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Self-perceived and observable self-direction in an online asynchronous programming course using peer learning forums

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This study broadens the objectives of previous work (Boyer, N., Langevin, S., Gaspar, A. (2008). Self direction and constructivism in programming education. *Proceedings of the ACM Special Interest Group in IT Education Conference*, 16–18 October 2008, Cincinnati, OH) in which we used a survey-based instrument, the Personal Responsibility Orientation Self-Directed Learning Scale – PRO-SDLS (Stockdale, S. L., & Brockett, R. G. (2006). *The continuing development of the PRO-SDLS: An instrument to measure self-direction in learning based on the personal responsibility orientation model*. Paper presented at the 20th International Self-Directed Learning Symposium, Cocoa Beach, FL), as a new perspective to measure the impact of innovative approaches in the teaching of computer programming in online courses. The data have been collected during the offering of an undergraduate online asynchronous programming course delivered in 2008 at the University of South Florida Polytechnic. Our primary pedagogical intervention has been the use of peer learning forums which attempt to (1) leverage peer learning dynamics in an online course, (2) help students better structure their work on a weekly basis, and (3) help them learn to engage actively with the material (e.g. exercises, reading assignments). This article studies the impact of peer learning forums on these students through the lens of various instruments. Some, such as the PRO-SDLS, are well established in the self-directed learning literature. Others are introduced in this article to provide a more complete picture of both the students' self-perception of their self-direction and its more observable aspects. We also identified intrinsic characteristics of our student population, which we believe to have a significant impact on these instruments' measures. Finally, we relate these data to student feedback obtained through more open question surveys. These observations, made using diversified instruments, on a small and well-characterized learner population, represent the foundation of our case study. Our findings suggest that, after using the peer learning forums for an entire semester, the self-perception of our over-committed online adult learners' ability for self-directed learning has evolved to realign itself with more observable manifestations of their self-direction.

Keywords: self-direction; Personal Responsibility Orientation Self-Directed Learning Scale; PRO-SDLS; observable self-direction; peer learning forums; learning habits

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Introduction

The ability for a professional to be self-directed in their learning is paramount to them staying up to date in their field. This skill is even more critical in technological fields that develop particularly rapidly. Such skills should be fostered in our students as early in the curriculum as possible as part of preparing them to be successful in their careers in the long term.

To this end, we introduced a new learning activity in an online asynchronous novice-level programming course offered in 2008 at the Information Technology department of the University of South Florida Polytechnic. *Peer learning forums* were used on a weekly basis in order to help better prepare our students to (1) learn on their own from written technical documents, (2) interact with peers to improve their knowledge of difficult technical contents, (3) better structure their work on a weekly basis, and (4) engage more actively with the material (e.g. exercises, reading assignments).

In order to investigate the role played by peer learning forums to attain these objectives, we reviewed the self-directed learning literature and identified an instrument to evaluate students' levels of self-direction: the Personal Responsibility Orientation Self-Directed Learning Scale – PRO-SDSL (Stockdale & Brockett, 2006), which we will define in more detail in the Methodology section. Preliminary observations from data collected for the purpose of course improvement during the summer of 2008 revealed that the students' levels of self-direction decreased over the course of the semester. The observations made from these data led us to further investigate this phenomenon by collecting data during the fall semester of 2008 and analyzing it with the help of other instruments that are able to complement the perspective offered by the PRO-SDLS instrument. More specifically, we considered the following potential shortcomings of our use of the PRO-SDLS in such a specific discipline:

- The PRO-SDLS is meant to measure self-direction in a rather general manner, regardless of the subject matter. It is conceivable that students who are generally self-directed might find themselves uncomfortable with programming activities. The fact that *IT Program Design* is an early course in our curriculum means that we are more likely to find, among enrolled students, individuals who will later opt out of the discipline after realizing it was not what they expected.
- It is also conceivable that our students' responses to the PRO-SDLS survey reflect a perception they have of themselves, which has not yet been challenged by the requirements of an asynchronous programming online course.

In order to investigate these possibilities, we set out to combine the PRO-SDLS measures of how students perceive themselves as self-directed with more objective indicators, which we developed to allow us to recognize *indicators of observable self-direction*. Note that this Observable Self-Direction (OSD) should be distinguished from the self-direction construct insofar that it relates only to those aspects of self-direction, which have an observable effect on the way the student engages in the various learning activities used in this specific course. Therefore, the two concepts should not be considered as equivalent.

The following questions, based on our preliminary data collected during summer 2008, guided our exploration during fall 2008:

- How can students' self-direction levels be assessed based on the questions they post to a mandatory, weekly peer learning forum?
- How does their self-direction, as measured by the PRO-SDLS instrument, relate to how their self-direction is expressed through their participation in peer learning forums?
- How does their self-direction, as measured by the PRO-SDLS instrument, relate to their learning habits?

In order to investigate these questions, we developed two complementary instruments to provide us with a more discipline-specific and less student-centric view of the phenomenon. We coined the term "Observable Self-Direction" (OSD) to characterize the learner's behaviors that are captured by these instruments and that constitute an observable aspect of their self-direction with a direct impact on their learning strategies. The first of these indicators is an attitude survey inquiring about the students' learning habits (e.g. the nature of the learning activities in which the student engaged). The second is a coding scheme to classify students' question posts in the peer learning forums, using indicators of self-direction, or lack thereof, in their formulation or their content. The measures provided by both the PRO-SDLS and these two new instruments are compared with student satisfaction and feedback in order to shed some light on how peer learning forums, as a social technology supporting peer learning in an online asynchronous course, impacted our students' sense of self-direction.

The peer learning forums, as well as the instruments used to analyze their impact on students, are generic enough to be adapted to various settings and disciplines. However, the results presented in this article should only be considered in the light of the specificities of the contents being taught, i.e. programming, and, even more importantly, in the light of the specificities of our student population. The latter has been established by querying students, early in the semester, about their academic and professional workload. This allowed us to establish that many of our online students were actually enrolled in too many classes to devote to them the required time in addition to their already existing professional commitments. We termed these *overcommitted adult learners* to concisely describe the nature of the intrinsic characteristics of our case study population. This allows us also to better understand the results provided by our various instruments and suggest reasonable hypotheses about how they differed from our original expectations.

The remainder of this article will be organized as follows. The next section presents the research design we adopted as well as the instruments we used and/or developed in order to gain a multifaceted perspective on our student population. We then describe the context of this study in order to help the reader consider our results in context. We then present our results in two sections on data analysis, focusing on the results obtained by each instrument individually as well as the relations existing between them. These are followed by a discussion of the role played by the peer learning forums in explaining our observations, based on student feedback collected at the end of the semester. Finally, we conclude with a discussion of our results.

Methodology

This section details the overall research design used in this study as well as the various instruments used to measure both the students' self-perceived self-direction and their observed self-direction.

Overall methodology

Before we discuss our observations from the application of the instruments mentioned above, it is necessary to outline explicitly the constraints under which this study has been conducted in terms of research design, scope, and intent.

This study does not aim to offer generalizations applicable to any junior-year programming course. Our intention is to present an in-depth exploration of a single entity and phenomenon. This phenomenon is bounded by time (fall 2008) and activity (IT Program Design course). Our observations are derived from a collection of detailed information obtained through a variety of data collection methods over the course of the semester. This exploration leads us to formulate hypotheses explaining the observations made from the collected data. These hypotheses are then tested to see how well they match reality by comparing and triangulating the results of the different instruments being used. Instead of presenting "generalizable" results that may not be applicable to any other student population than those sharing our students' and institutional specificities, we aim to offer a unique interpretation of events meant to generate further research into the observed phenomena we describe. Such a research design is typical of qualitative research methodologies and, more specifically, of the case study methodology as it is described by Merriam (1998) and Creswell (1994, 1998).

Our initial approach led us to develop our work into a *critical case study* meant to explore the impact of peer learning pedagogies on the students' self-direction in the context of a well-characterized student population, i.e. "*overcommitted adult learners*," specific field and discipline, i.e. Information Technology and programming, and delivery method, i.e. online asynchronous offering.

Such a case study requires the population to be observed from the perspective of a variety of instruments. One of the goals stated previously is to explore how self-perceived self-direction, as expressed by the PRO-SDLS, relates to observable self-direction, as expressed by students' participation in peer learning forums. In order to reflect on how the self-direction construct differs from its observable counterpart, new instruments had to be introduced to complement the perspective offered by the PRO-SDLS measures. Observations were based on two main types of instruments: (1) direct observations of the students' usage of peer learning forums over the duration of the semester, and (2) their answers to pre- and postattitude surveys exploring their self-direction and learning habits. Because of the nature of these instruments, quantitative data were leveraged to explore the phenomenon in hand. However, the discussion of these numerical results should not be interpreted as a shift in our study to a quantitative approach with claims of generalization. Our research design is simply hybrid, with a dominant/less dominant articulation between the critical case study and the statistics used as part of our observation of our bounded phenomenon.

Our surveys were administered online, using surveymonkey.com, during the first and last weeks of the semester. The presurvey was made mandatory by using it to

take "online attendance" during the first week, in compliance with "first day attendance" policy of the USF. However, students had the option to login to the survey instrument but opt out of actually answering its questions. The postsurvey was optional and available for students as a way to gain extra credit for the course. It is interesting to note that our experience with administering such optional, for-credit surveys' at the end of the semester over the past 2 years did not enable us to draw any conclusion on which students were volunteering for them. We had situations in which concerned students volunteered to take these in an attempt to get extra points to reach a passing grade or simply to ask later for extra points in the light of their good will over the semester. We also had exceptional students not taking them because they already had a A+ grade or, simply, because they had already a passing grade and were only aiming for such a performance.

Survey results were not accessible directly to the instructor but were instead received and processed by a team member not involved in the teaching of this course and who provided the instructor with a list of students who took the survey for crediting purposes. Only after the end of the semester did all team members gain full access to the data for analysis purposes.

Instrument no. 1 – measuring self-perceived self-direction with PRO-SDLS

In order to measure students' self-perceived self-direction, we relied on the PRO-SDLS instrument (Stockdale & Brockett, 2006), which was administered during both the pre- and postsurveys using an online survey tool. The scale consists of 25 questions representing two subcomponents: teaching-learning transaction component, which focuses on the teaching and learning process itself, and learner characteristic component, which focuses on the students. Within these two subcomponents are four factors: initiative, control, self-efficacy, and motivation. Likert-scale responses were used for these questions and represented the values strongly disagree (1) to strongly agree (5). The total possible score on the instrument is 125. The initiative, control, and self-efficacy factors have a maximum sum score of 30 with the motivation factor having a maximum sum score of 35.

For the purposes of this study, the Personal Responsibility Orientation model (Brockett & Hiemstra, 1991a,b) is used as a foundation for investigating self-directed (2) behaviors with the information technology discipline. Brockett & Hiemstra (1991a,b) describe self-direction as a combination of process and personal elements in which an individual "assumes primary responsibility for a learning experience" (pg. 24). Within their model, despite the emphasis placed on the internal characteristics of the individual, the social context also plays a critical role surrounding the learning experience. While the concept of self-direction is not a new one (Merriam & Brockett, 1997), its application to the study of programming pedagogies is innovative.

The factors that are integrated into the overall PRO-SDLS instrument represent four key elements: initiative, control, motivation, and self-efficacy, which contribute to an individual's perspectives and capacity to engage in self-directed learning. Table 1 provides sample questions for each of the factors. Initiative, taking personal action on an issue, which in this context relates to the learning process, has been identified by Knowles (1975) and Hiemstra & Brockett (1991) as a critical (3) component of the learners' ability to self-direct. The factor of control ties to the learner's ability to have ownership of the learning process and the act of learning

itself. Motivation, the reason and personal incentive that a person has for learning, coupled with volition has been noted in Garrison's (1997) comprehensive model of self-directed learning as a key component of self-direction. The final factor of the PRO-SDLS, self-efficacy, relates to a person's belief that they can ultimately exhibit agency, control, and/or mastery in a particular task (Gecas, 1989).

We computed the Cronbach's Alpha for the entire presurvey data set by using not only the students enrolled in IT Program Design but also all IT students enrolled in a course, which used the PRO-SDLS in its presurvey. This sample, with $n = 65$, allowed us to get a more statistically significant measure of the reliability of this instrument. Results confirmed the reliability of the overall instrument; Cronbach's Alpha scores for each element of the test are reported in Table 1. Overall, these strong alpha values suggest confidence that the questions are adequately capturing the concepts that we hope to measure.

Instrument no. 2 – measuring observed self-direction in peer learning forums

In order for us to observe students' self-direction with respect to programming as it is expressed through the participation in weekly peer learning forums, we devised a simple way to classify students' question posts into three categories. We developed two indicators discriminating between posts featuring positive (OSD/PLF+) and negative (OSD/PLF−) indicators of observed self-direction with respect to peer learning forums. Posts that did not match either indicator did not provide insights about the students' observable self-direction and were therefore assigned to a third "N/A" category. To simplify the definition of these indicators and the process of identifying them in students' posts, we started by separating all available posts into several broad types of questions. Each row in Table 2 corresponds to such a different type of question. For each of them, we then defined the two above-mentioned indicators and provided examples. The result of this work is presented in Table 2 and is discipline-specific with respect to the subject being taught: programming.

Instrument no. 3 – measuring observed self-direction with regard to learning habits

In order to observe students' self-direction from yet another perspective, we asked the following question, together with the PRO-SDLS instrument, in both pre- and postsurveys:

Table 1. PRO-SDLS reliability analysis.

PRO-SDLS factor	Cronbach coefficient alpha	Sample question
Initiative	0.80	I frequently do extra work in this course just because I am interested.
Control	0.811	If I am not doing as well as I would like in this course, I more often independently make the changes necessary for improvement.
Motivation	0.83	I complete most of my college activities because I WANT to, not because I HAVE to.
Self-efficacy	0.83	I am very convinced I have the ability to take personal control of my learning.
Overall	0.89	

Table 2. OSD indicators in peer learning forums with regard to programming.

Type of question	OSD/PLF+ Positive OSD indicator	OSD/PLF− Negative OSD indicator
The student asks for help verifying a hypothesis they have.	The hypothesis indicates that the student has developed an understanding (*correct or not*) of the situation – an understanding of what they are having problems with. The student points out perceived contradictions in the text or attempts to consolidate divergent perspectives presented within text or in various external sources. e.g. *"Section 3.9 states that x is always > y which I understand is because of the alignment problem, but then the program in figure 3 doesn't check for that explicitly. Does this mean the constraint is not implemented?"*	The hypothesis doesn't indicate that the student has developed an understanding (*correct or not*) of the situation. This encompasses direct requests for re-explanation of portions of the material without specifics. e.g. *"I don't understand section 3.9", "can I get more examples of sorting algorithms?"*
The student asks for help understanding a concept.	The concept is not covered in the material and the student's question indicates that they tried to gather information about it first. e.g. *"I'm assuming that sizeof measures the size of a variable by looking up its memory location?"* The student's question indicates that they are trying to understand how to apply specific knowledge beyond the scope of this class. e.g. *"The text refers to the pow( ) function and others but where do you find information on which functions are available for your programs?"*	The concept is already covered in the material; the student's question doesn't acknowledge the information provided in the text, the nature of the difficulties understanding it, or even what parts were understood. e.g. *"I can use the sizeof operator in my programs but I'm not sure how it works?"*

(*continued*)

Table 2. (*Continued*).

Type of question	OSD/PLF+ Positive OSD indicator	OSD/PLF− Negative OSD indicator
The student asks for help while experimenting with existing programs.	The student requests help to understand the reasons behind the results of experimenting with a program (trying alternative syntax, modifying an example or solved exercise, testing a specific construct). While the reasons for the outcomes are not clear, the student provides evidence of having actually experimented hands-on with the program. e.g. *"I used a %21.2f in my printf with various numbers (see list below) and it seems the 21 doesn't care about the number of decimals. This is not what is explained in section 9.3 though!"*	The student requests that others tell him what would happen when running a certain program, using a syntactical construct in a certain way, or modifying an example in a certain way. The outcome could be simply observed by actually typing the program and experimenting with it. e.g. *"What would happen if I used Printf instead of printf in one of my programs?"*
The student asks for help to solve a programming problem.	The student has developed for themselves a program to solve the given assignment. The student provides detailed information about the erroneous behavior exhibited by their program. The student provides information about hypothetical reasons for their program's erroneous behavior. e.g. *"My program is always off by one in the Fibonacci series and I've tried starting my loop at 0 or 1 but it seems it's the conditional that is not appropriate; any help?"*	Student asks for a solution to a given programming assignment without providing evidence of having worked on a solution of their own; e.g. a specific problem they encountered making their solution work. The student provides a program and requests that others find out what is wrong with it. e.g. *"Why is the program below not working?"* e.g. *"I don't understand how to start program 9.9"*

What kind of learning activities do you usually engage in while working on a course at home (check as many as apply)?

- Reading the textbook's assigned chapters
- Reading the textbook's unassigned or extra material*
- Doing assigned exercises (graded ones)
- Doing assigned exercises (nongraded ones)*
- Doing unassigned exercises (picked yourself)*
- Re-doing exercises for which you already have the solution*
- Reading the solutions to such exercises without redoing them
- Searching online for extra material (explanations)*
- Searching online for extra material (exercises to do)*
- Searching online for extra material (code samples)*
- Others

The responses marked with an asterisk (*) are the ones that we used as positive indicators of observed self-direction with respect to learning habits (OSD/LH+). Respondents were given one point for each positive indicator selected, resulting in an OSD/LH+ indicator ranging from 0 to 7. No student provided "others" responses.

Perspectives studied in this article

Both pre- and postsurveys measured our students' self-perceived self-direction, via the PRO-SDLS instrument, and their OSD/LH+ via the above-described multiple choice questions. In addition, both OSD/PLF+ and OSD/PLF− indicators were derived from the contents of students' posts in the peer learning forums over the entire semester. In the next two data analysis sections, we will consider two different samples of students:

- S1 ($n = 14$), the students who took the mandatory presurvey (entire class)
- S2 ($n = 5$), the students who took both the pre- and postsurveys
- We will use these samples to focus on two different perspectives;
- Perspective 1 – the differences between S1 and S2 on the presurvey
- Perspective 2 – the evolution of measures on S2 from the pre- to the postsurvey

The former can provide insight on how students from S2, who did not drop and volunteered for extra credit by taking the postsurvey, differ from the overall set of students enrolled during week 1 (S1). The latter can help us understand what impact, if any, our pedagogies had over the course of a single semester on students' self-direction as measured by the PRO-SDLS, OSD/PLF, and OSD/LH perspectives. Therefore, perspective 1 is intended to help us establish whether S2 was representative of S1 during the presurvey. If this is the case, it is therefore possible for this study to suggest that both subpopulations are similar enough to allow generalization from S1 to S2.

We recognize that our subpopulation S2 is extremely small with $n = 5$ and we do not claim to draw generalizations out of the results we will observe in it. Our intent is to leverage our measurements to better understand the phenomena that took place during the offering of IT Program Design to this specific group of students. Correlations between the various measures will be reported, along with their

statistical significance, for the purpose of presenting a concise and detailed picture of our student population.

The next section will provide detailed information about the context in which this study has been undertaken.

Background to this study

This section introduces the institutional, course-related, student-related, and pedagogical specificities of the study to help the reader assess the results in context.

Pedagogies used in IT program design

IT Program Design is a programming course intended for students who have already been exposed to at least one introductory programming course (typically taught in Java or C++ at community college level). It reexplores the fundamentals of programming by using a lower-level language, C, in order to not only strengthen students' programming rigor but also prepare them for upper level, system-oriented courses in the IT curriculum (e.g. operating systems). This course's online asynchronous offering relies heavily on weekly learning activities, which leverage peer learning dynamics through Blackboard's forums. Every Monday, students are assigned one or more chapters to read from their textbook. An online module is made available, which specifies the reading assignment and provides ''apprenticeship exercises'' (Gaspar, Langevin, & Boyer, 2008). The latter offer students the opportunity to apply the material to hands-on problems and are accompanied by solutions in the form of videos, which show them how to develop the programs from scratch, rather than providing a completed solution. We found in a previous study that this approach was a suitable adaptation of the idea of cognitive apprenticeship to programming courses (Boyer, Langevin, & Gaspar, 2008). By Thursday, students are expected to have posted one or more questions on a weekly peer learning forum devoted to the module being studied. These questions are meant to help students overcome learning barriers they encountered during their readings or while working on the apprenticeship exercises. The deadline is meant to give enough time for other students to see all the questions before the week is over. Students who indicate having no questions are required to post ''challenge questions'' on what they deemed to be the most difficult aspect of the material. This allows them to get credit when working on modules with which they do not have issues. From Thursday to Sunday, students revisit the posts and attempt to answer their peers' questions. It was expected that this would be easy for students who already grasped the material but would most likely lead others to realize they might have missed parts of the material and therefore revisit these, guided by their peers' questions. Each peer learning forum is graded; students receive credit points for timely and meaningful posts (both questions and responses). Over the 16-week semester, nine forums are used, each associated with a single module introducing new content. Three more, nongraded, forums are also used as a way to review prior to each of the exams. The Monday after the release of a module, the instructor ''wraps up'' every thread in the previous week's forums and provides answers to students; confirming responses which were appropriate and correcting those which were not. New mini-lecture videos are released, where appropriate, to convey answers to particularly difficult questions that tend to recur each semester. In addition, a graded quiz is released for students to take within a week in order to test

their conceptual and factual understanding of the contents of the previous module. Finally, the following module's reading assignments, apprenticeship exercises, and forum are released and a new weekly learning cycle begins.

These cycles encompass a variety of learning activities that require students to engage with the material by reading it passively at first but then by also revisiting in the context of specific peer questions that they are unable to answer. It also requires them to articulate specific questions about what they have difficulties with and make the effort to communicate both difficulties and solutions to their peers. Because of the lack of synchronous class meetings, these activities rely on the ability of the students to take control of their learning process. Despite the fact that regular deadlines are provided to motivate students and prevent them from falling behind, students are still the only ones who can elect to do a ''good job'' on the various activities rather than simply ''getting through'' them. This is where their ability to self-direct their own learning plays the most important role and is therefore one of the primary qualities we are hoping to see students develop to be successful learners and IT professionals.

Population and sample

This case study's population consists of students enrolled in an undergraduate Information Technology (IT) program; our sample consists of 14 students who were enrolled in the online asynchronous IT Program Design course offered at the Information Technology department, IT, of the University of South Florida Polytechnic, USFP, in fall 2008. Most of these students have transitioned from a community college into the university following the 2 + 2 model established within the State of Florida. Others may be more mature adults returning for further education beyond technician-level credentials. Most students are therefore non-traditional with regard to employment. This makes it extremely interesting to investigate how existing pedagogical interventions, which have been studied with traditional student populations, fare with students who often have little time (or motivation) for in-depth learning and might be tempted to get a ''drive through'' education as a way to facilitate professional advancement.

Our sample is composed of 13 males and 1 female. Ten students are 30 years old or younger (four were from 18 to 20 and six were from 21 to 30) and four students are older (three were from 31 to 40 and one was from 41 to 50). Table 3 summarizes our sample's characteristics in terms of workload. Students were asked in the presurvey about their course load (i.e. number of three-credit courses taken during the semester) and their workload (multiple choice with options such as working full time for more than 40 h, working less than 40 h, working less than 30 h). Responses indicate that there are no nonworking students in our sample, with an even division between those employed part and full time. At the same time, 11 of 14 students are taking more than 6 credit hours, implying that there is some overlap between those students employed full time and those enrolled in more than two courses that semester.

Table 3. Sample population workload ($n = 14$).

Academic workload (number of courses taken)	1 (2), 2 (1), 3 (1), 4 (8), 5 (2)
Professional workload	None (0), part time (7), full time (7)
Estimated overall workload (hrs)	Mean = 64.62, std dev = 25.36, min = 18, max = 75

In order to estimate how many of these students are *overcommitted adult learners*, we computed each student's overall workload by assuming that each credit hour would require 3 h weekly. A three-credit course would therefore translate to 9 h of work every week, which is a safe assumption given the 12 h expectation for face-to-face courses, including 3 h of class meeting. We then added to this number the hours they reported being employed. For the latter estimation, we rounded down "full time employment" to 40 weekly hours, "less than 40 h" to 35 weekly hours, "less than 30 h" to 25 weekly hours, and so on. One student was removed for analysis purposes due to reporting 67 credit hours taken (which would have been impossible); the sample size was therefore temporarily reduced to 13.

Results indicate that these 13 students have on average 65 weekly hours worth of academic and professional commitments. In fact, nine students, about 69% of our sample, have a workload exceeding 60 h a week with a mean of 79.33 weekly hours, [standard deviation 7.81; minimum value 72 and maximum value 90]. This confirmed that much of our sample is composed of "overcommitted adult learners."

Our experience at the IT department of USFP has confirmed that this is not an unusual circumstance. This specificity of our student population allows our study to be considered a critical case study of the application of an online pedagogy to overcommitted adult learners. While many studies of novice programmers may revolve around a specific learning barrier of a cognitive nature, this work integrates the learning experience further in its social context, as is usual for case studies, thus enabling us to gain a better understanding of how external factors affect the expected pedagogical impact on students. We observed that the quantity and quality of our students' participation to the peer learning forums is often not related to their academic performance, but rather to either the time they devote to these activities or the misconceptions they might have about what college education might represent in the IT field. Many have taken IT training courses and fail to see the relevance of more in-depth, less know-how, knowledge. Others are used to regurgitate knowledge at exams and find it unfair for the instructor to expect them to develop an ability to solve never-seen-before problems. The time constraints and students' expectations of what IT Program Design should be, often clash with the academic realities and reflects in the results we will be discussing in this article along with more traditionally studied cognitive dimensions of learning how to program.

The next section will begin by looking at the measures obtained from each instrument independently; PRO-SDLS, OSD/PLF, and OSD/LH. The following section will then explore correlations between these instruments' measures.

Data analysis – independent instruments' viewpoints

This section investigates perspective 1, i.e. the differences between S1 and S2 on the presurvey, and perspective 2, i.e. the evolution of S2 measures between the pre and postsurvey. We do so based on the measures obtained by applying the PRO-SDLS, learning habits surveys, and our classification of students' questions posts to S1 and S2.

Self-perceived self-direction analysis with PRO-SDLS

Descriptive statistics for the overall PRO-SDLS scores for both samples and both pre- and postsurveys are presented in Table 4.

Based on perspective 1, both samples S1 and S2 are strongly similar in their PRO-SDLS scores in the presurvey. This would indicate that, although not all of our 14 students who took the presurvey also took the postsurvey, both samples feature comparable PRO-SDLS results. We will use the instruments detailed in the following subsections to establish how the samples relate to one another from the various perspectives used in this study.

Based on perspective 2, Table 4 confirms a trend, which was already observed in two other instances; the offering, in 2008, of "IT Program Design" and "IT concepts," a breadth-first introduction to the IT field for junior-standing students, taught by a different instructor. Both were taught in an online asynchronous delivery format and both featured a decrease of students' self-perceived self-direction.

The first hypothesis we mentioned in our introduction was that, given the recent conversion of our IT program to online offerings, these students might have been confronting their self-perceived self-direction with the realities of taking a non face-to-face course for the first time. We therefore looked at other questions in our presurvey, which were meant to establish the extent of their experience with various delivery modes as well as their preferences. The results are summarized in Table 5. We considered five types of delivery modes: face-to-face courses with weekly scheduled meetings (F2F), face-to-face courses augmented with online contents or interaction (F2F + Web), online synchronous course with weekly scheduled online

Table 4. Descriptive statistics for PRO-SDLS scores [n=14 (S1) and $n = 5$ (S2)].

	S1 pre	S2 pre	S2 post
Mean	90.64	91.60	84.00
Std dev	12.30	13.35	4.74
Min	75	75	78
Max	109	107	91

Table 5. Students' experiences and preferences with delivery methods.

Students experiences	F2F	F2F + Web	Online synchronous regular	Online synchronous irregular	Online asynchronous
Percent of students in S1, $n = 14$	100%	64.29%	42.86%	21.43%	64.29%
Percent of students in S2, $n = 5$	100%	40%	40%	20%	100%
S1 preferences					
Mean	3.50	3.21	3.07	3.07	4.14
Std dev	1.22	1.12	1.00	1.14	1.17
Min	1.00	1.00	1.00	1.00	1.00
Max	5.00	5.00	5.00	5.00	5.00
S2 preferences					
Mean	3.40	3.40	2.80	3.00	4.40
Std dev	1.60	1.60	1.21	1.38	1.97
Min	2.00	2.00	2.00	2.00	3.00
Max	4.00	4.00	3.00	4.00	5.00

meetings using software such as Elluminate (online synchronous regular), online offering using synchronous meetings only a few times in a semester for review sessions (online synchronous irregular), and online asynchronous courses with no scheduled meetings (online asynchronous).

Students' experiences are expressed as a percentage of the respondents who were already exposed to each delivery method. The lower portion of the Table 5 presents descriptive statistics for students' pedagogical preferences as a Likert-scale value ranging from 1 "strongly dislike" to 5 "strongly like."

These data indicate that all students in S2 and approximately two thirds (65%) of students in S1 had already experienced an online asynchronous offering. This rules out the hypothesis that their self-perceived self-direction might be solely based on the face-to-face offering but still raises the question of to what extent these previous courses, although they were using a similar delivery method, relied more on traditional instructivist lecturing formats rather than requiring students to engage in peer learning interactions and to take the initiative for their learning, for example, posting questions rather than attending a preset lecture.

The preferences are similar between both samples and indicate that these students preferred online asynchronous delivery formats. Together with the previous observation, this observation rules out the possibility that most of the students were negatively influenced by the delivery format, leaving the pedagogy of content and the pedagogy of instruction as the main variables that could have impacted them over the course of the semester.

Observed self-direction in peer learning forums

We used Table 2 to categorize the students' peer learning forum posts; two of the authors independently classified the questions and then compared their results in order to refine the instrument. The results of our classification are provided in Table 6. For each student, we measured what proportion of their posts was classified in each of the three possible categories.

Based on perspective 1, both S1 and S2 have similar OSD/PLF− proportions. However, they differ with respect to the N/A (8.39% *vs.* 17.78%, respectively) and OSD/PLF+ (32.72% *vs.* 23.11%, respectively) proportions. The higher proportions of "N/A" indicates that question posts from S2 were either harder to categorize or simply not indicative of any positive or negative OSD. S2 is also apparently less

Table 6. Student postdistributions relative to OSD/PLF indicators.

	OSD/PLF+	OSD/PLF−	N/A
S1			
Mean	0.32	0.58	0.08
Std dev	0.31	0.31	0.19
Min	0	0	0
Max	1	1	0.66
S2			
Mean	0.23	0.59	0.17
Std dev	0.32	0.33	0.28
Min	0	0.33	0
Max	0.6	1	0.66

self-directed than S1 according to OSD/PLF+ . This observation is particularly interesting when taking into consideration the similar PRO-SDLS mean scores obtained by both samples. We will refine our judgment as we explore, in the next section, correlations between self-perceived self direction and the various OSD instruments.

Perspective 2 is irrelevant with respect to the OSD/PLF indicators insofar as the measures are not based on pre- and postsurveys but semester-long observations on students' peer learning forums question posts.

Observed self-direction in learning habits

We now take a look at students' responses to pre- and postattitude surveys on learning habits. Table 7 provides descriptive statistics for OSD/LH+.

Based on perspective 1, the S2 sample is composed of students who selected more of the learning habits we deemed indicative of self-direction in OSD/LH+.

Based on perspective 2, the pre and postdifferences in S2 indicate a negative impact on students' self-direction, in line with the observations made on their self-perceived self-direction's evolution.

Data analysis – relationship between self-perceived and observable self-direction

This section looks at the relationship between previously discussed self-direction measures from both perspective 1 and 2. Table 8 summarizes the correlations of the overall PRO-SDLS scores with the three indicators we have used so far. In the case of OSD/LH +, the information was extracted either from the pre- or postsurvey for correlation with the equivalent PRO-SDLS measurement. In the case of OSD/PLF+ and OSD/PLF−, the same data were used when correlating these scores to

Table 7. OSD/LH + descriptive statistics.

	S1 pre	S2 pre	S2 post
Mean	2.93	4.2	2.4
Std dev	2.02	2.59	0.55
Min	1	2	2
Max	7	7	3

Table 8. PRO-SDLS overall scores *vs*. OSD indicators correlations.

	S1 pre	S2 pre	S2 post
Correlations PRO-SDLS overall score with:			
OSD/LH+	0.011	−0.041	0.096
OSD/PLF+	**−0.584**	−0.247	**0.791**
OSD/PLF−	**0.535**	0.220	−0.140
Significance of above correlations			
OSD/LH+	0.485	0.474	0.439
OSD/PLF+	**0.014**	0.344	**0.056**
OSD/PLF−	**0.024**	0.361	0.411

the overall PRO-SDLS scores in both pre- and postsurveys; unlike OSD/LH +, which is measured through a survey administered along with the PRO-SDLS and therefore available as pre- or postmeasures, the OSD/PLF indicators reflect semester-long observations. For S1 ($n = 14$), statistical significance at $p = 0.05$ is achieved by correlations stronger than 0.5, whereas for S2, $n = 5$, such a significance would require a correlation higher than 0.8. Table 8 presents the Pearson correlation coefficients and their significance with respect to a one tailed hypothesis. Most significant correlations appear in bold; others will be used the latter to discuss suggested trends in the smallest sample of our case study. Note that the correlation between overall PRO-SDLS scores and OSD/PLF+ in the postsurvey on S2 is significant at $p = 0.06$.

Perspectives 1 and 2 on PRO-SDLS vs. OSD/LH+ results

Table 8 reveals that the OSD/LH+ indicator never correlate to the level of statistical significance with the PRO-SDLS scores. This is true whether looking at the data from perspective 1, both samples S1 and S2 feature a virtually random relationships with PRO-SDLS scores in the presurvey, or from perspective 2 since both pre and postmeasures on sample S2 lead to statistically insignificant correlations (although the correlation coefficient for the post PRO-SDLS is higher than the pre, its significance does not rise to even near the required level). This suggests that PRO-SDLS and OSD/LH+ might capture different perspectives on students' self-direction.

Perspective 1 on PRO-SDLS vs. OSD/PLF+ and OSD/PLF− results

Table 8 reveals that both samples, S1 and S2, feature the same relations although the correlations are not statistically insignificant in the latter, likely due to the rather small number of cases. In both cases, however, the overall PRO-SDLS scores correlate negatively with the OSD/PLF+ indicator and positively with the OSD/PLF− indicator. These correlations (which are statistically significant in S1 [$p = 0.014$ for OSD/PLF+ and $p = 0.024$ for OSD/PLF−] but not in S2, likely due to the low n) indicate that the self-perception students have of their own self-direction contradicts our observable measures. This might be interpreted as a flaw in either the PRO-SDLS instrument or the instrument used to categorize posts in the OSD/PLF+ and OSD/PLF− indicators detailed in Table 2. This might alternatively be interpreted as a flaw in the way the latter was applied to the peer learning forums' data or a bias in the way students perceive themselves.

Perspective 2 on PRO-SDLS vs. OSD/PLF+ and OSD/PLF−

Perspective 2 reveals that the pre- and postmeasures on S2 feature an inversion of sign when computing the correlations between the PRO-SDLS results and OSD/PLF+ then OSD/PLF−. In the postsurvey, these measures are respectively positive and negative with PRO-SDLS overall scores. However, the only statistically significant correlation is that of PRO-SDLS overall scores with OSD/PLF+. It suggests that, since none of our instruments changed, the students realigned their self-perception of their own self-direction to something more compatible with the observations that were made through their participation to the peer learning forum

activities. This variation happened over the course of the semester and after the students had been exposed to the learning routines implemented in this offering and received feedback on their performance through various grades. It is worth noting that, although participation in peer learning forums was graded, only 2 points were granted for each of the nine forums over the semester, thus representing 18% of the course grade. Also, points were granted based on students' efforts in posting both a question (1 point) and a response (1 point) but the quality of these posts, beyond being on topic, was not evaluated. This would suggest that it is not the grades related to their participation in the peer learning forums that influenced the observed change of perspectives in students but rather their performance on the other graded items of this course (e.g. exams). This suggests that it was not that participation in the peer learning forums did not impact on the students, but rather that the grade rewards received for it did not. This will need to be further studied to confirm the impact, if any, of students' performance on their realignment of their self-perceived self-direction.

On the other hand, when computing the correlation with OSD/PLF− we obtain a nonstatistically significant one. This might be due to our small population size or might be an indication that the classifications of student questions using negative indicators of self-direction might not be as accurate as their classification using positive indicators of self-direction. While the computed correlation is appropriately signed, more work will be needed to establish the reason behind the imbalance between both OSD/PLF indicators when related to the PRO-SDLS results. We are currently collecting similar data from the 2009 offerings of the IT Program Design course in order to further establish the presence, or absence, of a correlation.

Are the peer learning forums really at the root of these changes?

We observed an interesting realignment of students' self-perceived self-direction with observable self-direction aspects. While our study does not allow us to explain causally this transformation, we made the hypothesis that our main pedagogical intervention should be the one to be further investigated first in order to look for explanations in students' altered perspectives on their perceived level of self-direction. We therefore used the postsurvey to administer a series of satisfaction questions to S2 students, both open and Likert-based. These provided us with a more qualitative perspective on students' experience with peer learning forums.

Are the peer learning forums useful?

As part of our postsurvey, we asked S2 students to express through a Likert scale (1 for strongly disagree up to 5 for strongly agree) their level of agreement with statements shown as headings in Table 9. The results summarized in the table indicate that students did not perceive the peer learning forums activities as useful for their learning as indicated by a mean of 2.6 for the first question. This rating is consistent with their perception of the peer learning forum's usefulness for preparing them for the apprenticeship exercises (2.6) and exams (2.8). Their opinion about whether the peer learning forums were useful to motivate them to work on the reading assignments is slightly higher (3.0).

These perceptions indicate that students do not recognize the peer learning forums as having a large impact on their learning. However, the formulation of the

questions does not allow for feedback on how peer learning forums might have changed students' learning habits.

For what are the peer learning forums most beneficial?

We then asked our students in sample S2 to express, through the same Likert scale, their level of agreement with statements related to which aspects of weekly peer learning forums were most beneficial to their learning. Results are shown in Table 10 and suggest that students thought that the peer learning forums' most useful aspect (4.0) is the weekly provision of responses from the instructor. This makes sense insofar that the ''wrap up'' phase for each module is where definitive answers are provided to students. The second highest ranked aspect (3.8) is congruent with this first observation; students found useful the instructors' responses to their peers' questions. The peer learning dimension was only moderately appreciated since the peers' answers are the third highest ranking aspect (3.0), after the most instructivist ones. Following closely are the questions posted by the peers (2.8) and the peer answers to other students' questions (2.6).

When put together, these results suggest a preference from students in S2 for instructivist pedagogies over peer learning interactions. As we already discussed, it is difficult to characterize the students in S2 to draw any conclusion as to why they seem to prefer instructivist approaches. Some students took the survey only to improve an already good performance, others to reach a passing grade, others to show good will in hope of additional curving, and others just opted out of the survey since they already had enough points to pass the course regardless of their capabilities. Again, this part of the survey did not help us identify the link between the peer learning forums learning activities and the students' realignment of their self-perceived self-direction.

Table 9. Peer learning forums' usefulness ratings.

	Mean	Std dev	Min	Max
The forum-based peer learning activity is useful	2.6	1.34	1	4
It is useful to motivate me to read the text (as opposed to just have a reading assignment without any activity related to it)	3	1.87	1	5
It is useful to prepare me to work on the modules' exercises	2.6	1.14	1	4
It is useful to prepare me to the exams	2.8	0.84	2	4

Table 10. Peer learning forums' aspects' usefulness.

	Mean	Std dev	Min	Max
The students' answers to my questions help me learn	3	1.41	1	4
The instructor's answers to my questions help me learn	4	0.71	3	5
The questions posted by other students help me learn	2.8	1.3	1	4
The students' posts answering others' questions help me learn	2.6	1.14	1	4
The instructor's answers to others' questions help me learn	3.8	1.1	2	5

Open-ended feedback

We then collected open-ended feedback from students by prompting them with three different formulations of a feedback request ranging from general to specific to the peer learning forums. Results are presented in Table 11. The open-ended feedback we obtained was more useful in shedding light on students' realignment of their self-perceived self-direction.

The first question was extremely general; inquiring about the biggest challenges students encountered this semester and how it related to the specifics of this offering. The respondents identified challenges that related to self-direction, e.g. not having online or face-to-face meetings, finding the motivation to devote time to the course, establishing priorities, and organizing one's time between several commitments.

These challenges also hint that the overcommitted adult learner profile, common among the students enrolled in our IT online offerings, also weighs heavily on their perception of the validity of a teaching strategy. Any learning activity that requires too much time to be completed might be negatively perceived regardless of its potential benefits. Such activities might therefore end up being devoted a minimal amount of time and fail to yield the expected payoff. This, in turn, will only further convince the student that it is not worth spending time on them.

The second question was formulated to invite students to share how this offering's pedagogies influenced their learning habits. Responses are consistent with the above-formulated hypothesis; the time constraints and mandatory participation structures do not necessarily accommodate the students' overwhelming schedules.

Table 11. Open-ended student feedback on peer learning forums.

Describe the biggest challenges, whether they are academic, professional, or personal, that you had to deal with while taking this online course. Feel free to underline how these relate to the specifics of this particular course.
"The biggest challenge was taking the course completely online. I prefer a synchronous Elluminate course to an asynchronous online course."
"Devoting great time to a course can be more difficult when it is asynchronous."
"Staying organized and prioritizing my professional and academic obligations."
"Juggling time for work, time for school, and time for play."
Provide any additional feedback on how this course' pedagogies have influenced your learning habits during this semester.
"I liked the overall structure of the class and felt that we were given plenty of time to complete weekly assignments."
"Really need to drop the peer learning forums as a REQUIREMENT. Possibility, sure, but not requirement."
"The deadlines are tough to follow on my schedule."
Provide us with positive/negative feedback about the peer learning forums and weekly learning cycles
"They are a pain. Although I answered positively above, I do not want to be worrying about posting a question and responding to answers when myself in particular should be concentrating on other aspects of the class. There is a distinct noticeability *[sic]* between students that know what they are doing and the ones that do not. I believe this is unfair in some way."
"The peer learning forums seem time consuming for a full time student."
"The peer learning forums [. . .] as helpful as it could have been. Probably due to the small class size."
"I found the forums very useful, but I wish there had been more participation."

The third question prompted students for both positive and negative feedback on the peer learning forums themselves. The first category of responses confirmed, once again, the tremendous time-commitment issues the responding students are facing and their reactions toward time-consuming pedagogical approaches. The second category of responses stressed that peer learning forums might have been more successful with more participation. This might mean that more students need to participate, that the small class size is detrimental to peer learning forum efficiency (which is in itself good news for the scalability of this approach), or that students need to do more than minimal participation.

We counted the number of question posts per student over the nine peer learning forums used over the semester and found a mean of 5.36 (standard deviation 4.38) posts for students in S1 and 6.2 (2.68) posts for students in S2. These figures indicate that most students are posting below the minimum of one question per peer learning forum. This observation is further corroborated by the fact that, over the entire semester, only three questions were posted after the deadline, thus indicating that students seldom bothered posting questions if a direct reward was not provided.

Major findings and discussion

This section summarizes and discusses the major findings of this study.

Perspective 1

Based on perspective 1, we compared samples S1 (all enrolled students) with S2 (those who did not drop and took the postsurvey for extra credit). The reasons for wanting extra credit might range from trying to just pass to improving an already good grade standing, therefore it would be oversimplification to characterize sample S2 on grounds of academic performance. On the other hand, it is true that S2 is at least a subset of students who did not drop the course and it would be therefore easy to interpret S2 as representative of students with higher motivation or self-direction.

Both S1 and S2 have shown similar PRO-SDLS and OSD/LH+ scores. However, S2 has fewer of its students' posts classified by OSD/PLF+. This suggests that identifying S2 students as ''nondroppers'' with consequent motivation is misleading; based on OSD/PLF+, S2 students do not feature a higher self-direction than S1 students. By elimination, we are left with the observation that, with respect to the measures used in this study, samples S1 and S2 are similar enough to allow us to, at the very least, consider the trends noticed in perspective 2 as worth investigating further using a larger sample.

Perspective 2

The major finding related to perspective 2 is the inversion of correlative directionality between PRO-SDLS overall scores and the OSD/PLF+ indicator: negative in the presurvey and positive in the postsurvey. This switch indicates that there has been, even in the course of a single semester, a profound realignment of students' self-perception of their self-direction with its observable components as characterized by the OSD/PLF+ indicator. We further explored the link between peer learning forum activities and this switch from a more qualitative perspective,

which did not reveal any conscious attribution of significant benefits to the peer learning forums by the respondents.

On the other hand, the OSD/LH+ indicator did not correlate significantly with the PRO-SDLS measures in any of our scenarios. Either the instrument captures a different self-direction aspect, or the students do not show consistency between self-perceived self-direction, OSD/PLF+, and this particular aspect. It is arguable that our definition of the negative indicator is also responsible for this. While the presence of a positive indicator implies that the student exhibited self-direction in their post, their absence can be interpreted as either the student not exhibiting self-direction or his or her posts simply not conveying the self-direction they exhibited. Further investigation will be needed to establish which hypothesis is more accurate. Should it become apparent that students do not perceive learning habits we inquired about in our survey as foundations for self-direction, we will investigate how this misconception might be realigned in a manner similar to the self-perceived self-direction realignment.

New instrument – OSD/PLF

Table 2 is the main innovation of this study on how to measure observable self-direction in a manner that is discipline-specific. It is arguable that the instrument is only valid for a specific topic in the discipline (programming) and medium (peer learning forums). We expect it to be adaptable to other courses/disciplines as we have already started adapting it to other courses in our curriculum. However, this instrument illustrates the benefits of discipline-based educational research for improving our understanding of barriers to student learning in order to overcome them. Being able to archive the interactions between students and between instructor and students in an online asynchronous offering facilitates the development of instruments to analyze the impact of various pedagogies. While feasible in a face-to-face environment, capturing and processing "live" exchanges is often more demanding in terms of technology, e.g. video recording, personnel and time to analyze. Our research group strongly believe that online education is actually providing many opportunities to improve our teaching practice by facilitating computing education research.

It is still unclear why the negative correlation between OSD/PLF− and PRO-SDLS scores is not statistically significant in the postsurvey. Further research will have to be devoted to study this phenomenon and establish whether it is specific to the students in sample S2, due to the small sample size, or reproducible in other offerings. Our next efforts will therefore be focused on supporting the usage of this instrument by other faculty and the evaluation of its reliability.

New learning activity – peer learning forums

Overall, the feedback collected through the Likert-scale satisfaction survey and the open-ended ones indicated that students did not see a strong impact of the peer learning forums tool on their learning while acknowledging its usefulness to force them to stay on track. Paradoxically, while falling behind is a common cause of failure in face-to-face and, even more so, in online courses, students seem to react negatively to attempts at supporting a regular and sufficient time commitment in an online course. Their preference for an online flexible format is clearly expressed in our presurvey, thus indicating that they are not negatively reacting to the delivery method itself. The only alternative is therefore that their negative perception is

induced by other constraints that they perceive as defeating the purpose of taking a course online. Our hypothesis so far is that these constraints are the ones imposed by the demanding learning activities described in this article. The ''overcommitted adult learner'' profile is what motivated this hypothesis from the beginning. Under their time constraints, education is expected to be painless and swift, which would explain the tendency to expect lecture-only offerings and less involved pedagogies (that we identified in the responses).

These observations also tie in with the realignment of students' self-perceived self-direction with observable self-direction measures. Although not appreciated, the experience of students with an online asynchronous offering that is heavily structured by the weekly peer learning forum activities, led them to realize the real-world implications of self-direction, motivation and active learning in relation to an overcommitted schedule, on their capability to learn.

Conclusions

The questions that guided our initial exploration were as follows:

- How can students' self-direction levels be assessed based on the questions they post to a mandatory, weekly peer learning forum?
- How does their self-direction, as measured by the PRO-SDLS instrument, relate to how self-direction is expressed through their participation in peer learning forums?
- How does students' self-direction, as measured by the PRO-SDLS instrument, relate to their learning habits?

The first one has been addressed by the development of the instrument presented in Table 2. The second has been addressed by considering the differences between the positive observed self-direction measure, OSD/PLF+, when compared with the students self-perception of their own self-direction, PRO-SDLS. The third one still remains to be satisfactorily addressed in so far that the OSD/LH+ instrument we proposed seems to focus on aspects of the self-direction constructs that are not related to those captured by the PRO-SDLS instrument.

From a higher level perspective, this study also helped us realize that, unlike many others, this computing education research study did not contribute to improve our understanding of learning barriers or cognitive processes related to the novice programmer. Instead, our online peer learning activities ended up lowering the self-perception of self-direction in a population of students, which was unable to devote the time needed to their courses. The final outcome for these students is not measurable in terms of improvement/deterioration of grades or specific cognitive ability but rather in terms of realization of the unexpectedly demanding requirements of an online college course along with a revision of a somewhat optimistic self-evaluation. This type of impact is not what is necessarily sought by an instructor interested in improving their teaching. It is nonetheless arguable that it is probably just as far reaching in terms of impact on students and positive for the academic and professional paths they will engage in.

This study is also an illustration of the need for discipline-based educational research. While the instruments (OSD/PLF, OSD/LH) and pedagogical interventions (PLF) we used in this study could apply to a broad range of disciplines, each

would need to be adapted to the specifics of a discipline or even offering in order to fulfil its objectives.

In such a context, the case study methodology proved to be an extremely rewarding one, allowing us to combine various perspectives and design new instruments to study a well-established construct from a discipline-based perspective.

Last but not least, this study also illustrates how online teaching, which is too often perceived as an Ersatz for face-to-face offerings, allows the mining of multiple data sources which accurately reflect what happens in the virtual classroom; e.g. forums, emails, student work patterns. Online offerings seem to make it much more practical for the computing education researcher to gather such data than in most face-to-face settings in which an already busy instructor often attempts to fulfil the additional role of observer. Even when using video recordings to preserve information about the class, the researcher finds herself overwhelmed with data which is mostly "noise" in which one has to find the nuggets of relevant information. Online interactions are generally more focused on the learning transactions and therefore more easily amenable to study and relevant to the purposes of discipline-based educational research.

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