Insights from the Application of Universal Design Principles to Support English Language Learners

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ABSTRACT

The rising number of international students who are English Language Learners (ELL) at English-speaking universities has introduced challenges and opportunities for these students and their instructors. In this paper we present a case study of our experiences using Universal Design for Learning (UDL) principles to guide curriculum design that supports ELL students in a first programming course (CS1). We assess the success of our approach in terms of student grades with respect to the entire CS1 population, student feedback via surveys, and instructor reflections. Our contribution to the computer science education community is an argument for following UDL when designing curriculum to support language needs. We believe that this curriculum will benefit both ELLs and their native English speaking peers in a broad, linguistically diverse student population.

CCS CONCEPTS

• **Social and professional topics → Computer science education**;

KEYWORDS

universal design for learning; experience report; curriculum design; English language learners; content and language integration; international students; CS1

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1 INTRODUCTION

University students are diverse in a number of ways, including their linguistic backgrounds. Many English-speaking institutions are seeing an increase in the number of students for whom English is not their primary language. At our institution we teach students with a broad range of linguistic backgrounds, including both native speakers (English L1) and English Language Learners (ELLs)[1]. Even within each of these two groups, the students' reading, writing, comprehension, and speaking skills vary widely. As educators, we have a responsibility to support all of the students in our classrooms by making our curriculum accessible to all learners. Our challenge, given the breadth of language competencies, has been to find effective methods to facilitate learning for all students.

We argue that considering the needs of ELL students by following the principles of Universal Design for Learning (UDL) [11] during course development will result in material that better supports all learners. Universal Design for Learning was first proposed by Meyer and Rose as a set of principles and guidelines that are useful for developing educational tools that are effective for diverse learners [11]. These principles and guidelines are further described in Section 4. Much of Meyer and Roses' UDL work focuses on supporting the diversity that comes from working with students who have disabilities. The principles and guidelines also apply more broadly, and in our experience have proven to be an effective approach for working with students from a range of linguistic backgrounds as well as varying degrees of language proficiencies.

Our work is situated in Vantage One (V1), an interdisciplinary, 11-month, first-year program that provides an alternative entry to the University of British Columbia (UBC) for academically strong international students whose English language test scores are one band lower than UBC's general language requirements. Within this immersive program, students complete UBC academic courses following a content and language integrated learning approach [5]. Our V1 students take the same CS1 course as direct-entry (non-V1) students in terms of content. In contrast to the direct-entry sections, in Vantage One we have small class sizes and the students take their courses in cohorts. Students in the Vantage One program also take integrated Academic English language courses taught by an Academic English faculty member. The language courses aim to enhance students' comprehension and awareness of the concepts, genres, and registers in the respective fields of study by exploiting the links between language choices and meanings made in academic contexts. This innovative approach to university education provides a naturally collaborative environment for Science faculty members

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[1]The term ELL has become more widely used and accepted than ESL (English as a Second Language) as students may have learned other non-native languages before learning English.

and Academic English faculty members to provide an integrated and consistent learning experience.

In this paper, we describe our work supporting Vantage One students in CS1 in the initial two offerings of this program. First we provide an overview of related work (Section 2). We briefly describe our curriculum development process in the first offering and share our evaluation and reflection on our experiences from this first year (Section 3). We then describe an evolution of the curriculum for our second cohort, driven by our evaluation and reflection as well as literature from UDL, language, and general education research communities (Section 4). We provide an evaluation of our redesign in terms of student performance, student feedback, and TA and instructor observations (Section 5) followed by a discussion of these results (Section 6). From the lessons learned across two academic years, we make the following contributions: 1) an argument for following UDL to design curriculum that supports linguistically diverse students, 2) a description of the exercises and activities that we developed, 3) an evaluation of these exercises and activities and 4) a discussion of how our approaches may scale to the broader student population. We conclude with a summary (Section 7).

2 RELATED WORK

The concept of universal design first arose among architects focused on designing spaces and buildings that would be able to accommodate as many diverse needs as possible [10]. Since Ronald Mace first coined the term [10], principles for universal design have been adopted and developed for many contexts. For example, practitioners in the Human Computer Interaction community frequently apply universal design principles to ensure that a broad spectrum of end-user populations can experience high-quality interactions with their technology and devices [e.g., 1, 9]. Similarly, in medicine, universal design principles are guiding the development of projects and services that can be used by patients with a range of abilities, without requiring specialized adjustments or adaptations [e.g., 12].

Universal Design for Learning, as proposed by Meyer and Rose [11], provides principles and guidelines for creating curriculum suitable for a range of learners including those with disabilities and diverse language skills. We are not the first to argue that UDL is relevant to computer science education. For example, Burgstahler provides a description and history of UDL and argues that its use has the potential to benefit many students [2] and Hansen et al. used UDL to create computer science curriculum in elementary classrooms [8]. While the UDL framework is intended to be used from the ground up in course design, in this report we describe the creation and introduction of new exercises and activities to an existing course within the structure of Vantage One following UDL guidelines.

Vantage One's general philosophy for language learning is based on the Content and Language Integrated Learning (CLIL) approach [5]. The CLIL approach combines instruction and learning from both the subject content area (in our case, CS1) and the language content area. With this approach, any language learning activities are themselves tools to develop new learning in a subject area [4]. CLIL is consistent with the UDL principles that suggest providing multiple ways for students to interact with the curriculum. Given the CLIL context and the variety of resources used to disseminate curriculum in our existing CS1 course, including lecture, text, worked examples, and video explanations, we believe it is amenable to extension following the UDL approach.

Many universities and pathway programs offer language-intensive preparatory programs to ready international students for undergraduate programs, but Vantage One is somewhat unique. Rather than providing a preparatory program, our approach is to integrate the language-intensive program with first-year degree requirements. Vantage One students are UBC students rather than students attending a pathway institution to complete a language program. Vantage One students engage in enriched language support courses and in courses to fulfill degree requirements simultaneously. Our students meet UBC's academic entrance requirements so we expect them to succeed in their courses. While many universities have English language programs, most do not use the CLIL approach. However, CLIL is widely used in other contexts, such as European K-12 programs [3].

3 YEAR ONE

Our CS1 students learn systematic program design with a functional programming language following the How to Design Programs approach [7]. Our CS1 is a four-credit course and most courses at UBC offer three credits. In our direct-entry offerings, the students attend three lecture hours and a three-hour lab each week. They complete weekly problem sets alone or with a partner and they write two midterm exams and a final exam. Although we still call them lectures, the students are actively engaged for a significant percentage of each lecture. They watch videos as pre-class work, begin class with clicker questions that assess the pre-class work, and typically work on solving multiple hands-on problems in a 50- or 80-minute lecture.

Our Vantage One students participated in all of these activities but were also registered in a linked course (CS1-Content and Language Enrichment) comprised of a weekly one-hour CS1 language focused class (CS1-Language Class) that was taught by an Academic English faculty member and a weekly one-hour CS1 content focused tutorial (CS1-Content Tutorial) that was taught by computer science teaching assistants. The direct-entry students did not participate in these extra activities. In Year One, the V1 CS1 lecture section was taught concurrently with two direct-entry CS1 lecture sections. All three sections used common problem sets and exams.

3.1 Curriculum Design

The curriculum for the lecture and lab components of our CS1 course had been designed for use in direct-entry and was stable prior to our initial Vantage One offering. Thus, for the first year of V1, we focused our curriculum planning efforts on providing additional English language support, and on creating curriculum for the CS1-Language Class and CS1-Content Tutorial.

Throughout the semester, the CS1 instructor and the Academic English faculty member worked together to plan and develop curriculum for the CS1-Language Class and CS1-Content Tutorial. In order to plan our curriculum for Year One, we conducted brainstorming sessions with past CS1 faculty and teaching assistants to generate a list of language-related skills or concepts that past

Table 1: Performance on assessments and overall (out of 100).

	Problem Sets			Midterm 1			Midterm 2			Final Exam			Overall		
	n	M	SD	n	M	SD	n	M	SD	n	M	SD	n	M	SD
V1	60	76.7	10.8	60	70.6	19.6	60	62.6	26.3	60	61.0	21.9	60	68.9	17.6
Direct-entry	308	66.7	17.8	292	75.8	18.0	289	72.5	20.0	294	68.3	19.5	294	72.4	16.5

students had found challenging. We used this list to plan the CS1-Language Class and CS1-Content Tutorial. We focused on vocabulary for the first month of the CS1-Language Class and then shifted our focus to in-class student presentations. We asked the students to solve CS1 problems and then verbally present the solutions to their peers in English. In the CS1-Content Tutorial, we planned to have the students solving problems in small groups in order to facilitate their use of English for discussion and negotiation. We created new problems for them to work on that were isomorphic to problems they had seen in the most recent week of lectures.

3.2 Student Performance and Feedback

To understand how well our curriculum supported the V1 group, we examined student performance between the V1 and direct-entry groups and solicited feedback from the V1 students.

3.2.1 Performance. In Year One, the V1 students did not differ significantly in their overall performance in the course from the direct-entry students $t(81.57) = 1.40$, $p > 0.05$. On average, the direct-entry students performed better on exams; we found that this difference was significant for the second midterm $t(73.86) = 2.76$, $p < 0.05$, and for the final exam $t(79.17) = 2.38$, $p < 0.05$, but not for the first midterm $t(80.91) = 1.90$, $p > 0.05$ (see Table 1).

However, the V1 students did demonstrate more consistent engagement with the course, as measured by the number of weekly problem sets that they submitted. On average, the V1 students missed significantly fewer of the 11 problem sets ($M = 0.67$, $SD = 1.32$) than the direct-entry students ($M = 1.83$, $SD = 2.44$), $t(150.60) = 5.30$, $p < 0.01$. We also found that the V1 students performed significantly better on submitted problem sets than the direct-entry students $t(130.83) = 5.81$, $p < 0.01$. We excluded problem sets that were incomplete due to an excused reason such as illness, but included problem sets that were submitted but received 0. The V1 students' higher grades on problem sets explain how their overall course performance was similar even though although they did not perform as well on exams.

3.2.2 Student Feedback. We also conducted a post-term survey of the V1 students to gather their feedback on the helpfulness of the CS1-Language Class and CS1-Content Tutorial. In total, 41.6% (25/60) of the students responded. We suspect this somewhat low response rate was the result of heavy surveying of the V1 group. In the survey, the students rated helpfulness on a 5-point scale from very helpful to very unhelpful, with 3 being neutral. We collapsed these results into three bins for analysis: helpful, neutral, and unhelpful. As the survey questions were optional, for each question we excluded null responses. Our results showed mixed results for the success of the CS1-Language Class and the CS1-Content Tutorial. While a clear majority of 80% found the CS1-Content Tutorial helpful for their learning, this dropped to only 48% for the CS1-Language Class. Unfortunately, analysis of the open-ended responses to our request for comments and suggestions on how the course could be improved yielded no insights into the reasons for the lower ratings for the CS1-Language Class.

The student feedback on the helpfulness of the CS1-Language Class and our observations over the term indicated room for improvement that we felt should be addressed with revisions in a subsequent offering. In the CS1-Content Tutorials, the TAs reported at the end of the semester that they were often demonstrating problem solving activities rather than requiring the students to complete the problem solving activities themselves. We felt that the various components of the course were too disconnected even though they were covering the same topics. We discussed these issues as a team and came up with a plan to redesign the curriculum.

4 YEAR TWO CURRICULUM DESIGN

Our goals for Year Two were to redesign curriculum in the CS1-Content and Language Enrichment components to increase the integration between components and to add further support for our ELL students by following the UDL principles and guidelines.

The three principles of the UDL approach to curriculum development are to provide multiple means of: 1) engagement 2) representation, and 3) action and expression [11]. To sustain the motivation for learning of a diverse set of students, a range of options for engagement are required. Multiple representations allow a diverse population to consume information and support connections within and between concepts. Allowing students to demonstrate their knowledge via multiple forms of action and expression lets a diverse population demonstrate understanding of a concept while supporting the development of their understanding and associated skills. Each of the three principles of the UDL framework is accompanied by a set of guidelines to aid in curriculum development. We describe the relevant guidelines below in our discussion of how we applied each principle.

We did not apply the full set of guidelines in our redesign as we focused on those that we felt would have the most impact on students who are language learners. The majority of these changes were made to the CS1-Content and Language Enrichment courses (CS1-Content Tutorial and CS1-Language Class) leaving the core CS1 content intact to maintain alignment with the concurrent direct-entry CS1 sections.

4.1 UDL Principle 1: Engagement

Our focus on increasing opportunities for *engagement* was in response to student feedback suggesting that the purpose of the CS1-Content and Language Enrichment classes for CS1 in the initial year was unclear.

Following the guideline to *provide options for sustaining effort and persistence* we ensured that the students encountered a repetition of concepts across the CS1-Language Class, CS1-Content Tutorial, labs, lectures, and problem sets giving students multiple opportunities to understand course content, keep on top of material, and subsequently remain engaged. Working closely with the CS1-Language Course instructor and CS1-Content Tutorial TA from year one, our goal was to have students work with CS experts (Teaching Assistants) in the CS1-Content Tutorial on exercises, generating artefacts of their work. These artefacts were then used as the basis for the CS1-Language Course lesson plans, which focused on language skills and were led by a language expert. We further encouraged collaboration and communication with group work and presentations as suggested under this UDL guideline.

This guideline also suggests providing *mastery-oriented feedback* that focuses on students' effort rather than on their inherent abilities. The resources and delivery of the CS1 course itself are already consistent with this suggestion by emphasizing students' use of deliberate practice [6] to improve their program design skills.

Further, the existing CS1 course also already follows the guideline to *provide options for self-regulation* by offering an online schedule, module breakdown of content, graded problem sets, and online multiple-choice questions. Since the V1 students have strong academic backgrounds we did not provide additional support for study and organizational skills. We did, however, experiment with practice quizzes in the CS1-Content Tutorial that facilitated self-assessment and reflection. Quizzes were written individually, exchanged, and graded by peers following an exam-like rubric. This process was designed to give students an opportunity to reflect on their own understanding of the concepts tested by the quiz.

4.2 UDL Principle 2: Alternative Representations

The core CS1 offering has had extensive resources put into curriculum development to *provide multiple means of representation* of course content through active-learning exercises in lecture, worked examples in a problem bank, video explanations, and screencast walkthroughs. This delivery of content already follows the UDL guideline to *provide options for perception*, as it offers alternative ways to access the course material. The course content *provides options for language* by presenting multiple forms of explanation for terms and processes including videos and examples augmented with hyperlink glossaries. The existing offering also *provides options for comprehension* by developing necessary background knowledge in the form of structured, systematic processes [7] that are taught in the first quarter of the course and are built upon as the course develops. These processes are explicitly laid out in steps and guide information processing and manipulation for the student. As the problems get more complex, the processes we teach explicitly activate relevant prior knowledge for the student. The students are given a copy of the processes for use during lecture practice and exams, which takes the focus off rote memorization.

In the redesign of the CS1-Content Tutorial and CS1-Language Class we wanted to provide additional representation support for language-specific content and for complex concepts that both ELL and English L1 students struggle with. In order to support our ELL students as they learned new vocabulary, we spent time in the CS1-Language Class getting students to explain terms orally that have definitions provided in multiple forms in the core CS1 content. Additionally, in lecture we provided a visual representation of a complex data structure to help students understand a recursive traversal algorithm. We used this same visual representation when introducing new but similar data structures and algorithms to highlight patterns of similarities and differences, again activating prior knowledge.

The ability to apply the processes and understand how the steps build on one another is the basis of the remaining three-quarters of the course. In the CS1-Content Tutorial, extra time was spent on a group discussion of the steps of the fundamental processes to provide additional *options for comprehension* of this core concept. Each step in the process was discussed in terms of: 1) the purpose of the step, 2) where to look for information to begin the step (from the problem description or previous step(s)) and 3) why the step is performed.

4.3 UDL Principle 3: Action and Expression

The UDL principle to provide *multiple options for action and expression* had the most substantial impact on the redesign of the CS1-Content Tutorial and CS1-Language Class. We focused our redesign on the one (of three) guideline under this principle that was most relevant to our population of ELL students. This guideline, which recommends *providing options for expression and communication*, was a foundation for the exercises students completed, how they communicated their results, and the progression of these learning activities throughout the term.

Specifically, under this guideline, UDL suggests to *build fluencies with graduated levels of support for practice and performance*. Throughout the term in CS1-Language Class we asked students to communicate results from an exercise they completed in the CS1-Content Tutorial or from another course resource. At the beginning of the term, more scaffolding and structure were provided for presentations, which were kept short and focused on a single concept. For example, in the first week small groups defined a subset of vocabulary terms with their own words and examples which was followed up by an explanation of each term volunteered by a different student. In the second week student groups analyzed a short program and presented their findings but were not yet analyzing a solution that they had created. For example, groups were given a full solution to a problem that contained multiple errors and identified a course concept underlying each error, developed a short lesson, and taught the concept to the class. As the term progressed, presentations were longer, groups generated solutions, and students facilitated more question and answer discussions. For example, groups solved a problem with multiple possible solutions, presented their results, and answered questions that identified errors and alternative solutions from non-presenting classmates. By the end of term, groups were asked to create a screencast that provided a walkthrough of a solution to a graph traversal problem. Students were asked to describe the problem, the reasoning behind their solution, and an explanation of the implementation.

In the expressions of knowledge described above, students were asked to use different forms of media and tools to communicate

Table 2: Performance on assessments and overall for Year Two (out of 100)

	Problem Sets			Midterm 1			Midterm 2			Final Exam			Overall		
	n	M	SD	n	M	SD	n	M	SD	n	M	SD	n	M	SD
V1	63	78.2	9.4	56	71.2	21.4	56	66.5	19.8	56	59.7	19.7	56	70.5	16.6
Direct-entry	347	74.1	13.9	321	73.2	20.6	318	70.0	16.1	323	60.6	19.7	323	70.5	16.7

their results as suggested in this UDL guideline. For example, in the groups' teaching presentations they used hard copies of solutions containing errors on an overhead projector as an artefact, allowing pen annotations to support their explanation. When presenting their own full solutions to the class, students used a code editor which allowed them to scroll through, update, and add to their solutions to augment their explanations. The end of term screencast project was performed outside of class time and groups of students used screen capture software with voiceover support to record the walkthrough of the solution.

5 YEAR TWO RESULTS

To evaluate the redesign effort, we again examined student performance between the Vantage One and direct-entry groups and solicited feedback from both groups of students. We also compiled a list of observations from instructors and TAs detailing considerations for future semesters.

5.1 Student Performance and Feedback

In Year Two, the Vantage One students and direct-entry students again performed very similarly, and the V1 students closed the small gap in exam performance. Student feedback showed clear improvements on the V1 CS1-Language Class from Year One and also highlighted some interesting differences between the V1 and direct-entry groups in terms of their use of resources.

5.1.1 Performance. Both groups had an identical overall course average. While the direct-entry students appeared to perform a bit better on exams, none of these differences were significant: midterm 1 $t(73.80) = 0.65$, $p > 0.05$, midterm 2 $t(68.50) = 1.25$, $p > 0.05$, or the final exam $t(75.29) = 0.31$, $p > 0.05$ (see Table 2).

The V1 students again demonstrated more consistent engagement with the course, as measured by the number of weekly problem sets that they submitted. On average, the V1 students again missed significantly fewer of the 11 problem sets (M = 0.71, SD = 1.53) than the direct-entry students (M = 1.24, SD = 2.00), $t(104.79) = 2.41$, $p < 0.05$. The V1 students also performed significantly better on submitted problem sets than the direct-entry students $t(117.84) = 2.93$, $p < 0.01$. We again excluded problem sets that were incomplete due to an excused reason such as illness, but included problem sets that were submitted but received 0.

5.1.2 Student feedback. The post-term survey gathered feedback on the helpfulness of course components from both the direct-entry and V1 students. Response rates for both groups were comparable, at 73% for V1 (46/63), and 67% for direct-entry (239/357).

We asked the students to rate the helpfulness of each of the main course components for their learning in the course (lecture, labs, problem sets, and the Language Class and Content Tutorial for V1) on a 5-point scale from very unhelpful to very helpful, with 3 being neutral (neither helpful nor unhelpful). In our analysis we collapsed these results into three bins: helpful, neutral, and unhelpful.

Our results show clear improvements over Year One for the CS1-Language class, although results were more mixed for the CS1-Content tutorial (see Table 3). We found that in all cases, a majority of the students found the CS1-Content Tutorial and CS1-Language Class helpful for both mastering the English language and mastering the course content. The CS1-Language Class was also helpful for both purposes for a similar proportion of students, while, the dedicated CS1-Content Tutorial was helpful to a slightly larger proportion (8% more students).

We also compared the perceived helpfulness of the lectures, labs, and problems sets between the direct-entry and V1 students. A large majority within both groups found the labs to be similarly helpful. We found a striking difference between the helpfulness of lectures, with 37% more of the V1 students finding lecture helpful compared to direct-entry, and 22% fewer V1 students reporting that the lectures were unhelpful. In addition, 20% more V1 students reported finding the mandatory problem set assignments helpful for learning compared to the direct-entry students.

In addition to assessing the mandatory class activities, we also asked students to rate the helpfulness of several optional course resources. There were some notable differences in use of some resources between the direct-entry and V1 students. The V1 students appear to work in a more social way by more often completing problem sets with a partner, studying with peers, and visiting office hours. They also report finding these types of resources more helpful than the direct-entry students.

5.2 TA and Instructor Observations

Many of the UDL-inspired exercises worked well, but we also encountered some unexpected complications. From all of our observations, we have compiled several lessons we learned about applying UDL that we believe will improve instruction for classes that consist of both language learners and English L1 students.

Table 3: Helpfulness of the CS1 V1 components

		Helpful	Neutral	Unhelpful
Mastering English language	Language Class (n=46)	57%	34%	9%
	Content Tutorial (n=46)	64%	30%	6%
Mastering course content	Language Class (n=44)	60%	29%	11%
	Content Tutorial (n=46)	72%	22%	7%

Our TAs, who are all past CS1 students, have told us that they struggled with the use of technical and academic language in the beginning of their CS1 course. As instructors who have taught direct-entry CS1 sections as well as Vantage One CS1 sections, we have also observed that it's difficult for English L1 students to understand and appropriately use technical vocabulary when they are new to the field. We recommend providing vocabulary exercises and activities to serve as scaffolds so all students learn to use the new vocabulary appropriately.

The practice quiz followed by peer-grading using an exam-like rubric worked well to promote self-reflection on preparedness for the midterm exam and to reinforce the steps of the systematic processes. We recommend allowing groups to communicate as they grade so that they can build their peer review skills. The screencast assignment worked well as it required students to go beyond solving a problem and explain how the problem was solved. We recommend including similar activities in computer science courses to provide an opportunity for critical reflection.

The students did well critiquing solutions that contained errors. This exercise was intended to highlight nuances and common mistakes made in applying the systematic processes and most students found most of the errors and were able to identify the course concepts underlying the errors. However, when the students tried to teach the underlying concept it became more of a description of the errors they found than teaching the concept. The students had difficulty articulating which step of the process was being used incorrectly and which information from previous steps could have been helpful. We recommend providing scaffolding, perhaps in the form of a worksheet, to facilitate this work.

When groups presented their own solution and then facilitated a question and answer period it allowed students to discuss alternative solutions and see that there is more than one correct solution for a problem. However, managing the discussion was challenging as students were identifying errors in their peers' solutions.

The high-level discussion of the course's systematic processes were challenging for the teaching assistants to facilitate as it was difficult to get the students to speak. We suspect that the students would have been more engaged if the same questions were asked on a worksheet rather than as a class discussion.

6 DISCUSSION

We found that following the UDL principles and guidelines allowed us to create curriculum that supported our linguistically-diverse students' learning, and going forward we believe that this curriculum will also be valuable for English L1 students' learning as it supports skills that are important for all students.

The improved student feedback on the helpfulness of the CS1-Language class and the CS1-Content tutorial suggests that the integrated UDL-inspired exercises were useful in facilitating language learning and content learning in language- and content-focused classes. As all computer science students are learning the language of computer science, we believe that the language-focused exercises will be beneficial to a broader student population as they provide multiple options of expression and communication.

The higher helpfulness ratings for problem sets and higher use and helpfulness ratings for working with peers by V1 students suggest that the focus on providing multiple options of expression and communication through varied exercises and group work may have encouraged the V1 students to see the benefit of working with peers. However, as the V1 students take courses in a cohort and have smaller class sizes, it's also possible that they have simply formed tighter bonds with their peers. Although reductions in class size for the direct-entry students are not possible, our results suggest that these students might benefit from an increased focus on group work and more effort to facilitate connections with their peers. As many large classes, including ours, also have small lab sections, some of the UDL-inspired activities could be deployed in lab.

The exercises that required the students to communicate about course content, such as the screencast activity, will be beneficial for all students because they provide options for self-regulation by encouraging metacognition. The students must consider their solutions and be able to clearly articulate the rationale behind their design choices. We think that these communication and metacognitive skills should be developed in all CS students.

Our work is limited by the fact that we did not attempt to directly measure the success of our approaches and by the fact that we were teaching unique cohorts of students in each year. Despite these limitations, we believe that our experiences demonstrate that designing curriculum that is accessible to ELLs can lead to curriculum that is valuable for all learners.

7 CONCLUSIONS

Our experience following the UDL principles to design curriculum that supports ELL students in CS1 has led us to believe that by following UDL we created curriculum that is better suited for the learning of all students. We recommend the use of UDL for curriculum design or redesign projects.

REFERENCES

[1] Eric Bergman, Alistair Edwards, Deborah Kaplan, Greg Lowney, T.V. Raman, and Earl Johnson. 1996. Universal design: Everyone has special needs. In *Conference companion on Human factors in computing systems*. ACM, 153–154.

[2] Sheryl Burgstahler. 2011. Universal design: Implications for computing education. *ACM Transactions on Computing Education (TOCE)* 11, 3 (2011), 19.

[3] Do Coyle. 2008. CLIL–A pedagogical approach from the European perspective. In *Encyclopedia of language and education*. Springer, 1200–1214.

[4] Do Coyle, Bernardette Holmes, and Lid King. 2009. Towards an integrated curriculum–CLIL National Statement and Guidelines. *The Languages Company* (2009).

[5] Do Coyle, Philip Hood, and David Marsh. 2010. *Content and language integrated learning*. Ernst Klett Sprachen.

[6] K. Anders Ericsson, Ralf T. Krampe, and Clemens Tesch-Römer. 1993. The role of deliberate practice in the acquisition of expert performance. *Psychological review* 100, 3 (1993), 363.

[7] Matthias Felleisen, Robert Bruce Findler, Mathhew Flatt, and Shriram Krishnamurthi. 2001. *How to Design Programs*. MIT Press.

[8] Alexandria K. Hansen, Eric R. Hansen, Hilary A. Dwyer, Danielle B. Harlow, and Diana Franklin. 2016. Differentiating for Diversity: Using Universal Design for Learning in Elementary Computer Science Education. In *Proc. SIGCSE '16*. 376–381.

[9] Seunghyun Tina Lee, Yilin Elaine Liu, Ljilja Ruzic, and Jon Sanford. 2016. Universal design ballot interfaces on voting performance and satisfaction of voters with and without vision loss. In *Proc. CHI '16*. ACM, 4861–4871.

[10] Ronald Mace. 1985. Universal Design, Barrier-free Environments for Everyone. *Designers West* (1985), 147–152.

[11] Anne Meyer and David H. Rose. 2000. Universal design for individual differences. *Educational Leadership* 58, 3 (2000), 39–43.

[12] Ann S. Williams. 2009. Universal Design in Diabetes Care An Idea Whose Time Has Come. *The Diabetes Educator* 35, 1 (2009), 45–57.