Developing the ITL framework and committing to inquiry as a method for reducing equity gaps in high-impact, computer science and engineering courses

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Abstract

The educational literature provides a roadmap for instructors and institutions that want to close equity gaps in coursework pass rates and degree outcomes for underrepresented minority (URM) students which include students who identify as Black, Hispanic, and/or Native American. It is to transition teaching methods from Transmission, telling students how to do things, to Inquiry, which has been shown to improve teaching and learning outcomes by incorporating students' prior knowledge, ideas, and life experiences into the learning process, including unique questions, backgrounds, and connections they make to course content. In contrast to Inquiry, the ubiquitous Transmission method is mainly relied upon by instructors teaching large, gateway undergraduate engineering courses where the instructor is the keeper of the static knowledge that matters to students and students report they rely on their instructors to learn and are not developing their own learning methods and expertise. Inquiry encourages students to engage, identify their questions and misconceptions, design experiments and use evidence in the process of improving their understanding. By adopting Inquiry as the primary teaching method in engineering, instructors facilitate and guide students in the learning process, clarifying student prior knowledge, incorporating student questions and misconceptions, and eliciting student ideas about how they learn.

This paper presents findings from the research partnership between a psychometrician and curriculum advisor and two faculty members of Computer Science and Engineering in a Californian institution of higher education. The partners met weekly over the course of 2021-2022 academic year to explore and refine their understandings of what it means to teach and assess with Inquiry, and develop practical examples to demonstrate Inquiry teaching as applied to engineering content. These meetings included unpacking the data and evidence surrounding equity gaps, exploring methods in the literature that closes them, and innovating practical examples of Inquiry applied to engineering content to illustrate pre- and post-teaching activities, before and after the transition to Inquiry. This work allowed for designing and testing the Inquiry Teaching and Learning (ITL) method and framework that specifically addresses challenges engineering instructors face when teaching and offers a suggested pathway forward for faculty and programs intending to transition from Transmission to Inquiry teaching, improve student learning to better resemble the thinking and work of engineers, and reduce persistent and historic equity gaps in engineering education.

Using institutional outcomes and pass rate data from our large, high stakes, foundational computer science course, CSE 12, Computer Systems and Assembly Language, the efficacy of ITL for improving student achievement was measured by comparing results to previous course offerings before this pedagogical transition. The data analysis and course outcomes comparison suggest a significant reduction in the equity gap between URM and non-URM students because of the transition to Inquiry. We present the evidence of this and propose Inquiry and the ITL framework as what is needed to foster a new teaching mindset for faculty, undergraduate tutors, and teaching assistants that will improve student learning and close equity gaps between student subgroup populations.

Introduction

The educational literature provides a roadmap for instructors and institutions that want to close equity gaps in coursework pass rates and degree outcomes for underrepresented minority (URM) students or students who identify as Black, Hispanic, and/or Native American. The solution is to transition teaching methods from Transmission, telling students how to do things, to Inquiry, a method that has been shown to improve teaching and learning outcomes by incorporating the prior knowledge, ideas, and life experiences that students bring to the learning process, including unique questions, backgrounds, and connections they make to content and to the field ([1], [2], [3], [4]).

The current proposal, **Inquiry Teaching and Learning** or ITL, extends the concept of teaching with Inquiry, a proven approach for closing equity gaps as **(i)** instructors incorporate Inquiry to understand and improve teaching efficacy [5], and **(ii)** students apply it as a tool to any learning challenge as they learn to problem solve and learn to learn ([6], [7], [2]). Questions from instructors about teaching and questions from students about learning are central to this method and provide both the motivation and mechanism for closing equity gaps and improving teaching efficacy over time ([8], [9], [10]). Successful adoption of ITL must incentivize, guide, and develop the engineering instructor's expertise during the transition period when students are learning to design tests from questions that challenge their previously held beliefs, build upon prior knowledge, and develop engineering expertise ([4], [11], [12], [13]). The ITL approach is grounded in the educational research on Inquiry, on evidence of equity gaps specific to the undergraduate student experience in engineering, and on data from the first two years of study in a Californian institution of higher education, when equity gaps and attrition rates are greatest. The ITL project will allow for developing a a training approach that can be applied to any stakeholder, engineering instructors, engineering undergraduate tutors, and even high school science teachers and students who are learning Inquiry to solve any teaching or learning dilemma. The ITL approach is is highly collaborative and should incorporate and include existing computer science and engineering student support services, other engineering divisions, advisors from industry, and high school teachers and their students so that all stakeholder groups are learning to identify questions, test hypotheses, and improve work practices and student pass rates in engineering courses, closing equity gaps and engaging in the transformation [14]. If adopted, the ITL approach changes what it means to learn and expectations of learning to participate in that learning. It changes the culture of engineering education or the shared understanding of what it means to think, learn, and work like engineers.

Analyzing Equity Gaps

The work of ITL or the ITL approach is highly dependent upon course level data and student learning outcomes to identify equity gaps for identifying the motive for change and for transitioning from Transmission teaching to Inquiry. This is represented in the first ITL program activity carried out by the ITL Project Team, analyzing equity data by engineering gateway course to identify gaps. The result of this first ITL activity is an Excel spreadsheet with courses and corresponding equity data.

To analyze these data, we relied on institutional dashboard data developed and supported by the university and available campus-wide, an example of commitment to closing equity gaps using evidence and a process that is sustainable. If this type of tool is not available in your institution, we suggest building one, and Power BI is a wonderful option for doing so. With a data dashboard tool, we can easily find pass rate data by course, filter on student demographics, and create a simple differential statistics to understand pass rate differences between majority and minority student groups by quarter and by instructor. . The equity data we obtain is provided broadly to our Computer Science and Engineering instructors and referenced in leadership meetings, creating the evidence and hallmark of Inquiry. These data become a "shared experience" and one that motivates instructors to hypothesize why these equity gaps exist, why they vary, and how they might be reduced. It is the data that allow our instructors to apply Inquiry and test theories that may explain trends we see in equity gaps in our engineering division. engineering.

For instance, the initial question we developed was "Can we use available institutional data to identify differences in pass rates between student subgroups and can we predict time to declare success for these different groups?". We hypothesized there would be no detectable differences, and found we disproved that null theory. For academic years 2015-16, 2016-17, 2017-18, 2018-19, and 2019-20, 3,286 frosh students came to the concerned Californian university to study engineering. Of that entire group, 2,514 (77%) were able to successfully meet course requirements and declare engineering major by the end of their second year. However, of the 539 URM students and the same 5-year period, only 332 (62%) met course requirements and declared an engineering major by the end of their second year as compared with the 2747 non-URM students of whom 2281 (83%) met timely declaration. Our Inquiry and subsequent tests of hypotheses show that meeting course requirements within 2 years and declaring engineering major highly correlates with success to engineering degree within 5 years. We have also applied this type of Inquiry in developing ITL-ITL goals and activities.

A second, more specific Inquiry question focused specifically on equity gaps in our Computer Science Engineering degree program revealed that for years 2013-14, 2014-15, 2015-16, 2016-17, of the 650 students who entered Engineering as frosh and were able to meet course requirements and declare their Computer Science major within 2 years, 586 (90%) graduated with a B.S. in Computer Science within 5 years. Students who remained at proposed major status at their 2-year mark graduated within 5 years at the rate of 42%. For CSE as a division, students who meet course requirements within their first two years and declare their engineering major graduate within 5 years from engineering at a rate of 84%, while students who do not declare within the 2-year period graduate from engineering at a rate of 51%. From this process of Inquiry, identifying questions and refining them, we now understand declaration within 2 years as a predictive milestone for our undergraduate population. We can also use our institutional data to identify the specific gatekeeping courses that are barriers to declaration for our students, and URM students, in particular. We find that the same courses that act as barriers to declaration present the greatest equity gaps or differences in pass rates between URM and non-URM student groups.

Of the 302 URM students who entered the engineering division in the university during the 5 years (2015-16, 2016-17, 2017-18, 2018-19, 2019-20), 207 (69%) met course requirements and declared Computer Science Engineering major by the end of their second year. Looking at who has graduated in engineering at the 5-year mark and for academic years 2013-14, 2014-15, 2015-16, 2016-17, URM 11% do not graduate, as compared to 4% for their non-URM peers.

This process of using our course and institutional data is the first practical step organizations need to take to engage and adopt ITL. It is in looking at engineering student data that are the motivation for instructors to form their questions, develop their tests of hypotheses, and better understand the learning experiences of URM students who migrate out of engineering and do not declare degree The goal of the ITL approach is to use evidence and and shift from persistent use of Transmission teaching through incentivizing, training, and fully supporting teaching teams, faculty, and our tutors using Inquiry. ITL provides the roadmap to continue this important work, identifying our questions and hypotheses, and using institutional data to build equity measures that allow for evaluating the efficacy toward closing equity gaps, beginning with these gateway courses: CSE12 (Computer Systems and Assembly Language/Lab), and including CSE20 (Intro to Python), and CSE30 (Programming Abstractions: Python). And the adoption of ITL is expanding in our division and not includes course CSE 13S and C programming.

Inquiry, Teaching and Learning (ITL)

The work of ITL, developing a targeted ITL program for instructors, initiates in the CSE department of Engineering but absolutely must be driven by the faculty and instructors. It is designed to measure, monitor, and close equity gaps in undergraduate prerequisite gateway courses within the first 2 years of university study, a crucial milestone and predictor of student success to engineering degree. ITL can be modeled by one department, studied, and expanded to other Engineering undergraduate programs, such as Electrical Engineering. Making the ITL transformation within a department or an engineering division is transformational and the process should be documented with training materials and instructor experiences, including videos artifacts of instructors teaching and applying Inquiry to teach specific engineering content available. These artifacts provide evidence for other instructors learning how to teach through Inquiry, and allow for building and sustaining communities of engineers committed to moving away from Transmission teaching to a more student-centered approach to teaching and learning. [33]. ITL aligns to guidelines provided by the Accreditation Board for Engineering and Technology (ABET) [34] to establish that students should be learning engineering in ways that look like the work engineers do ([4], [35]). To meet ABET learning objectives and teaching through Inquiry, students work on teams to identify, design, and solve complex problems and to create ways to test their ideas that meet specific needs and constraints of health, culture, environment and economics, while communicating effectively to different stakeholders and exercising ethical and professional judgments. ABET learning objectives are representative of Inquiry and not Transmission teaching ([4], [14]).

Even today, after an abundance of educational studies show the efficacy of Inquiry when used to close equity gaps ([36], [12], [37], [38], [39], [40], [41], [42], [24], [43], [44], [9], [21]), and that, still today, engineering instructors primarily rely on delivering content through Transmission ([4], [46], [47]), telling students what they need to know and do, and continuing to tell them until they appear to get it ([6], [46], [14], [48], [32]). Transmission teaching perpetuates and widens equity gaps because it restricts learning environments by failing to recognize different ways of understanding and knowing for URM students, ([49], [11]) does not allow students to build from their prior knowledge and unique cultural frames [1], is not student-centered ([50], [51]) or Constructivist ([52], [53], [11], [2]), does not allow for deep and expert learning ([4], [11], [36]) and fails to foster a sense of belonging correlated with success to degree ([44], [50], [54], [55], [56], [57]). Transmission teaching fails to scaffold or offer footholds that URM students need to learn at par with the majority peer group that are likely to have had greater prior advantages and resources for learning ([60], [10], [62]). Without identifying and incorporating prior student knowledge into the learning experiences, instructors rely on their own cultural frames of reference and assumptions [1], a trend that is likely insufficient and inaccurate for students from underserved backgrounds ([58], [37], [41]). ITL is grounded in and extend from previous educational literature on teaching with Inquiry, the value of student questions and prior understandings, and evidence that Inquiry reduces learning and opportunity gaps between student groups with different levels of preparation and backgrounds ([46], [44], [21], [1]).

Transmission, teaching by telling or direct instruction, has been well explored in the educational literature ([61], [10], [62]). Transmission positions students to be inactive receivers of passive, empty vessels waiting to be filled up with the knowledge their instructor holds. By contrast, Inquiry is both a teaching and learning method dependent on participants' questions, involves tests of hypotheses, and uses evidence to advance and build new and better theories ([63], [64], [2], [11], [39]). Inquiry belongs to Constructivist theory where learning is attached to previous knowledge and experience ([52], [53], [49], [11], [35]), allows for development of expert knowledge or deep learning ([11], [4]) is effective because it is student-centered ([50], [51]) and is powerful because it acknowledges and incorporates various cultural frames [1]. Inquiry is also referred in the literature as scientific reasoning ([65], [3], [66]) and represents the thinking and the work of engineers ([4], [34], [67], [66], [68], [69], [9]). The ITL program proposes to transform engineering education with the Inquiry method of teaching and learning (ITL) and to contribute and advance research on how students learn in engineering. Research questions that guide this project are 1) how do we as a team of engineering educators apply Inquiry to advance project activities? 2) What aspects of the proposed work improve pass rates? 3) Can development of ITL training lead to broader participation in CSE within the university's Engineering division and beyond? 4) Does effective dissemination and communication of ITL activities increase participation by CSE Engineering instructors to transition teaching practices to Inquiry?

From prior survey research in preparation for adoption of ITL, one in five instructors in our engineering school report having had teacher training prior to starting as the instructor of record at university. Four out of five faculty surveyed say they are unfamiliar with different learning theories and would like to see practical examples of how methods can be applied to engineering content. Anecdotally, during yearly departmental meetings with the Dean, faculty comment they feel underprepared to reduce equity gaps by changing teaching practices. Faculty also report they teach the way they were taught, by Transmission method. Yet, we understand that Transmission teaching exacerbates equity gaps because it 1) does not consider or include student prior knowledge and 2) does not engage students so they can construct new knowledge ([14], [70], [71], [72]). Teaching observations of Engineering instructors show they do not assess or encourage students to communicate prior knowledge, what they already know or understand [47]. and from prior inquiry conducted in preparation for ITL during the past 2021-22 academic year and in CSE12, we found equity gaps decreased after shifting teaching method from Transmission to Inquiry.

Because the main goal for the ITL approach is to close equity gaps and support URM students to complete course requirements and declare engineering major within 2 years of study, we build upon the foundational research of White and Frederiksen, [65] and adopt their model for Inquiry that emphasizes and places the student question at the center of all activities, and this parallels the with the work and thinking of engineers [4] (see Figure 2).

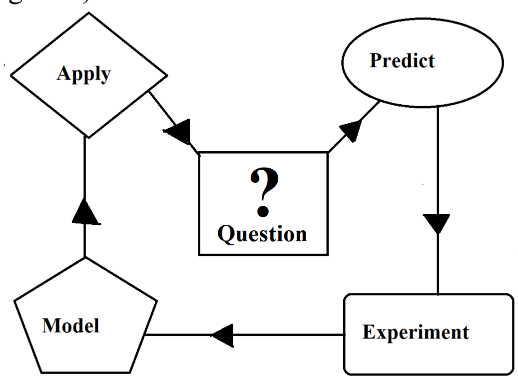

Figure 2 Inquiry model as applied in ITL

We use the term Inquiry Teaching and Learning (ITL) to emphasize that this work is adopted by both students and their instructors. The ITL approach will support undergraduate students to learn and apply Inquiry to become more engaged, successful learners and also to support instructors to engage in their own teaching improvements and better support undergraduate students so as to close equity gaps in large, gateway engineering courses. All ITL activities are defined by the above Inquiry model and reach all aspects of the student learning experience, including lecture, lab sections, and tutoring sessions. Practical descriptions or applications of the 5 parts of the Inquiry to teaching follow.

(i) Question: To initiate discussion around a course concept, the instructor will ask the budding engineers what they already know and why they believe the learning matters. Student questions and prior knowledge are elicited to understand the independent insights.

(ii) Predict: Given that the necessity of a concept's existence is established, how would the concept apply to real world examples? (At this stage, the instructor has not yet fully articulated the concept as they would have had in a Transmission method setting. The onus is on the students to discuss amongst themselves and come up with a rationale to apply to solve the given problems).

(iii) Experiment: The instructor guides students through a process materializing the course concept through trial and error while everyone contributes ideas toward solving the given problem. The instructor models methods for resilience when "stuck" problem solving.

(iv) Model: The outcome of the Experiment stage has finally yielded a cohesive model of the course concept. The instructor now guides students through further structuring of their created concept to evaluate and be compatible with the actual defined version in the textbook.

(v) Apply: Now that a cohesive model of the course topic has been laid out, various classroom examples that apply the newly learned concept are assessed.

A key feature of ITL is that throughout the 5 steps outlined above, the student body is never a singular passive listener. The students are constantly made to apply themselves actively in the formulation of the concept, starting from doing the relevant background research to finally applying their created model to various classroom exercises.

Practical Example of Transmission to Inquiry

We offer a brief side by side comparison of the aforementioned ITL philosophy to the more traditional Transmission teaching is shown in Figure 3 below. As context, this is the course CSE 12 (Computer Systems and Assembly Language). The content focus is Byte Ordering ([89]), a very important topic in computer memory.

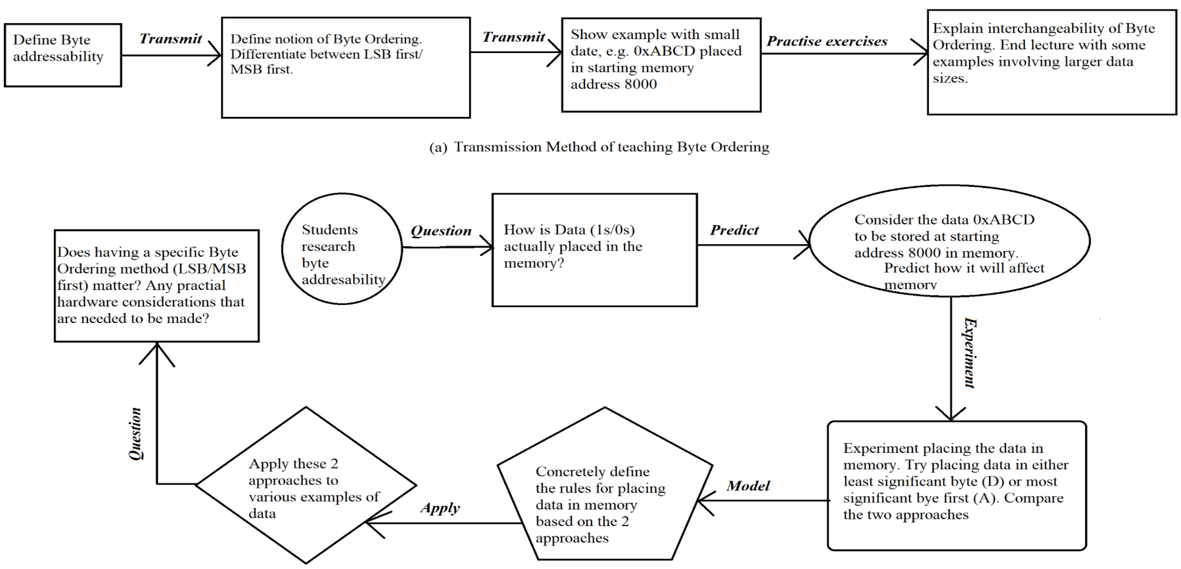

Figure 3 Teaching Byte Ordering in CSE 12 in the classroom through (a)Transmission vs (b) Inquiry

The traditional Transmission method would find the instructor explaining the relevance of Byte Ordering including the 2 types, Least Significant Byte (LSB) first and Most Significant Byte (MSB) first. Often, the instructor would then directly work through examples in class (Figure 3(a)), and students would observe and take notes. The lecture on Byte Ordering would conclude with the instructor explaining compatibility of the two different types of Byte Ordering.

Now, by contrast and as an effort to adopt Inquiry (Figure 3(b)), the work begins before the shared lecture time when students are asked by the instructor to prepare for the content by doing background research into byte addressability, an activity that would preclude learning about Byte Ordering itself, thereby asking students to ponder upon date placement in memory itself. In this model, the question is introduced and is central as motivation and a roadmap for learning. The question is introduced and becomes the driving force for the coming shared experience of lecture. Herein, the instructor only provides only a simple problem on data placement and asks students to work with a partner to predict how it affects the memory distribution of the data bytes. Student pairs are expected to experiment with data placement and gradually arrive at the modeling of the two Byte Ordering methods: LSB first and MSB first. They are positioned to apply their self-discovered knowledge on Byte Ordering to bigger problem sets as practice exercises. And this extends to their lab experiences.

Next, students will work on laboratories created around software in CSE gatekeeping courses, such as the RISC-V assembler and runtime emulator RARS [77]. Having been introduced earlier to

Inquiry, they are expected to apply the scientific method to advance their own understanding, reflecting and documenting their questions and experiences at every stage of the lab.

Regarding the framework for ITL shown as an example in Figure 3, questions can surface over the exact time overhead required of the instructor of any general targeted course. Would ITL require additional classroom time to engender the concept-based flowcharts as shown in Figure 3? How would this impact the effort and time instructors need to spend to change the way of teaching from transmission method to that if Inquiry? The answers lie in forming a scalable ITL training project where instructors can be trained to identify the concepts that require a switch in classroom introduction from Transmission to Inquiry prior to the start of the class quarter. The instructors can also identify in advance the foundational topics which can be researched by students before they instigate the 5-pronged approach to Inquiry discussed beforehand. Such a dedicated ITL training project realization would be part of the more all-encompassing scope of ITL as discussed in the section "ITL future work and applicability to scalability" .

As with any cultural change to how students understand learning, it is advisable that instructors who are adopting Inquiry over Transmission spend time explaining the method to students, sharing the visual diagram of the different stages of Inquiry, and providing scaffolds, such as graphic organizers that prompt students to reflect while engaging in what may be a very new and foreign approach to learning. The more explicit instructors can be about the value they place on learning through Inquiry, how this happens, challenges students face initially, and other factors, the better prepared students will be to adopt the ITL approach. A learning statement around Inquiry as the focus method can be designed and vetted by the department, included in the syllabi of instructors who are using Inquiry, as well as a diagram of the steps of Inquiry. Instructors can take less than 5 minutes at the start of each lecture to elicit and list student questions, and really celebrate these questions, as the foundation for Inquiry. Small actions that instructors take will center students on this new approach to learning, their role in the process, and will serve as time well spent in training students to be successful practicing learning through Inquiry.

CSE12: Foundational gateway course to initiate ITL

For this work, Computer Systems and Assembly Language (CSE12) was selected as the gateway course to emphasize Inquiry Teaching Learning (ITL) and address equity gaps. CSE12 is also a course that is alternatively taught by the two authors of this paper. The curriculum for this course broadly targets 4 core knowledge areas where students must demonstrate mastery:

1. Algorithms, data structures, and complexity (Area 1)
2. Programming languages (Area 2)
3. Software engineering and development (Area 3)
4. Computer systems (Area 4)

The partners chose CSE 12 because it is a compulsory, lower-division undergraduate course that establishes a foundation for computer science and engineering courses to come and prepares students to be successful in upper division courses. It has been identified within the division as a "gateway" course that does a high amount of "gatekeeping", a course with a history of large equity gaps (see Figure 4).

Accordingly, CSE12 is curated as an important introductory class (7 credits) and organized to address the four broadly defined learning outcomes into one cohesive pedagogical narrative aimed at preparing students with skills they need to be successful in upper division courses after declaring their major. There is a lot at stake with CSE12. The sponsors of the ITL program recognize CSE12 as the best starting opportunity to close equity gaps by infusing the course experience with ITL training and practices. Ideally and foundationally, students bring some prior programming experience to CSE12. Thus, they either must take CSE20 (Beginning Programming in Python) or pass a python test that ensures they have some basic programming knowledge to apply and are prepared to program in the RISC-V assembly language. CSE 12, taught over the span of a quarter (10 weeks), can be divided, in terms of a natural growing complexity of the course topics, into the following modules:

- **Module1(M1):**
  Boolean algebra and the foundations of digital logic design (Weeks 1-3): Fundamentals of Boolean algebra. They are taught the implementation of Boolean operators as combinational logic gates in increasing complexity, from simple AND/OR gates to more complicated digital logic designs such as adders, shifters, decoders/encoders and a basic Arithmetic Logic Unit. They also learn the low-level device implementation of logic gates in Complementary MOS (CMOS) design. They also learn of simple sequential logic gate behavior such as those of latches and D flip flops. M1 is intended to meet to an extent the target of Area 4.
- **Module2(M2):**
  Information representation (weeks 4-6): Students are taught how information is represented across various bases, example base 2, 10, octal, hexadecimal, 1s complement, 2s complement representation, IEEE single/double precision representation, etc. Students also learn basic bitwise operation concepts and shifting/rotating, topics which are fundamental to developing better insights as to optimizing speed of executing program code. M2 is intended to meet to an extent the target of Area 4 and Area 2.
- **Module3 (M3):**
  The Von Neuman computer model and coding in RISC-V assembly language (weeks 7-10): Students are taught of the general idea of a Von Neuman stored program computer model [41] that is at the heart of all modern processor designs. The course then uses the basic Von Neuman model as a platform to introduce RISC-V assembly language coding and how it interacts directly with the memory model as opposed to the abstraction presented in a high-level programming language like C, C++ or Python. M3 is intended to meet to an extent the target of Area 4 and Area 2 and satisfy the basic requirements of Area 1 and Area 4.

CSE12 is a required course taken sophomore year and prerequisite to other courses that build on the skills and knowledge, such as CSE13, Computer Systems and C Programming and then CSE120, Computer Architecture with RISC-V. With CSE12 successfully completed, students can elect to take CSE 101, Intro to Data Structures & Algorithms, a pathway to CSE102, CSE103, CSE112 or CSE114A. The enrollment capacity of CSE12 each quarter is 450 students and typically utilizes more than 20 Engineering Tutors who have previously and successfully taken the course. These tutors offer critical support to students, facilitating tutoring learning sessions at the peer-to-peer level. ITL allows for training our Tutors in TL and this holds incredible benefits for URM students learning to learn and think like engineers.

Because of the recent pandemic and due to emergency conditions, hitherto in-person lectures were delivered to students using online technology and remotely. However, beginning spring of 2022, in-person lectures were revived. What remains constant is that lectures are recorded, posted, and available to students as a follow up resource, something students report as highly valuable to their learning. Because of the pandemic, the university transitioned teaching entirely to online early in February of 2020, conditions that exacerbated equity gaps and have lasting consequences for institutions and programs attempting to close gaps ([78], [79]). The COVID-19 pandemic has illuminated disparities in higher education and heightened the urgency to find effective ways to reduce gaps and support URM students to succeed to degree. Training teachers to transition from Transmission to Inquiry holds promise for supporting students that have been disproportionately impacted by pandemic learning conditions. The ITL program will allow us to advance educational research and answer many pedagogical questions around effective ways of closing equity gaps in engineering education during this recovery period.

During the past academic year, from fall of 2021, CSE 12 instructors of various quarters began to engage and explore ITL teaching practices in Engineering Teaching Community (ETC) meetings and during one-on-one consultation sessions with the Curriculum Advisor. These meetings provided the prototype for ITL training and opportunities for faculty to understand inclusive teaching methods. Instructors of CSE12 **(i)** identified their questions around equity gaps and teaching for inclusion, **(ii)** explored ideas and methods for closing the gaps, **(iii)** employed new tools for measuring student learning and student experience, and **(iv)** made teaching alterations knowing student prior knowledge. As a result, the pass rate data from CSE 12 since 2017 is shown below in Figure 4. **We believe these efforts to explore equity data and learn ITL methods have led to smaller gaps in pass rates between URM and non-UMR peers in quarters Fall 2021, Winter 2022 and Spring 2022.** We look forward to the greater ITL effort, making ITL available to all Computer Science Engineering instructors as a method for closing equity gaps in gateway engineering courses.

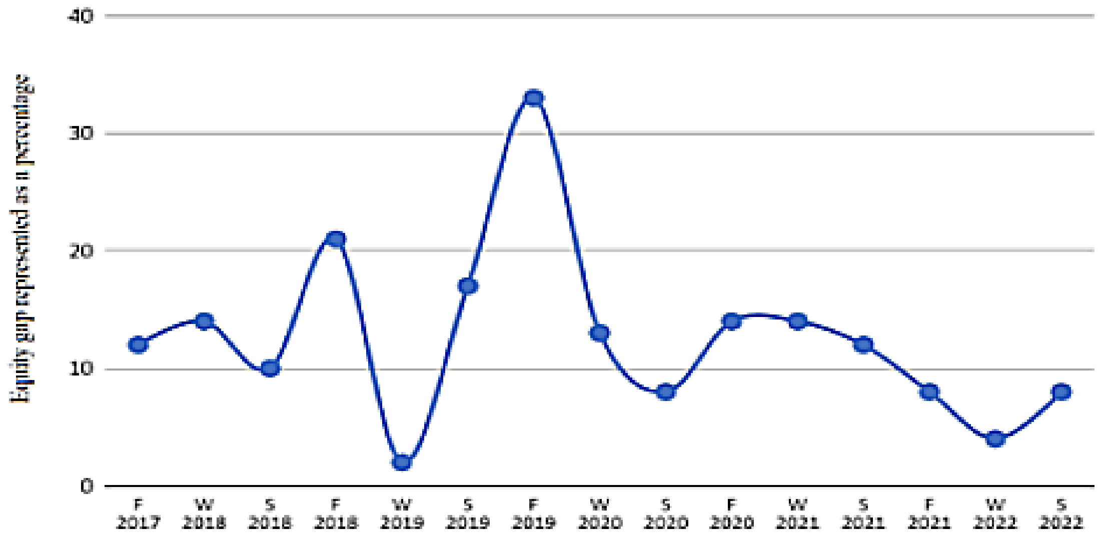

Figure 4 Equity Gaps in CSE12 Fall ‘17 - Spring ’22. The equity gaps are a measure of the difference between pass rates in URM students and their peers.

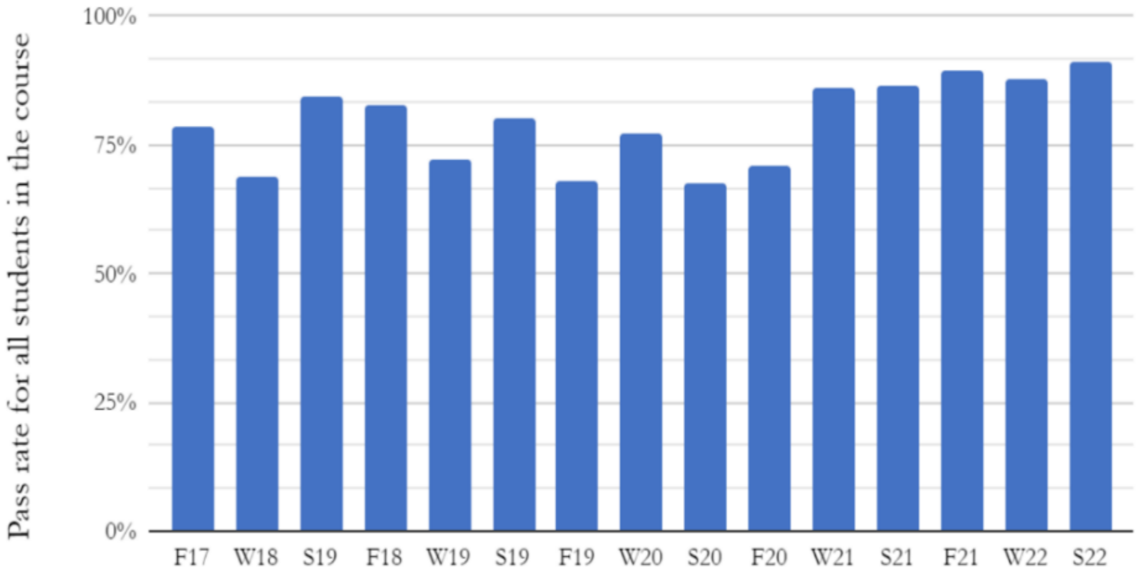

Figure 5 CSE12 pass rate data from Fall '17 - Spring '22

In preparation for the greater ITL effort, we have been focused on closing equity gaps in our large, gateway CSE12 course, beginning fall of 2021. We used institutional data and developed a process for improvement as detailed in the later section Training Development Plan. Through a series of meetings, members of the ITL Team during academic year 2021 - 2022, collaborated in meetings to review 1) teaching methods, 2) assessments, and 3) scalability in relation to student outcomes and course data, and specifically looking at equity gaps between URM and non-URM student subgroups. Inquiry was the foundation for all pre-ITL meetings with the guiding question "How can we teach differently to better support undergraduate engineering students from all backgrounds and preparations to succeed?" Guided by the educational literature on teaching through Inquiry, the investigators of the ITL training plan unpacked their current understandings and pedagogical practices in collaboration with their colleagues. To answer their inquiries, new tools were developed to elicit student prior knowledge and learning experiences and to illuminate data trends. Instructors were able to theorize on how students learn and students were able to communicate and explain their level of learning engagement and study habits. From this ITL approach came proof-of-concept processes that are the foundation for ITL, as well as timely changes to how CSE12 is taught, a shift from Transmission to one mixed with Inquiry. This ITL preparatory period proved fruitful now that we have the equity data and see what we hope will become a trend, a downward reduction in the pass rate difference between URM and non-UMR students. We are using this preliminary CSE12 work to capture and refine elements of the ITL program. We intend to make explicit through development of examples and materials the process of transitioning teaching from Transmission to Inquiry, and to incentivize and support other faculty to understand and adopt the practices with the goal of changing what it means to teach and learn in engineering.

ITL future work and applicability to scalability

For future ITL work, we intend to expand this effort within the department and to new partnerships. Using Intentional Change Theory [31] they will guide faculty and new partners to identify 1) ideal teaching and learning outcomes for newly targeted courses 2) actual student learning outcomes in these courses and 3) develop ITL methods closing the gap between 1 & 2 and 4) practice these new methods and 5) support the greater engineering community to transform teaching practices using Inquiry.

(i) Training plan statement: ITL development is constructed as a collaborative, sustainable, communicated effort complete with a plan for dissemination of findings. All meetings and development activities model Inquiry. The main research question is, how does a transition and transformation to Inquiry by an engineering department improve pass rates for URM students in Computer Science Engineering in our large, gateway courses, and how does early success impact timely declaration to degree? Those involved in development of ITL and all who take the training will be able to identify and apply Inquiry in any context, beginning with eliciting prior knowledge and questions to drive learning. Development of ITL training and implementation is not a stagnant, one-shot experience, but cyclical, modeled leading to continuous improvement and program sustainability and reaches 1) Engineering instructors, 2) Engineering tutors who have incredible influence on student learning at the peer-peer level and 3) High School science teachers and their students who will experience how engineers work and think, far from the Transmission model of teaching that is prevalent.

(ii) Purpose of training: The purpose of ITL training is to close equity gaps in engineering education by supporting instructors, engineering undergraduate tutors, and high school teachers and their students to transition teaching and learning using Inquiry, creating a sustainable approach because of a culture shift or shift in shared understanding [83] of what it means to learn in engineering ([4], [35], [21])

(iii) Training team, roles, and responsibilities: ITL project team members were identified because of the strong contributions they made in to prior ITL work, contributing expertise in redesign of CSE undergraduate courses and assessments through collaboration with colleagues and in content, assessment, and scalability reviews, providing proof-of-concept for the ITL proposed activities.

(iv) Training materials to develop: ITL training will be developed as modules in the university campus learning management system, Canvas. As part of our plan for sustainability, these courses can be shared through Canvas with any other university Engineering Instructor and will be complete with teaching videos of instructors demonstrating the ITL method as directly applied to engineering content, something that is very rare and unavailable to university Engineering instructors at this point. As part of broader impacts, developed training and relevant materials and videos that concisely demonstrate the ITL method will be made available outside of the university's Engineering department and to engineering instructors anywhere through a public platform. Broader dissemination of Inquiry teaching allows for remote, self-study of the method. As part of the Collaboration Plan, ITL Project Team members will meet every other week as an ITL check-in. During this short meeting, progress toward the ITL development will be assessed and work flow adjusted in order to ensure deliverables are met in time to facilitate a quality ITL training experience for Engineering undergraduate Tutors, and High School teachers and their students. ITL Project Team meetings will happen over Zoom for convenience and to encourage and support participation.

(v) Training schedule and rollout: Scheduling of ITL training for the high school community will be done as per recommendations by the high school teacher and liaison to the ITL Project Team. All participants in ITL training will be surveyed and encouraged to share their experiences and ideas for improving the training. All participant feedback will be included in the ITL shared Google folder so that all ITL Project Team members and Expert Evaluator can reflect and incorporate feedback in their work of review, development, and evaluation. Findings from participant data will be used to revise and improve ITL training as part of a continuous improvement process and in light of ITL goals. Efficacy of ITL training and participants' experiences will be assessed as part of a formative and summative assessment efforts by an Expert Evaluator. Please see Figure 6 for training schedules.

(vi) Review process: ITL training development incorporates a series of review activities that are specific to the expertise represented by the ITL Project Team. Every member has a unique role, conducts an individualized review, and brings informed and through recommendations back to the entire team and then engages with the team in critique to arrive at the ultimate decision. The ITL plan for collaboration uses Intentional Change Theory [31] and Inquiry, eliciting prior knowledge and experiences from meeting participants, identifying the ideal learning and actual learning outcomes, steps for closing the gap, methods for practicing those steps, and ways to sustain the work in community. This process will be taught to all ITL members by the Curriculum Advisor at the first ITL meeting and revisited at the start of all subsequent meetings. Meetings will resemble peer-reviewed practices and meetings of Critical Friends ([66], [67], [68],[69], [70]).

(vii) ITL training implementation within the current University:

ITL training will operationalize the main goal of closing equity gaps and supporting URM students to declare engineering major within 2 years into subgoals and steps or activities for participants to transition to Inquiry teaching and demonstrate their understanding. Two distinct groups in the Engineering department will take ITL developed training, 8 Computer Science Faculty and 60 undergraduate students.

(viii) ITL training beyond the current University: ITL developed training will be offered to a public school. The high school ITL training will be facilitated in person and on the university campus, bringing students to experience Computer Engineering. ITL training will include content that is appropriate for high school teachers and their students. The training will expose high school students and teachers to Computer science and Engineering, to the thinking of engineers, and will energize them to consider a career in engineering.

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