The development of CLAS, as a fully automated system that provides developmental scores, enables the scaling of Lectical Assessments and facilitates their deployment within formative assessment practices in higher education settings.

Given the recentness of this development, there are currently few design examples showing how this type of computerized domain independent scoring system can be utilized for formative assessment of cognitive complexity can be used in higher education learning environments. In this study, we explore possibilities for designing a responsive learning environment based on Lectical Assessments scored with CLAS, with the overall goal to support students in the development of metacognitive capacity and reflective judgment. Grounded in the theoretical context of CLAS, we describe the exploratory deployment of the system in a master level course. The aim for this study is two folded. First, we want to get an idea about the range of students' scores within the course population and examine these scores in relation to the cognitive task complexity and implicit expectations of the course. The second aim was to investigate the possibilities to use the reports generated by CLAS to aid in the design of customized learning activities. In this way, this paper provides a reference point for researchers and academic practitioners in conceptualizing, designing, and creating CLAS supported responsive learning environments.

Theoretical Background

In connection with the emphasis on *student-centered learning* in higher education, self-regulated learning has become a central construct to describe effective academic learning (Butler & Winne, 1995). Pintrich and Zusho (2007) define self-regulated learning as situations where students: "….set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features in the environment" (p. 741).

In this context, it is important to recognize that students will not automatically become self-regulated learners in student-centered learning environments. Indeed, as pointed out by English and Kitsantas (2013): "For many students, the [self-regulated learner] role conflicts with deeply ingrained habits they have developed through more familiar classroom experiences, in which they have been passive recipients of knowledge" p. 129).

Self-regulated learning emphasizes knowledge as something that students actively co-construct, which requires them to become authors of their own learning and development, through what Kegan (1994) and later Magolda (2007, p. 69) call *self-authorship*: the internal capacity of a student to define his/her own belief system, identity, and relationships. It is therefore important that HEIs aim at creating learning environments that actively support the development of a *self-authoring mindset* (King & Kitchener, 1994; Magolda, 1992) throughout all their courses, while taking into account students' personal departure points. Educators need to help students to develop intellectually and become authors of their own learning and development. In the following two sections, we will situate our work within different strands of previous theoretical and empirical research; first epistemological beliefs, metacognitive and reflective skills and second, formative assessment and cognitive developmental models.

Epistemological Beliefs, Metacognitive and Reflective Skills

Epistemological beliefs are the beliefs we hold about the nature of knowledge and how we can know things (Hofer, 2001). Developing students' ways of thinking about knowledge and knowing is a key objective of higher education and at the core of students' ability to engage in a self-authoring mindset, as they are foundational for how students use and develop their skills. As Muis (2007, p. 173) proposed, epistemological beliefs: 1) constitute one component of the cognitive and affective condition of a task; 2) influence the standards students set for their goals; 3) serve as inputs to metacognition; and 4) are subsequently influenced by the students' development in self-regulated learning and self-authorship.

Early work in understanding the epistemological development of college students was undertaken by Perry (1970; 1999; 1981) who made extensive studies of epistemological growth in students. His research generated a stage model that went from absolutist perspectives of truth being a form of right or wrong, to relativist perspectives where conflicting versions of "truth" are to represent legitimate alternatives and a nuanced perspective of right and wrong. Perry's original intent was "a purely descriptive formulation of students' experience," rather than a "prescriptive program intended to 'get' students to develop" (Perry, 1981, p. 107). His work has been further extended in the domain of student services by Magolda (1992, 2007, 2008) who focused on how educational environments and experiences could be conducive to growth into self-authoring epistemologies.

Empirical studies have shown that epistemological complexity differs among students, and King and Kitchener (1994), as well as Magolda (1992), pointed out that the majority of first and second year students at HEIs are not engaging in self authorship and not all of them will develop this capacity by the time they leave HEIs. Given the age at which the majority of students enter higher education, it is natural that they come with a *socialized mind*, as achieving this order of consciousness is a major task during mid to late adolescence (Kegan, 1994). As characteristics of this stage, they subjugate their ego desires to the imperative of interpersonal relationships (King & Kitchener, 1994; Magolda, 1992), and look to authority figures like teachers to provide relevant knowledge and information. Kegan's (1994) research has estimated that two thirds of the adult population operate from this (or an earlier) epistemological structure and have yet to achieve a fully self-authoring mindset. In a self-authoring mindset, there is a more mature and self-directed approach to using knowledge that enables a greater freedom and scope of behaviors where one is not subject to interpersonal relationships, but considers them in relation to internally driven values. Furthermore, empirical studies suggest that students' average epistemological complexity is interrelated to the discipline they are studying (Paulsen & Wells, 1998). There are studies showing that students tend to hold more naïve epistemological beliefs in fields such as mathematics, science, and engineering, which could be seen as an attunement to the culture and teaching in these fields with a strong emphasis on facts, principles, and procedures presented in a dualistic mode (Felder & Brent, 2004; Wankat, 2002).

Students' epistemological beliefs are deeply interdependent with their metacognitive and reflective skills (Muis, 2007). These skills are concerned with the processes by which students reflect upon their own learning, what learning means to them, dissecting their own thoughts, thinking about in what way they know something, arguing with themselves about possible alternatives, and thinking about how their experiences will shape their future (Gall, Gall, Jacobsen, & Bullock, 1990). Student-centered education both requires and stimulates the development of metacognition, but it is important that teachers provide the necessary scaffolding for students to enable them to develop over time (Handelsman, Pfund, Lauffer, & Pribbenow, 2005). While certain epistemological beliefs can limit the use of metacognitive and reflective skills, e.g. Dweck's (1995) notion of the importance of attitude towards learning of either a fixed or a growth mindset, specific skills also offer an entry point to become aware of one's own beliefs and develop a self-authoring mindset (Kegan, 1994). It is through learning and training metacognitive and reflective skills that students can advance their epistemological complexity level within the learning environments and support provided by HEIs (Wallin & Adawi, 2018).

The students' pathway towards a self-authoring mindset emphasizes the development of skills for questioning beliefs, in particular the ability to make reflective judgments in relation to values, in order to determine if they are primarily coming from external sources or are one's own (Wyn, Cuervo, & Landstedt, 2015). Shifting to an emphasis on skill, rather than a focus on the self or ego as a centralized meaning making system, enables the notion of self-authorship to be operationalized and its development scaffolded in learning environments at HEIs. In Fischer's *dynamic skill theory*, the core concept of skill is defined as "the capacity to act in an organized way in a specific context. Skills are thus action-based and context specific" (Mascolo, Fischer, & Lerner, 2010, p. 321).

With this in mind, it is important to realize that there is mounting evidence that metacognition as a skill needs to be learned – it is not something that all students carry with them when entering higher education (Wedelin & Adawi, 2014). This holds also true for reflection, which not all students will engage in on their own (Wallin & Adawi, 2018). Therefore, the development of metacognitive and reflective skills should be an important goal of higher education, as these skills are closely linked with the students' ability to plan, monitor, regulate, and evaluate their own learning (Bråten & Strømsø, 2005; Butler & Winne, 1995; Clark, 2012). HEIs need to support students' skill development in order to help them to become lifelong, self-regulated learners (Pintrich & Zusho, 2007).

Formative Assessment and Cognitive Developmental Models

Given that these metacognitive and reflective skills, described in the previous section, are central to the goals of higher education, the question becomes on how to support students in achieving them (Boekaerts, Pintrich, & Zeidner, 2000). To answer this question there is a clear need to better understand how to create learning environments that explicitly support the development of underlying cognitive and epistemological complexity and are conducive for growth into such a self-authoring epistemology (Magolda & King, 2004). Within this research, two important aspects of the learning environment have been identified: formative assessments and the application of cognitive developmental models (Clark, 2012; Nicol & Macfarlane-Dick, 2006).

In general, formative assessment supports students during the learning process by providing them with feedback on their performance and aims at helping students to reach their full capacity (Yorke, 2003). In contrast, summative assessment focuses on outcomes and the main question is to what extent students have reached the learning objectives (Clark, 2012). Formative assessment aims at helping the students to learn, and in this way is closely linked to scaffolding, a process described by Bruner (1973) as a practical approach to making use of Vygotsky's concept of the *zone of proximal development* (ZPD). Scaffolding is a teaching approach, where students learn through the interaction with a knowledgeable person that helps them in their development process and gradually reduces their support as the student becomes more independent (Wood, Bruner, & Ross, 1976).

On this basis, Nicol and Macfarlane-Dick (2006, p. 199) argued that ´*in higher education, formative assessment and feedback should be used to empower students as self-regulated learners*.´ However, one large challenge with implementing formative assessment widely at HEIs is the time demand it brings to teachers, as they should follow up all students individually and scaffold their development (Clark, 2012). In addition, the move towards student-centered learning environments and inductive teaching methods means that students work more and more independently, which limits students' direct interactions with teachers and constrains the possibility for formative assessment and scaffolding from the teacher (Clark 2012).

One way to overcome these limitations of formative assessment practices is to design responsive learning environments that scaffold student development on an individual basis. The CLAS version of the *Lectica Reflective Judgment Assessment* (LRJA), like other Lectical Assessments, was built specifically to support individualized instruction of this kind by providing diagnostic information that helps instructors and students themselves to identify their individual learning edge, or ZPD. Lectical Assessments can perform this function because each of them is informed by extensive primary research into the development of a given assessment target construct. This research involves the use of methods that build on a long history of research in the field of cognitive development, beginning with Baldwin (1895), followed by Piaget (1954, 1970), Kohlberg (1969, 1975), and Fischer (1980). The learning model and developmental scale that most directly inform the methods employed to build Lectical Assessments are Fischer's (1980; Fischer & Bidell, 2006; Fischer & Yan, 2002; Mascolo et al., 2010) dynamic skill theory and *skill scale* (Stein & Dawson, 2011).

Lectical Assessments measure the developmental level of understanding demonstrated through assessment responses (Stein & Dawson, 2011). Numerical scores (called Lectical Scores) provided with Lectical Assessments are calibrated to Fischer's (1980) skill scale. The hierarchical complexity of cognitive tasks mapped by Fischer's skill scale describes how sensory motor actions develop from single actions, through mappings into systems and even systems of systems of actions. The latter are 'chunked' into single representations, which then also go through a similar set of stages before cognitive processes move into the tier of abstractions. While Lectical Assessments are typically scored by trained humans, CLAS is a fully automated system that provides developmental scores that agree with human scores 85% of the time within one fifth of a level. This rate of agreement is comparable to human inter-rater agreement (Dawson, 2017). In contrast to other text analysis systems that measure and quantify simple text parameters like vocabulary and punctuation, CLAS algorithms are based on deep studies of learning and development that involves a blend of human expertise and analytics. At the core of CLAS is the Lectical Dictionary that provides a constantly evolving taxonomy of the development of meanings. At the moment, the dictionary contains 230,000 words and phrases that are assigned to a Lectical Phase (1/4 of a Lectical Level). The CLAS system uses the dictionary to measure the hierarchical complexity of the text provided by the users and measures growth along the Lectical Scale. While the dictionary and CLAS algorithms do not learn on their own, the systems is developed through a human/machine collaboration, where trained human analysts curate CLAS and CLAS makes suggestions based on its existing algorithms.

College students who have taken the LRJA generally perform in the range of 10.5 to 11.4 on this scale, which represents the range from the middle of abstract mappings through the middle of abstract systems. While CLAS and human scorers are able to provide very precise Lectical scores on a given assessment performance, it is understood that the range of performance variability means that for practical purposes, formative feedback to test takers is designed to address Lectical phases within ¼ of a level of a test takers score. This range can be considered to be within their ZPD and thus instructions and instructional material, in order to meet achievable learning goals, should be designed to be no more than 0.25 above their score. The typical rate of growth in the college years is around 0.13 of a level per year (Stein, Dawson, Van Rossum, Rothaizer, & Hill, 2014). Research on city workers using Lectical assessments as part of a training program were found to have growth of 0.18 – 0.27 over a four to nine month period (Stein et al., 2014).

The CLAS / demonstration version of the LRJA employed in this research provided students with a report that covered three areas: 1) the Lectical Score from CLAS, 2) a description of the kind of reasoning typically associated with this score and a description of typical reasoning at the next quarter of a level together with a learning activity that involves a comparison of these two ways of thinking with the students' responses, and 3) a description of the students' likely learning edge (or ZPD) accompanied with a learning activity targeting either deliberation skills or skills for working with evidence (Stein et al., 2014). The learning activity in the report is based on the individual growth edge of the student and specific tasks are outlined for how to go forward in a *Virtuous cycle of learning* (VCoL) (Stein et al., 2014). VCoLs are a generic adaptation of various cyclical learning models such as Kolb's (2014, p. 50) experiential learning cycle. It involves; 1) setting a goal (usually informed by some aspect of a formative developmental assessment), 2) seeking information related to that goal at a ZPD relevant level of cognitive complexity, 3) applying this information to real life situations for practice, 4) reflecting on what happens during the application of this new information and 5) resetting the goal based upon the reflections in step 4.

To our knowledge, there is no published research to show how this kind of computerized system and the automatically generated individualized skill development sequences can be made context specific within a course. Others have used different types of intelligent tutoring systems, but these systems are often task specific and do not offer students with information about their developmental level of understanding and how they can improve it. For example, Murray & Arroyo (2002) used Animalwatch as an intelligent tutoring system that provides students with progressive hints when they enter incorrect answers to word problems. CLAS on the other hand provides much more advanced information and therefore consideration of the relationship of these sequences and skill building activities to course specific learning objectives in higher education learning environments need to be carefully addressed. Thus using the LRJA report content as a starting point, we explored the possibility of working with students to develop more personalized learning activities tied to students' growth edges and in relation to a specific course context, as we will describe and discuss below.

Context

The *Experts in Teamwork* (EiT) course was selected as a pilot course to implement the use of the CLAS version of the LRJA for four reasons: its interdisciplinary nature, its emphasis on experienced-based learning, its size, and its organizational support structure. EiT is an interdisciplinary, and to some extent an intercultural, team-based 7.5 ECTS (European Credit Transfer and Accumulation System) course at the Norwegian University of Science and Technology (NTNU), with the aim of developing students' interdisciplinary and intercultural collaborative competencies (www.ntnu.edu/eit). By virtue of being mandatory in almost all five-year undergraduate and master programs, EiT is one of NTNU's largest courses with more than 2300 students each year. Due to a recent fusion between NTNU and several colleges, NTNU has become the largest university in Norway and the EiT course will expand to include approximately 3000 students unevenly distributed in three Norwegian cities by the year 2021.

The structure in EiT is that a teacher provides a general theme suitable for an interdisciplinary working approach that up to 30 students can select. These groups of students organized by themes, called villages, each have a teacher who is responsible for structuring and guiding the teams' work process, as well as providing the necessary thematic content that the students need. In total, there are about 90 teachers teaching in EiT each year, representing all faculties. The course is coordinated centrally by academic developers and staff from the EiT Section who organize and administer the villages in cooperation with the faculties. To support the teachers, basic training in the experience-based approach used in EiT is given through seminars and lectures, as well as teaching and learning material for all students that they can use within their villages, including a *Book of Reflections*. In addition to a teacher, or in EiT terms, village leader, each village has two learning assistants that facilitate the teams. These are students employed on a part-time basis that receive training in observing team behavior and asking open-ended questions, and conducting reflection and feedback exercises. The learning assistants' role is to initiate reflections, highlighting aspects of the team dynamics that may be less evident to the team itself, thus giving the team an opportunity to discuss and become aware of previously hidden dynamics. It is important to point out that the teams retain autonomy on what inputs from the learning assistants they want to consider, evaluate, and use to change their team processes, and what actions to take.

Within each village, the students are put in interdisciplinary teams of 5-7 students to work on a self-defined project coupled to the village theme. With all of NTNU's faculties represented, a team may include students from medicine, natural science, engineering, computer science, social science, humanities and/or economics. As a result, students will expand perspectives on their disciplinary knowledge through their encounter with skills from other disciplines.

The desired learning outcomes in EiT are strongly focused around the students' ability to become aware, reflect upon, and improve their interdisciplinary team work, dynamics, and processes. Throughout the project work, the students develop these teamwork skills by analyzing, on their own and together, the situations that arise as the team works on their interdisciplinary project. Based on their understanding of situations, the students reflect on how they communicate, plan, make decisions, solve tasks, handle disagreements and relate to academic, social and personal differences. Through individual and team reflection activities, as well as the application of relevant concepts and fundamental group theory, the student teams can become aware of their group dynamics and learn how to collaborate in interdisciplinary teams by taking actions to improve their teamwork. In this way, EiT aims at providing students with a learning environment that stimulates the development of reflection and metacognitive skills, as well as overall intellectual development and personal growth.

Assessment in EiT has both formative and summative elements. The continuous interactions between the students, learning assistants, and teachers allows direct feedback and individualized formative assessment that is targeted towards students' current level of cognitive complexity. However, there are limits to the depth and amount of formative assessment that the learning assistants and teachers can provide, as we will discuss later. In addition to the formative assessment, the student teams are assessed on both their project work, as well as their analysis and reflection of their group dynamics and team development processes. The summative assessment is based on a project report and a process report, each worth 50% of their final grade. There are no individual grades; each team is given a grade as a whole. However, all students are required to present an evaluation at the end of the course that focuses on their individual and team development during the period of the course.

Mapping Students' Reflective Capacity

The large scale of the EiT course, in combination with the disciplinary diversity of students provides a challenging situation to support and scaffold individual students' development. This is especially true in the area of reflection and reflective judgment, where students come with a range of different experiences and training. During the time EiT has been offered, a number of anecdotal stories emerged related to perceived difficulties for many EiT students in understanding the reflection and group process components of the course. Taking this as a starting point, the CLAS version of the LRJA was used to map the range of LRJA scores among students. In addition, the cognitive task complexity of the EiT Book of Reflections given to students as a course resource was assessed to get an idea about the match between the students' level and the level of the instructional material.

In this pilot study, the aim was to explore the general suitability of CLAS and develop strategies to frame the system for the students. Therefore, students in selected EiT villages were invited over the last two years to participate in taking the LRJA demo and try out learning activities based on their Lectical score and designed to complement the Lectical reports they received. The students had free access to the system and could do the assessment at any time. Neither the teachers nor the researchers had access to the students' scores or reports directly from Lectica, but students were asked to submit their reports to the researchers in order to adapt the use of CLAS and associated learning materials in the future. Over the two years of this research project, 76 students sent in their reports and scores as input into mapping the range of reflective judgment skills among EiT students (26 in the first year, and 50 in the second year).

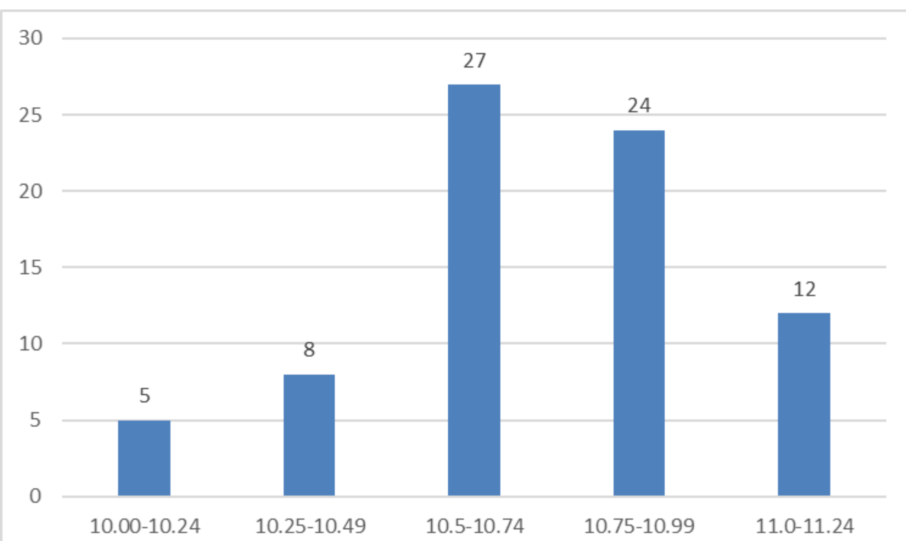

Figure 1. Scores on CLAS version of the LRJA.

The scores from the students ranged from just below 10.2 up to 11.24, as shown in Figure 1. These results indicate that the sample of students participating in the EiT mapping exercise generally fell within the normal range of distribution, which is 10.5 – 11.4 for college students. This pilot study showed that it is possible to get information about the complexity of reflective judgment in a diverse student population that is highly relevant for the course, yet otherwise difficult to obtain. While a normal distribution curve is one aspect, it can also be that different subject areas promote the development of reflective judgment as a skill more than others do (Felder & Brent, 2004; Wankat, 2002). With a limited number of students and a potential self-selection bias that might affect the score distribution, it is however not possible to explore this area more at the moment.

While from a research perspective information about the student population is interesting, detailed information and statistics are primarily of interest in supporting the design process of a responsive learning environment. Here, it is important to point out that CLAS should not be used to stigmatize and judge students, but to enable teachers to provide individuals with the best possible support and scaffolding of their learning and development. The type of mapping described here can be viewed as a starting point, but the focus needs to remain on the individual students in the class.

One area where this type of student population mapping is of interest is in connection with the general design of instructional material that should support students during the course. We therefore chose to score the cognitive complexity of the EiT Book of Reflections, a central resource for the students in their development of reflective skills, with CLAS in order to get an idea of how well it matched with the students' level of cognitive complexity. The text from the EiT Book of Reflections scored 11.2. (Note that the original text is in Norwegian, and the text we scored was translated by one person, which could have contributed to the uniform score across different sections of the book, which were written by different and collaborating authors in Norwegian. As well, there is a larger issue with how different languages construct meaning over time and that building a similar Lectical dictionary in other languages has not yet been attempted). This means that the majority of students in this small sample scored between 0.2 and 0.7 of a Lectical level below the material meant to support them. A gap of 0.25 can be considered to be within their ZPD and the types of activities and explanations provided in the EiT Book of Reflections can be seen as providing an optimal scaffolding and learning activities for these students. For the students scoring in the same range as the Book of Reflections, it is likely that the reflection skills described in the book are already natural cognitive processes. They would likely be able to understand and practice those activities as described without extra effort.

However, for those students whose LRJA scores have a gap from the EiT Book of Reflections of more than 0.25, it could be that the expectations and activities described are outside of their ZPD. This can arise from how constructs used at higher Lectical levels of complexity 'chunk' lower complexity constructs, or have internalized them as implicit, or taken for granted. Thus there can be a lack of sufficiently explicit use of a wider range of constructs that are necessary to provide access for all students to the instructions provided. This could contribute to a number of issues arising for these students, as reported in anecdotal evidence from learning assistants and teachers over time. It could be that they read and discuss with classmates the reflective activities and believe they have understood them, when key aspects implicit in the expectations from EiT may actually be misunderstood. It could also be possible that students read the descriptions and activities in the EiT Book of Reflections and feel frustration at not understanding them. This frustration could contribute to critical or outright negative perceptions and evaluations of the course, giving up on trying out suggested activities, or other forms of reaction to being asked to perform cognitive tasks beyond their ZPD in this skill domain.

In more general terms, it is clear that the general instruction material works very well for some students, but will be more problematic for other students. In the case of the EiT Book of Reflections, it is likely that the cognitive complexity level it implicitly presents is outside of the optimal ZPD for a considerable part of the student population. This mismatch can be mediated through the support from the learning assistants and teachers, but does not provide optimal base conditions for learning. Grounded in our mapping exercise and the potential challenges associated with a mismatch between students' and instructional materials' cognitive complexity levels, we will in the next section discuss our exploratory experiments with the design of instructional material that could address this potential gap. Our aim was how to provide individual students with the necessary support suited for their current level through the design of a more responsive learning environment.

Design of a Responsive Learning Environment in EiT

In the previous section, the variation in students' scores in relation to the level of the instructional material was discussed. In this section, the design of a more responsive learning environment based on the CLAS version of the LRJA in combination with new instructional material will be explored and discussed. The focus in this pilot study lies in using CLAS to support teachers and learning assistants in their ability to scaffold and support student learning. By providing a tool that enables individualized formative assessment that is targeted towards students' current level of cognitive complexity, it is possible to create a more responsive learning environment. Figure 2 provides an overview of the different types of learning materials designed within this study to create a supportive learning environment.

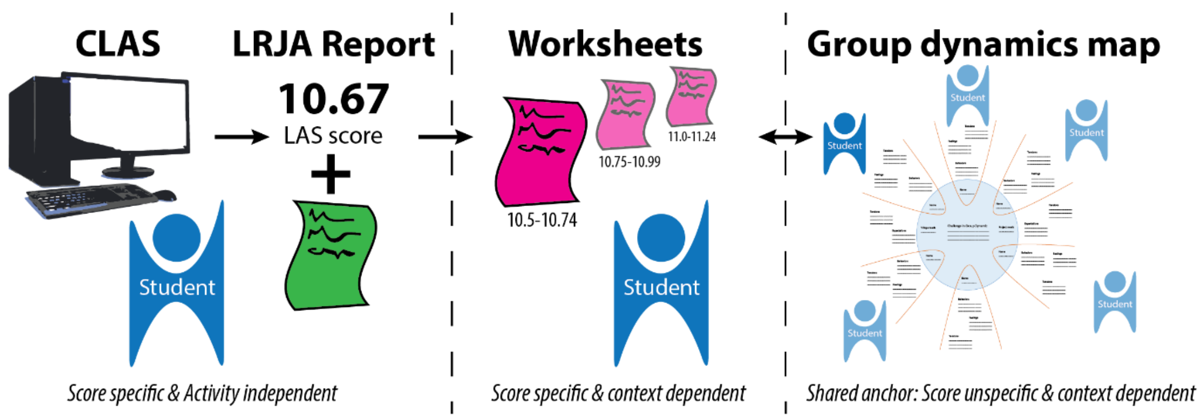

Figure 2. Schematic overview of the CLAS based responsive learning environment with the different learning materials.

Formative assessments that scaffold students' learning and development can be divided into two categories: general formative assessment and context dependent formative assessment (Evans, 2013). General formative assessment is independent of a course's format and content, and provides more general help on how a student can improve. The CLAS version of the LRJA report falls in this category of general formative assessment and the VCoLs associated with it support the students in a broad way, independent of the EiT context. While the information in the report and the VCoLs themselves are useful, as a kind of meta-cognitive process of making the character of their own thinking an objective description that they can then reflect on, it does not necessarily help the students achieve their context specific learning goals within the course. For the current project, the broad nature of these VCoLs provided in the LRJA reports would require significant investment from students in order to adapt them to the more specific contextual requirements of the EiT course.

Therefore, a special interest in this study was on the development of context dependent formative assessment. To bridge the gap between the context specific learning goals in EiT and general LRJA report, a set of worksheets were designed in an attempt to make the learning activities more directly related to aspects of the learning requirements in the EiT course, and increase the perceived relevance of the LRJA. This context dependent formative assessment more easily helps students to realize the value of the LRJA, as it resonates directly with something that they are working on and situates their learning into their current experience (J. S. Brown, Collins, & Duguid, 1989).

The learning material that was designed particularly for the EiT course consists of two parts, a group dynamics map that works as a shared anchor for the students, and context specific VCoLs. The group dynamics map (Appendix A) is a score independent document, which invites students to identify other team members in relation to their behaviors and the feelings and tensions they might experience. It supports students in capturing their current understanding of the group dynamics and how their understanding changes after working with the VCoLs. While the students might have different scores and work with different VCoLs, the map provides the team with a shared document to exchange ideas and develop as a team. The map also anchors the LRJA report and VCoLs to the course by making the use of it explicitly relevant to the desired learning outcomes of increased awareness, reflection, and suggested improvements in the areas of teamwork and group dynamics.

In the first year of this study, a detailed series of context specific VCoLs were designed to closely match the specific LRJA demo reports the students received. (Assessment takers would receive a report based on their Lectical level and feedback focused either on *thinking and deciding*, or on *working with evidence*). The aim was to provide a bridge from the LJRA demo reports to the EiT course requirements and activities. Feedback from the villages and students trying these out was that the process was overly complex and that the links between the LRJA reports, worksheets we provided and their course activities was not clear enough.

This led to revising the set of worksheets and instructional materials in the second year of the study. This time, context specific VCoLs targeting the three predominant phases of student scores were developed and used (10.5-10.74, 10.75-10.99, and 11.0-11.24, also independent of the focus of the LRJA feedback on either *thinking and deciding*, or on *working with evidence*). By developing VCoLs with different cognitive complexities, most students were provided with material that fell within their ZPD . The VCoLs designed for the EiT course were structured around the same five steps as the general VCoLs: Target, seek, apply, reflect, and reset. An example of a worksheet can be found in the Appendix B.

On a content level, two different factors informed the design process, the learning outcomes of the course and the historical knowledge about common student experiences and challenges. By using both factors, the adapted VCoLs coupled material from the LRJA report with the students' activities more directly to the rest of the course than in the first attempt at this the previous year. The aim of these new worksheets was to provide students with methods to gain relevant information about other team members and how their interactions affected the group dynamic. The main adaptation was to take the information seeking phase, which was generally taken straight from the CLAS system, and adapting the application of it to how students could complete their reflection tasks as an individual. To help the students to learn about this and be able to reflect on their experiences, both individually and as a team, the worksheets were designed to make it easier for them to learn from their direct experience in the teams. From this, the students were invited to consider what elements of their individual reflections they might want to share with the team, as a way of contributing to the team reflection activities.

In this way, student learning and development was individualized through CLAS score dependent VCoLs and students on all levels get the optimal instructional material that could support their learning of reflective skills. At the same time, the group dynamic map acted as an anchor to keep the group together and facilitate processes in which all students could contribute to the team development.

Framing this type of next-generation assessment system is a key factor to be considered to develop new formative assessment practices and fully use the opportunities of computerized systems (Heritage, 2010). The advantage of using a computer based system is that students can take the assessment as often as they want and whenever they want (Bull, Quigley, & Mabbott, 2006). In addition, the use of the CLAS system is independent from the university and the students themselves choose if and when they want to share their scores with the teacher. This means that the students themselves stay in control of the whole process, which mediates risks described above (Nicol & Macfarlane-Dick, 2006). Within a responsive learning environment, the information gained from the LRJA can be used to help students take the next step and create learning opportunities that lie within their individual ZPD. As Shepard (2009) pointed out "it is the use of an instrument, rather than the instrument itself that must be shown, with evidence, to warrant the claim of formative assessment" (p. 33). The CLAS version of the LRJA needs to be seen, both by teachers and students, as an entry point for development and growth rather than as a summative assessment. Otherwise, the formative assessment dimension is compromised, and the assessment is seen as a high stakes test, associated with a potential negative impact on motivation for learning, especially for weaker students (Black & Wiliam, 1998). At the same time, the approach described here offers interesting opportunities for HEIs to provide teachers with the necessary tools to support students in their intellectual development.

Summary and Future Research

Overall, the design of responsive learning environments is facilitated by the development of technology solutions like CLAS. However, the skill in framing and integrating of this type of technology into specific learning environments is the decisive factor in the success of scaffolding student learning. It is through the careful and collaborative integration of technology between students and teachers that responsive learning environments can be created.

In this article, we have explored and discussed important aspects to consider when using technology to create responsive learning environments that aim to contribute to the development of self-regulated student learning. The described approach has significant potential to support students and scaffold their development. Supporting and scaffolding students' development is difficult and demanding and this is especially true in large classes, where interactions between teachers and students are limited. Automated systems offer an interesting approach to this dilemma, but need to be balanced through social interactions and framing to minimize the risk of being perceived as summative assessment tools, high stakes tests, or control instruments. While the numerical score provided by CLAS can be helpful to get a better understanding of the overall student population, it is in itself of little help for the students. It is through using the score to inform the design of ZPD and context specific skill building activities that students' learning can be scaffolded efficiently.

Based on the experience and insights that we have gained from this pilot application of the CLAS version of the LRJA in the EiT course, we plan to take further steps to integrate this information about the range of reflective skills students bring to the EiT course with more robust learning activities. In the future, we want to look at two different research directions. First, we will continue to study the effects of responsive learning environments created with the CLAS system and explore students' experiences, development, and reflective capacity in more detail. Within this strand of research, we will also look at possibilities to use CLAS in other courses and further consider the framing of this type of system within the higher education context. In light of the current emphasis on digital tools and formative assessment, we think that CLAS can make an important and interesting contribution in the future, but more research is clearly needed to better understand how to use this type of system in higher education to its full potential.

The other research direction that we want to explore in the future is to combine utilizing dynamic skill theory and the knowledge gained from using the CLAS system with other ways to create responsive learning environments. In particular, we are going to collaborate with a broader group of colleagues on creating a developmentally informed sequence of reflective prompts for students to use in conjunction with their daily journaling activity. For this, we will utilize Snowden's (2010; 2007) SenseMaker platform to enable students to log their journal entries into an online platform, either through a web browser, smartphone or tablet. Students will then be invited to reflect on their entry using the sensemaking process of placing a marker in relation to a triad of three equally weighted signifiers. We will design a sequence of these signification triads keyed to what we understand in relation to the types of constructs that will be in the ZDP of different students. Thus all students can use the same platform, but find the reflective prompts that best fit their learning needs. One advantage of the SenseMaker platform is its flexibility and the fact that it can be adapted more easily to the specific context, as well as to the students' native language. Comparing CLAS and the SenseMaker platform will allow us to gain a deeper understanding of responsive learning environments, their creation, and the underlying learning and development processes stimulate by this type of learning environment.

In summary, we believe that the general aspects of the approach explored and discussed here are highly relevant for many courses in higher education. Using computerized systems in the manner described here can enable HEIs to provide the necessary formative assessments to scaffold students' development in many domains. The possible adaptation of CLAS to a broader range of skill domains is one aspect of this. More broadly, as an essential factor in later success in society, HEIs can help students towards a self-authoring mindset even in large scale courses commonly found in today's mass education by creating responsive learning environments.

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Appendix A

Mapping the Group Dynamic

Appendix B

VCoL Worksheet A

10D Deliberation

Take your group dynamic map and fill in the parts that you already have some ideas about.

Goal: *To fill out parts of your group dynamic map as a rich picture of a system.*

Seek: Watch this video suggested in your report: https://www.youtube.com/watch?v=-sfiReUu3o0 (12 minutes) Then watch this three minute video: https://www.youtube.com/watch?v=17BP9n6g1F0 .Finally, this seven minute video: https://www.youtube.com/watch?v=lhbLNBqhQkc

Make notes on what you learn about systems thinking.

Apply: Examine your group dynamic map and apply your new knowledge about systems thinking to make connections or patterns explicit.

Make any changes to what you noted earlier about specific individuals or contexts.

Reflect: What changed in terms of what you entered into your group dynamic map about different team members? About connections between them? Or between them and the project or village?

Were you surprised by anything you learned?

Write down what you learn from doing this activity in your personal reflection book. Also write down any new insights you get from these dynamics or patterns to the map. Is anything clearer now? Is something new unclear? What would you want to share with the group?

ReSet: Given what you have learned from this process so far, how might you further fill in other parts of your group dynamic map? What else can you clarify, the next time you try it? How might you adjust how you contribute to the group?