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Progression of Self-Directed Learning in PBL: Comparing Consecutive Semesters at AAU

Nicolaj Riise Clausen *

ABSTRACT

The purpose of this article is to describe the results from an investigation of the development of students' attitudes and behaviours conducive to self-directed learning (SDL) in problem-based learning. The article reports the results from an application of a newly validated statistical instrument to measure self-directed learning on bachelor students in sociology and data science, comparing first-, second- and third-year students. The results are analysed through factor analysis and by comparing mean scores across the three generations of students. The results suggest that the students develop their SDL attitudes and behaviours through their first three years at a Problem-based learning (PBL) university, but also show that this is not a linear or uniform process. The results of the factor analysis show that the students develop their ability to be self-regulating during their second year and move towards a more internal locus of control during their third year.[1]

Keywords: Self-directed learning, Problem-based learning, Quantitative, Statistics, Locus of control, Self-regulation

Many modern educational practices incorporate self-directed learning elements to some degree. Recent developments such as the COVID-19 pandemic, as well as the rise of hybrid learning models incorporating opportunities for digital and online cooperation, have emphasised that having a student population able to self-regulate is very advantageous. While we will not fully understand the impact of COVID-19 on the education of current students for a long time, theory and previous research on the practices in use let us

* Nicolaj Riise Clausen, Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability under the auspices of UNESCO, Department of Planning, Aalborg University, Denmark
Email: nclausen@plan.aau.dk

hypothesise about potentially mitigating factors that could help students manage while separated and learning primarily through digital means. One key factor that might alleviate the negative impact is the ability of students to direct their own learning, allowing them to rely less on the authority and support of teachers.

One of the educational models purported to cultivate self-direction in students is problem-based learning (PBL). Several different conceptualisations have highlighted skills for lifelong learning, self-regulation or self-directed learning as an advantageous learning outcome of PBL (de Graaff & Kolmos, 2003; Hmelo-Silver, 2004). Students in PBL environments have been found to attain more deep-level learning, stray further from their teachers' authoritative guidance when seeking information and become continuously more self-reliant throughout their studies (Dolmans & Schmidt, 2000; Loyens et al., 2008). However, these advantages have also been found to be contingent upon the students' developing better self-directed learning (SDL) skills, such as information seeking, personal learning strategies, handling of group discussions and reflecting on their learning (Blumberg, 2000; Blumberg & Michael, 1992; Evensen et al., 2001). Therefore, self-directed learning skills have long been seen as one of the most central learning goals for PBL institutions, essentially an antecedent for many of the other advantages, as well as one of the most significant benefits.

While many efforts have been made to investigate the connection between PBL and SDL, two key factors set our study apart. First, most studies have focused on case-based PBL models often applied by medical and nursing programs. In contrast, our efforts will focus on the project-oriented PBL practiced at Aalborg University (AAU), which is applied mostly by engineering programs. One of the most significant differences between the models is the length of the typical self-directed learning cycle; while cases are often completed within a week, a typical student-directed project at AAU spans a full semester. Second, most studies, especially those conducted within project-oriented models, have investigated PBL implementations at a course or semester level, while students at AAU are exposed to an institutionalised implementation of PBL.

One study that looked at SDL development within an engineering PBL context showed mixed results. The study concluded that a statistically significant increase in readiness for SDL could be found in the students, but that upon further analysis the outcomes were found to be very ambiguous, some students even reporting significantly lower readiness for SDL (Litzinger et al., 2005). Another study, applying the same statistical instrument as in this article (the OCLI) in an institutionalised PBL environment at the University of Toronto Faculty of Medicine, found no significant correlation between the students' progression of study and level of SDL (Harvey et al., 2003). These studies show that the proposed correlation between SDL and PBL is not always present, and lead us to ponder further about what the development of SDL might be contingent on.

The AAU model has often been highlighted because of its role as one of a few reform universities that have implemented institutionalised PBL across all study programs; as such, a lot of research has also been done into this particular institution and its approach to PBL. One of the special elements that have been highlighted at AAU as essential to the model is the first-year course that introduces students to the problem-based project-oriented approach. This course is supported by an explicit focus on learning collaborative skills, process competences and what is otherwise conceptualised as PBL skills (Kolmos et al., 2019; Spliid, 2011). Previous evaluations of the progression of skills related to PBL, such as SDL, at AAU, have found that among all the problems first-year students faced, the ones they rated the hardest to manage were to structure and regulate their work and to collaborate in groups (Kolmos, 1999). One way of managing this is to help the first-year students by simplifying the task of operationalisation. Staff often provide students with a catalogue containing project proposals in the first and second semester, gradually directing continuously less of the process of problem identification and analysis, until the students are able to fully self-direct the process, being given as little as a theme for the semester (de Graaff et al., 2016).

The purpose of the study is to test the hypothesis that students develop attitudes and behaviours conducive to self-directed learning through their education at Aalborg University, where they are engaged in a PBL curriculum. We focus on the first few years of the students' education, elaborating on individual aspects of SDL, developed from year to year. We achieve this through the application and analysing of the results of the Oddi Continuing Learning Inventory (OCLI) on five cohorts of students from two bachelor programs in sociology and data science. The OCLI has recently been translated into Danish and validated in an effort to evaluate its properties in the cultural context of Denmark. During the validation, a confirmatory factor analysis revealed a revised factor structure with three factors that we will apply in this article: (1) internal locus of control (ILoC), (2) ability to be self-regulating and (3) avidity for learning (Clausen & Hansen, 2022).

BACKGROUND

Self-directed learning in Problem-based learning

In problem-based learning, self-direction is often seen as a critical component, as both an advantageous learning outcome of the approach and as a specific goal. One of the perceived advantages of PBL is that students gain a deep and complex understanding of the subjects of their projects. There is, however, the inherent danger that the students might lack the broad knowledge of their field. SDL has often been seen as a learning goal for PBL to mitigate such issues, making sure that students have the means to attain whatever shortcomings of knowledge they might have (de Graaff & Kolmos, 2003).

Counterintuitively, one of the elements highlighted as conducive to developing good SDL skills in PBL is group work. Group work has been found to promote the development of competencies needed to ask good questions and give explanatory feedback. The correlations between the methods of PBL and the skills needed in SDL have also been emphasised by research. Students of PBL tend to develop strategies and plans for their work and manage to integrate a lot more new information in their problem solving, As long as they are allowed to define their learning objectives (Evensen, 2000; Hmelo & Lin, 2000).

A highlighted issue for PBL in connection to SDL is that of less mature learners, who tend to have difficulty engaging with self-direction and require a higher degree of external scaffolding and structuring of their work (Hmelo-Silver, 2004; Knowles, 1980; Tough & Knowles, 1985). A related issue is that this particular type of learner tends to be less reflective about their learning, a characteristic that is crucial for developing and modifying personal learning strategies to be effective (Evensen et al., 2001).

In an attempt to evaluate the synergies between SDL and PBL, Loyens, Magda, and Rikers (2008) found that PBL fosters at least some of the SDL skills encompassed in what Brookfield conceptualised as the techniques of SDL (Brookfield, 1985, 1986). They found, among other things, that students in PBL environments applied a more comprehensive range of resources and information relating to their learning goals than their peers in traditional programs (Loyens et al., 2008). These findings are very similar to those of both Evensen and Blumberg (Blumberg, 2000). Schmidt and Dolmans found that during the span of their education, PBL students become continuously more self-reliant, depending less on lectures but increasingly on group discussions (Dolmans & Schmidt, 2000). Results that to some extent mirror these are those of Kivela and Kivela who studied students during an implementation of PBL in Hong Kong. They found that the students relied on the teachers' guidance to a lesser extent after having been subject to PBL. In their first semester they tended to rely on their fellow students, but this tendency seemed to have lessened in their second year, where they seemed to have developed self-direction and autonomy to some extent (Kivela & Kivela, 2005).

Through a literature review, Blumberg looked into the evidence that problem-based learners are also self-directed. She found that PBL students become very active library users compared to students in traditional education. Blumberg also found that the students of PBL generally seek many more sources of knowledge and tend to stray further from the teacher-assigned literature than traditional students, self-directing their literature search (Blumberg & Michael, 1992; Blumberg & Sparks, 1999). They seemed to develop what she referred to as 'library skills', self-directed information-seeking behaviour. Another finding was that PBL students tend to employ learning strategies that secure their deep-level learning, seemingly resulting in more learning for meaning instead of

recitation. A general observation was that this same strategising for learning and reflection seemed to give them an advantage in assessing materials and structuring their work and studies (Blumberg, 2000). Evensen also found that in first-year medical students in a PBL learning environment, there were indications that they had developed skills for dealing with reflections on learning, environmental influences, goal setting and self-efficacy and had developed strategies for information seeking (Evensen, 2000).

Self-directed learning

The origins of the concept of self-directed learning (SDL) in modern learning research is often attributed to either Allen Tough, who in 1967 first conceptualised the SDL project, or his contemporary, Malcolm Knowles, who had a more theoretically-oriented approach and argued for assumptions specific to the adult learner. Some would contend that Carl Rogers was an initial influence, because as early as 1958, he famously concluded that 'I have come to feel that the only learning which significantly influences behaviour is self-discovered, self-appropriated learning' (Rogers, 1958; Tough, 1967).

Another central figure whose importance is difficult to overemphasise is Cyril Houle, of whom both Allen Tough and Malcolm Knowles were students. In 1961 he authored *The Inquiring Mind*, in which he described the characteristic behaviours, activities and motives of adult learners who could readily be identified as such by their surrounding community, and identified three characteristic groups of learners based on the orientation of their motivation (Houle, 1961). With *The Inquiring Mind*, Houle sparked a trend of explorative research efforts within SDL, seeking to describe and outline adults' self-initiated learning efforts and attempting to define and delimit it as a research subject, establishing a tangible focus for investigations. Through his authorship, Houle contributed notably to SDL's collective knowledge base, but he arguably had an even more significant impact by inspiring his two aforementioned students, Malcolm Knowles and Allen Tough.

Malcolm Knowles focused primarily on the distillation of theory, and while he is acknowledged as having worked extensively with SDL, he primarily conceptualised it through the term 'andragogy', which he popularised, understanding it as a 'model of assumptions about learning or a conceptual framework that serves as a basis for an emergent theory', and as one end of a continuum, opposite pedagogy (Knowles, 1989). Andragogy roughly translates to 'leading men' in the same way that pedagogy translates to 'leading children'. Knowles initially theorised that pedagogy and andragogy were diametrical opposites and directly correlated with the learners' age, children being malleable and dependent upon strong teachers for direction and guidance. Knowles thought that this was because of their limited experience, making them less critical about what to learn and how it would benefit them afterwards. Adult learners, on the other hand, were understood to be self-directed and motivated by the immediate application of new-

found knowledge (Knowles, 1970). Knowles later arrived at the opinion, through correspondence with primary-school teachers who had applied the tenants of andragogy and reported excellent results, that the assumptions about learners in pedagogy and andragogy were not necessarily linked to age, but rather to a set of characteristics, some of which usually, but not necessarily, correlated with age (Knowles, 1975, 1980).

Allen Tough had a very different and much more empirical approach. His developed methodology has had an enormous impact on the research field of SDL, primarily through the design of his highly structured interview scheme, which has been replicated extensively over the years. It is among the most influential methods in the field and makes up one of the most obvious of the previously mentioned research efforts inspired by Houle. While Tough's methodology can hardly be said to have been explorative, his findings played a large part in outlining SDL as a research subject and proving the extensive prevalence of self-directed learning projects. The obvious strength of Tough's interview scheme is its highly structured nature, which has allowed researchers worldwide to replicate his studies, supplementing the already disclosed results with their own. Tough's approach was to study particular learning projects undertaken by a given individual, defining learning projects as 'a series of related episodes, adding up to at least seven hours' where 'more than half of the person's total motivation is to gain and retain certain fairly clear knowledge and skill, or to produce some other lasting change in himself' (Brockett & Hiemstra, 1991; Tough, 1971).

Tough and his associates initially conducted 66 interviews, finding that the learners themselves planned 68 % of all learning projects. Along with the monumental finding that less than 1% of the initiated learning projects were motivated by attaining particular institutional credits, this was very surprising at the time, seeing that earlier scholars had assumed that a majority of projects were instigated institutionally. Another curious finding of his initial study was that although learning projects were planned and thought out individually, the actual learning rarely took place in isolation (Tough, 1966, 1967).

Given these significant findings, learning project studies played a considerable role in SDL and adult education research, to the point where later researchers in the field have suggested that any further iterations should be avoided, considering the methodology applied in such a vast number of studies that any further uses would be redundant at best (Caffarella & O'Donnell, 1988). Other critics have pointed out that the deductive approach along with the rigid interview structure might help reproduce misconceptions cemented in the underlying conceptions of the interview scheme that other new approaches to the field might otherwise help dispel, further emphasising the need for different approaches in the research of SDL (S. Brookfield, 1981). It should be noted that Allen Tough originally developed his learning project approach to illuminate how

widespread the phenomenon of SDL is, an objective his efforts absolutely succeeded in accomplishing (Tough, 1971).

SDL and Statistical Instruments

One of the research methods to take up the mantle from Tough's learning project research was statistical instruments designed to measure SDL in different ways (Brockett & Hiemstra, 1991). To this end a number of self-reported questionnaires were developed, most successfully the Self-Directed Learning Readiness Scale (SDLRS) in 1977 and the OCLI in 1984.

Lucy M. Guglielmino developed the SDLRS for her doctoral dissertation to, as the name suggests, ascertain how ready individuals were for self-directed learning. She was motivated by prior studies, which had revealed high attrition rates in independent study programs. These studies found that this was likely caused by a misalignment between the requirements the students had previously experienced and those set by the self-direction needed by the independent study programs. Another key motivation for Guglielmino was the experiences of Dunbar and Dutton (1972), who had attempted to convert a traditional business school to a more self-directed learning approach, but had apparently failed because of the students' unpreparedness for the transition. Guglielmino reasoned that a statistical instrument designed to assess students on several skills and attitudes related to SDL would allow facilitators to better identify students ready for SDL, as well as help the individual student recognise areas for improvement. The SDLRS was thus developed primarily as a predictive instrument for people preparing to begin academic self-directed learning at a high-school, college or graduate level (Guglielmino, 1977). The resulting instrument was a 58-item questionnaire, applying a 5-point Likert scale.

Another instrument that was developed to measure the concept of SDL, though with a slightly different approach than the SDLRS, is the OCLI, which was created partly as a reaction to some of the criticisms of previous instruments of measurements. Lorys Oddi adopted a new perspective in developing the instrument in that she conceptualised SDL not as an instructional process, but rather as a personality trait that determined certain behavioural tendencies characterised by initiative and persistence in learning over time and which often correlated with the maturity of the learner (Oddi, 1984).

Lorys Oddi developed the OCLI by deducing three underlying theoretical dimensions from a review of the literature and findings on SDL. The three dimensions of personality exist as continuums, each end representing a trait either conducive or nonconductive to SDL. The dimensions were theorised to be overlapping and mutually reinforcing and were described by Oddi as:

- Proactive drive versus reactive drive: 'This dimension focused on the learner's ability to initiate and persist in learning without immediate or obvious external reinforcement.'
- Cognitive openness versus defensiveness: 'Salient characteristics of CO/D included openness to new ideas and activities, ability to adapt to change, and tolerance of ambiguity. The opposite pole included attributes such as rigidity, fear of failure, and avoidance of new ideas and activities'.
- Commitment to learning versus apathy or aversion to learning: 'Salient characteristics of CL/AAL included the expression of positive attitudes toward engaging in learning activities of varying sorts and a preference for more thought-provoking leisure pursuits. The opposite pole included expressions of indifferent or hostile attitudes toward engaging in learning activities and reports of less engagement in activities commonly regarded as promoting learning'. (Oddi, 1986)

Oddi then formulated 100 items representing the three dimensions, gradually reviewing and reducing the number of items through content validation by getting law, nursing and adult education graduate students and a panel of adult education experts to review them. This resulted in 65 items that were subsequently reduced to 31 through a pre-pilot study with 30 respondents, including an evaluation of individual items, item analysis and evaluations of item-total and item-subscale score correlations. The 31-item instrument was then administered to 287 law, nursing and adult education students and reduced to 26 items through a factor analysis, obtaining five interpretable factors accounting for 44.5% of the total variance. Through further validation, Oddi found that two items correlated negatively with the total instrument score and they were therefore removed, resulting in the final 24-item instrument.

The OCLI has subsequently been extensively validated, initially by Oddi herself, who conducted several construct validations, testing the instrument against other, thoroughly validated instruments of theoretical constructs that she reasoned the OCLI would either correlate with, correlate negatively with or not correlate with (Oddi, 1984).

In addition to the construct validations, studies of the factor structure of the OCLI have also been conducted. Most of the studies reveal similar factor structures, indicating that the factors are mostly stable across contexts and cultures (Harvey et al., 2006; Oddi, 1984; Six, 1989; Straka, 1996). For a thorough analysis of previous validation efforts and a validation of the factor structure, see (Clausen & Hansen, 2022).

METHOD

Sample

This article presents findings from a study of students' self-directed learning conducted in 2019. The OCLI was sent to 754 students, of whom 400 replied with a complete response. Sociology and data science were selected as cases because of the high number of students in each program and the perceived diversity between the two studies. It was a priority for the authors to research the development of SDL skills in two very different groups of students, making the common denominator the application of project-oriented PBL. Professors responsible for lectures for the students selected for the study were contacted, and all but one offered the authors time during a course lecture for data collection. The students were all in the first month of their second, fourth, or sixth semester when they answered the survey, so the sample from the first-year students must not be considered a pre-test before they started their university education, but can more accurately be viewed as a measure of their development through the first semester.

	Responses (n)	of total	Response rate
1st Year	101	25.25 %	67.3 %
2nd Year	203	50.75 %	58.5 %
3rd Year	96	24 %	37.4 %
Total	400	60 %	53.1 %

Table 1. Response Rate.

Data Collection and Management

The students were informed about the study during a lecture; immediately after the presentation they received the questionnaire by email and were given time to answer it during the class. The questionnaire used was a Danish translation of the OCLI, which had been validated on a separate sample of students (Clausen & Hansen, 2022). The researcher's presence ensured that all the students received the same information about the questionnaire, had adequate time to answer and experienced no technical difficulties. The students' answers were subsequently loaded into IBM SPSS Statistics 25.0, which was used for all analytical purposes. The authors have not removed any respondents as outliers or otherwise invalid.

Analysis

A few factor structures were initially tested on the data in an exploratory effort to ensure that the model with the best fit on the data would be presented in the article. The most recently validated factor structure was expected to result in the best fit on the data, and analysis confirmed this assumption. The factor structure in question has three factors: (1) internal locus of control, a measure of a student's general belief in their ability to successfully influence their work, including items like *I successfully complete tasks I undertake* and *When I do a job well, it's because I have been prepared and have put in*

personal effort, (2) ability to be self-regulating, comprising of reverse-coded variables like *I'm not comfortable with my performance on an assignment until my supervisor, teacher or colleague says it's acceptable* and (3) avidity for learning, with questions like *I have been an eager reader since childhood.* The validation and reinterpretation of the instrument along with the revised factor structure is explained in greater detail in author (year). The derived factors, as well as the total scores of the OCLI scale, will be used to compare students across semesters. They will be analysed as independent samples; means, standard deviations and two-tailed tests of significance are reported and discussed when relevant. Two-tailed tests are preferred over single-tailed because of previously reported results not supporting the theoretically backed notion of correlation between progress in PBL education and OCLI-score (Harvey et al., 2003).

Levene's test for equality of variances is applied to ensure that appropriate adjustments can be made if the observed variance in the compared parts of the population are not approximately the same (Brown & Forsythe, 1974; Schultz, 1985).

RESULTS

All results from the statistical analysis will be briefly presented in this section and discussed in the subsequent. This format has been applied to allow for as much transparency as possible, allowing the reader to see any and all results, before engaging in the discussion. In this presentation of the results, all significant differences (p-value < 0.05) will be described.

The scores will be presented chronologically, initially examining the differences between the first- and second-year students, then the second- and third-year students. Lastly, we will look at the results from comparing the first- and third-year students, summarising the two years as a whole. For all comparisons, the scores for the total OCLI score and each of the factors will be presented.

Differences Between First and Second-Year Students

The only factor with a significant difference between the populations is the ability to be self-regulating, which sees a rise in mean score from the first (M = 12.87, SD= 4.29) to the second year (M = 14.12, SD= 4.47) $t(302) = 2.332$, $p = 0.020$.

	Means		Standard deviation		P-value	Levene's test for equality of variance		Degrees of freedom	T-test
	1st year	2nd year	1st year	2nd year		F	Sig.		
OCLI total score	106.91	108.38	13.33	12.94	0.355	0.129	0.720	302	0.926
Internal locus of control	31.48	31.23	4.6	4.91	0.678	0.323	0.570	302	0.416
Ability to be self-regulating	12.87	14.12	4.29	4.47	0.02*	0.352	0.554	302	2.332
Avidity for learning	28.79	28.95	5.26	4.98	0.798	1.323	0.251	302	0.257

Table 2. Differences Between First- and Second-Year Students.

Differences Between Second and Third-Year Students

Scores on the total OCLI scale were significantly higher for third-year *(M* = 111.57, *SD*= 12.95) than for second-year students *(M* = 108.38, *SD*= 12.94), *t*(297) = 1.989, *p* = 0.048. The results also show a significant rise in the internal locus of control of second-year *(M* = 31.23, *SD*= 4.91) and third-year students *(M* = 32.83, *SD*= 3.74), *t*(238) = 2.829, *p* = 0.002. Levene's test for equality of variance was significant, so a correction of degrees of freedom was made.

	Means		Standard deviation		P-value	Levene's test for equality of variance		Degrees of freedom	T-test
	2nd year	3rd year	2nd year	3rd year		F	Sig.		
OCLI total score	108.38	111.57	12.94	12.95	0.048 *	0.038	0.846	297	1.989
Internal Locus of Control	31.23	32.83	4.91	3.74	0.002 **	5.687	0.018	238	2.829
Ability to be self-regulating	14.12	14.47	4.47	5.49	0.591	12.213	0.001	157	0.579
Avidity for learning	28.95	29.32	4.98	5.57	0.562	2.607	0.107	297	0.581

Table 3. Differences Between Second- and Third-Year Students.

Differences Between First and Third-Year Students

As seen from Table 4, third-year students have a significantly higher OCLI score *(M* = 111.57, *SD* = 12.95) than first-year students *(M* = 106.91, *SD* = 13.33), *t*(195) = 2.488, *p* = 0.014. We can also note that there is a rise in the students' internal locus of control from

their first year *(M* = 31.48, *SD* = 4.6) to their third *(M* = 32.83, *SD* = 3.74), *t*(195) = 2.265, *p* = 0.025. The students additionally report a significantly improved ability to be self-regulating from the first year *(M* = 12.87, *SD* = 4.29) to their third *(M* = 14.47, *SD* = 5.49), *t*(180) = 2.269, *p* = 0.024 (Levene's test indicated unequal variance (*F* = 12.696, *p* < 0.001) so degrees of freedom were adjusted from 195 to 180).

	Means		Standard deviation		P-value	Levene's test for equality of variance		Degrees of freedom	T-test
	1st year	3rd year	1st year	3rd year		F	Sig.		
OCLI total score	106.91	111.57	13.33	12.95	0.014*	0.020	0.887	195	2.488
Internal locus of control	31.48	32.83	4.6	3.74	0.025*	2.976	0.086	195	2.265
Ability to be self-regulating	12.87	14.47	4.29	5.49	0.024*	12.696	0.000	180	2.269
Avidity for learning	28.79	29.32	5.26	5.57	0.492	0.203	0.653	195	0.688

Table 4. Differences Between First- and Third-Year Students.

DISCUSSION AND CONCLUSION

From the comparisons presented above we can see that that the overall hypothesis that the students develop attitudes and behaviours more conducive to SDL as they progress in their studies at AAU seems to be confirmed by the data, in the sense that third-year students have a significantly higher OCLI total score than the first-year students. Most of the rise in total scores happens from the second to the third year, resulting in a significant difference between those student groups, compared to a non-significant one between the first- and second-year students. While the difference between the first- and second-year students is non-significant, Table 2 shows a slight rise in the mean score. The most obvious inference is of course that the students seem to develop attitudes and behaviours conducive to SDL between their first and third years at AAU. This is especially interesting because of the results from Harvey, Rothman, and Frecker who applied the same instrument on a cohort of medical students in a PBL environment and found no significant rise, even seeing a fall in total OCLI scores from one year to the next, thereby proving that PBL does not guarantee a rise in OCLI total scores (2003). Looking more closely at the results, we can see that the difference in OCLI total scores is mostly a product of two independent significant rises – the ability to be self-regulating from the first to second year and internal locus of control from the second to third year.

One factor that might help explain the progression is that students have recently transitioned from a typically very traditional classroom setting, with an asymmetric power relation between students and teachers, to a project-oriented setting with more symmetric power relations, where they are often met by supervisors who offer more questions than answers as the students themselves become specialised experts within the subject area of their projects (de Graaff et al., 2016; Kolmos et al., 2008). The management of such a transition from a learning environment where the students can rely heavily on their teachers as authority figures who either approve or reject their work to one where they act more like a member of the group and that supports student group autonomy might be essential to the progression we observed. Studies have found that thrusting students into a more self-directed learning environment without adequate clarification of expectations and time to prepare can negatively affect students' retention and learning (Dunbar & Dutton, 1972; Margarones, 1961; McCauley & McClelland, 2004). Rogers remarked that for such a move to be successful and not cause the students too much anxiety, learners must gradually become accustomed to the added responsibility for their learning (C. Rogers, 1969). One could theorise that the drop in internal locus of control from the first to the second year, although non-significant, might be related to this notion of transition. Our data suggests that this transition is handled appropriately at AAU, as we see the students develop self-regulating behaviour and attitudes as well as a heightened affinity towards SDL, unlike what we have seen from other studies in PBL environments (Harvey et al., 2003). Our results support previous studies showing that students engaged in a PBL environment supported by SDL had developed a preference for self-directed learning by year two of their education. One of the same studies also found that students moved from dependence on their lecturers and groups to be much more independent and intrinsically motivated, having a higher internal locus of control (Kivela & Kivela, 2005). This notion also supports the second result from the factor analysis, namely, the move to a more internal locus of control from the second to the third year of study.

This type of student development has previously been theorised in the literature on SDL, maybe most notably by Knowles in defining the set of assumptions about learners that define andragogy. Knowles saw pedagogy and andragogy and the assumptions about the learner derived from each as two ends of a spectrum (Knowles, 1970). An interpretation of our findings based on this notion could be that what we perceive as a rise in SDL is the learners' maturing from pedagogical to andragogical learners. This would entail them becoming less dependent on teacher guidance, approval and extrinsic motivation, and instead developing a preference for self-regulation, becoming critical of their teachers' authority and craving intrinsic motivation and control. Knowles remarked in later writings that for a transition to SDL to be successful, the students initially need direction and facilitation (Knowles et al., 2005). At AAU, a part of this facilitation is the first

semester PBL course, which introduces the students to the AAU model, offering them tools to better engage in problem-based projects and making them reflect on their previous and current practices. Another key aspect is the gradual transition of responsibility for defining and analysing the problem at the centre of projects to the students themselves, allowing them to ease into directing their own learning step by step (Kolmos et al., 2008, 2019). Taking this and our results into account, another interpretation could be that the first semester course, gradual transition into self-direction and experience with PBL and project work initially allows the students to self-regulate their projects, learning and practising the craftsmanship of problem analysis and project work. Subsequently, based on experiences of success in project work, they then gain belief in their ability to work well within the AAU model, moving them to a more internal locus of control. This interpretation would explain the sequence of the students' developments in our data.

There are certain limitations to our study that future research should address. Most notably, our research design does not, by design, yield results which allows us to elaborate on students' experiences of their transition to the self-directed learning environment of a PBL institution and the development of SDL. Qualitative studies should be conducted to gain these insights. Although access to the respondents might be limited, a true pre-test, conducted, if not before, then as close to the start of the students' enrolment at AAU as possible could also help improve the reliability of our conclusions. An iteration of the study with longitudinal data across three years on the same cohort of students would also remove some doubts as to whether or not fluctuations between the generations might have affected the statistics, although we have no reason to believe such fluctuations exist within our data. A data collection where each student could be followed individually would also allow researchers to check for selection bias, e.g., whether what we measure as a rise in mean scores is actually an effect of the students with the lowest scores dropping out.

References

Blumberg, P. (2000). Evaluating the Evidence That Problem-Based Learners are Self-Directed Learners: A Review of the Literature. In D. H. Evensen & C. E. Hmelo (Eds.), *Problem-based Learning—A Research Perspective on Learning Interactions* (pp. 199–226).

Blumberg, P., & Michael, J. A. (1992). Development of self-directed learning behaviors in a partially teacher-directed problem-based learning curriculum. *Teaching and Learning in Medicine, 4*(1), 3–8. https://doi.org/10.1080/10401339209539526

Blumberg, P., & Sparks, J. (1999). Tracing the evolution of critical evaluation skills in students' use of the Internet. *Bulletin of the Medical Library Association*, *87*(2), 200–205.

Brockett, R. Grover., & Hiemstra, Roger. (1991). *Self-direction in adult learning: Perspectives on theory, research, and practice*. Routledge. https://eric.ed.gov/?id=ED359423

Brookfield, S. (1981). The Adult Learning Iceberg: A Critical Review of the Work of Allen Tough. *Adult Education (London)*, *54*(2), 110–118.

Brookfield, S. D. (1985). Self-directed Learning: A conceptual and methodological exploration. *Studies in the Education of Adults*, *17*(1), 19–32.

Brookfield, S. D. (1986). *Understanding and facilitating adult learning: A comprehensive analysis of principles and effective practices*. Open University Press.

Brown, M. B., & Forsythe, A. B. (1974). Robust Tests for the Equality of Variances. *Journal of the American Statistical Association*, *69*(346), 364–367. JSTOR. https://doi.org/10.2307/2285659

Caffarella, R., & O'Donnell, J. M. (1988). Research in Self-Directed Learning: Past, Present and Future Trends. In H. B. Long (Ed.), *Self-directed learning: Application and theory.* University of Georgia.

Clausen, Nicolaj R. & Hansen, Claus D. (2022). Revitalizing the Oddi Continuing Learning Inventory. *International Journal of Learning, Teaching and Educational Research, 21*(5). https://doi.org/10.26803/ijlter.21.5.18

de Graaff, E., Holgaard, J. E., Bøgelund, P., & Spliid, C. M. (2016). When Students Take the Lead. In *(Re)Discovering University Autonomy: The Global Market Paradox of Stakeholder and Educational Values in Higher Education* (pp. 125–135). https://doi.org/10.1057/9781137388728_9

de Graaff, E., & Kolmos, A. (2003). Characteristics of Problem-Based Learning. *International Journal of Engineering Education*, *19*(5), 657–662.

Dolmans, D. H. J. M., & Schmidt, H. G. (2000). What directs self-directed learning in a Problem-Based Curriculum? In *Problem-based Learning—A Research Perspective on Learning Interactions* (pp. 251–262).

Dunbar, R. L. M., & Dutton, J. M. (1972). Student Learning in a Restructured Environment. *Journal of Research and Development in Education*, *6*(1), 26–39.

Evensen, D. H. (2000). Observing self-directed learners in a problem-based learning context: Two case studies. In *Problem-based Learning—A Research Perspective on Learning Interactions* (pp. 263–297).

Evensen, D. H., Salisbury-Glennon, J. D., & Glenn, J. (2001). A qualitative study of six medical students in a problem-based curriculum: Toward a situated model of self-regulation. *Journal of Educational Psychology*, *93*(4), 659–676. https://doi.org/10.1037/0022-0663.93.4.659

Guglielmino, L. M. (1977). *Development of the self-directed learning readiness scale (Doctoral dissertation).* [University of Georgia]. https://search-proquest-com.zorac.aub.aau.dk/docview/302856217?pq-origsite=primo

Harvey, B. J., Rothman, A. I., & Frecker, R. C. (2003). Effect of an Undergraduate Medical Curriculum on Students Self-Directed Learning. *Academic Medicine*, *78*(12), 1259–1265. https://doi.org/10.1097/00001888-200312000-00015

Harvey, B. J., Rothman, A. I., & Frecker, R. C. (2006). A confirmatory factor analysis of the Oddi Continuing Learning Inventory (OCLI). *Adult Education Quarterly*, *56*(3), 188–200. https://doi.org/10.1177/0741713605286167

Hmelo, C. E., & Lin, X. (2000). Becoming Self-Directed Learners: Strategy Development in Problem- Based Learning. In *Problem-based Learning A Research Perspective on Learning Interactions* (pp. 227–250).

Hmelo-Silver, C. E. (2004). Problem-Based Learning: What and How Do Students Learn? *Educational Psychology Review*, *16*(3), 235–266. https://doi.org/10.1023/B:EDPR.0000034022.16470.f3

Houle, C. (1961). *The inquiring mind.* University of Wisconsin Press. http://www.worldcat.org/title/inquiring-mind/oclc/1013274

Kivela, J., & Kivela, R. J. (2005). Student perceptions of an embedded problem-based learning instructional approach in a hospitality undergraduate programme. *International Journal of Hospitality Management*, *24*(3), 437–464. https://doi.org/10.1016/j.ijhm.2004.09.007

Knowles, M. S. (1970). The modern practice of adult education: From pedagogy to andragogy. In *Business*. https://doi.org/10.1109/HICSS.2002.994194

Knowles, M. S. (1975). *Self-directed learning—A Guide for Learners and Teachers*. https://doi.org/10.1016/j.jcrysgro.2011.10.051

Knowles, M. S. (1980). What is Andragogy? In *The modern practice of adult education* (pp. 40–59). https://doi.org/10.4324/9780203802670

Knowles, M. S. (1989). *The making of an adult educator: An autobiographical journey*. Jossey-Bass.

Knowles, M. S., Holton, E. F., & Swanson, R. A. (2005). *The Adult Learner—The definitive classic in Adult Education and Human Resource Development*. Elsevier.

Kolmos, A. (1999). Progression of Collaborative Skills. In J. W. A. null Conway & J. W. A. null Conway (Eds.), *Themes and Variations in PBL, Vol. 1: Refereed*

Proceedings of the 1999 Bi-ennial PBL, Conference, July 7-10, 1999, Montreal, Canada.

Kolmos, A., Bøgelund, P., & Spliid, C. M. (2019). Learning and Assessing Problem-Based Learning at Aalborg University: A Case Study. In *The Wiley Handbook of Problem-Based Learning* (pp. 437–458). John Wiley & Sons, Inc.

Kolmos, A., Du, X., Holgaard, J. E., Jensen, L. P., Kolmos, A., Du, X., Holgaard, J. E., & Jensen, L. P. (2008). *Facilitation in a PBL environment*. UCPBL UNESCO Chair in Problem Based Learning.

Litzinger, T. A., Wise, J. C., & Lee, S. H. (2005). Self-directed Learning Readiness Among Engineering Undergraduate Students. *Journal of Engineering Education*, *94*(2), 215–221. https://doi.org/10.1002/j.2168-9830.2005.tb00842.x

Loyens, S. M. M., Magda, J., & Rikers, R. M. J. P. (2008). Self-Directed Learning in Problem-Based Learning and its Relationships with Self-Regulated Learning. *Educational Psychology Review*, *20*(4), 411–427. https://doi.org/10.1007/s10648-008-9082-7

Margarones, J. J. (1961). *Critical requirements of independent study based upon an analysis of critical incidents as observed and reported by students and instructors* [Boston University]. https://open.bu.edu/handle/2144/26838

McCauley, V., & Mcclelland, G. (2004). Further studies in Self-Directed Learning in Physics at the University of Limerick, Ireland. *International Journal of Self-Directed Learning*, *1*(2).

Oddi, L. F. (1984). *Development of an instrument to measure self-directed continuing learning* [Northern Illinois University]. https://search-proquest-com.zorac.aub.aau.dk/docview/303318103/abstract/2CF04F6547564F81PQ/1?accountid=8144

Oddi, L. F. (1986). Development and validation of an instrument to identify self-directed continuing learners. *Adult Education Quarterly*, *36*(2), 97–107. https://doi.org/10.1177/0001848186036002004

Rogers, C. (1969). *Freedom to Learn: A View of What Education Might Become* (1st ed.). Charles Merill.

Rogers, C. R. (1958). Personal Thoughts on Teaching and Learning. *Improving College and University Teaching*, *6*(1), 4–5.

Schultz, B. B. (1985). Levene's Test for Relative Variation. *Systematic Zoology*, *34*(4), 449–456. JSTOR. https://doi.org/10.2307/2413207

Six, J. E. (1989). The Generality of the Underlying Dimensions of the ODDI Continuing Learning Inventory. *Adult Education Quarterly*, *40*(1), 43–51. https://doi.org/10.1177/074171368904000105

Spliid, C. M. (2011). Mastering projects and processes in the Aalborg PBL model. *PBL across the Disciplines: Research into Best Practice. Aalborg: Aalborg Universitetsforlag*, 555–568.

Straka, G. A. (1996). Construct validation of the Oddi Continuing Learning Inventory. In *Current developments in Self-Directed Learning.* (pp. 65–80). Classic Book Distributors.

Tough, A. (1966). The assistance obtained by adult self-teachers. *Adult Education, 17*(1), 30–37. https://doi.org/10.1177/074171366601700105

Tough, A. (1967). *Learning without a teacher: A study of tasks and assistance during adult self-teaching*. Ontario Institute for Studies in Education, Toronto, Ontario, Canada.

Tough, A. (1971). *The Adults Learning Project—A Fresh Approach to Theory and Practice in Adult Learning*. Ontario Institute for Studies in Education.

Tough, A., & Knowles, M. S. (1985). Andragogy in Action: Applying Modern Principles of Adult Learning. *The Journal of Higher Education*. https://doi.org/10.2307/1981081

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