Fusion of COPUS and DEI Tools for Equitable STEM Classroom Engagement

Blessing Isoyiza ADEIKA, Morgan State University

Blessing Isoyiza ADEIKA is a Ph.D. student in Computer and Electrical Engineering at Morgan State University, with a strong focus on neuroscience and artificial intelligence. She has completed her Master's degree in Advanced Computing, where she honed her skills in Research Methodologies, Data science, and Machine Learning. Although Blessing's research aims to bridge the gap between neuroscience and AI, she is also dedicated to integrating experiment-centric teaching methods to simplify complex concepts for students, fostering practical learning and innovation. She is driven by a commitment to impactful problem-solving, addressing challenges in the medical, education, and technology sectors.

Dr. Oludare Adegbola Owolabi P.E., Morgan State University

Dr. Oludare Owolabi, a professional engineer in Maryland, joined the Morgan State University faculty in 2010. He is the assistant director of the Center for Advanced Transportation and Infrastructure Engineering Research (CATIER) at Morgan State Universit

Mr. Pelumi Olaitan Abiodun, Morgan State University

Pelumi Abiodun is a current doctoral student and research assistant at the department of Civil Engineering, Morgan State University, Baltimore, Maryland. Pelumi got his BSc and MSc degree in Physics from Obafemi Awolowo University, where he also served as a research assistant at the Environmental Pollution Research unit, in Ile-Ife, Nigeria. As part of his contribution to science and engineering, Pelumi has taught as a teaching assistant both at Morgan State University and Obafemi Awolowo University. With passion to communicate research findings and gleaned from experts in the field as he advances his career, Olaitan has attended several in-persons and virtual conferences and workshop, and at some of them, made presentation on findings on air pollution, waste water reuse, and heavy metal contamination.

Kingsley Matthew, Morgan State University

Mr. Kingsley Matthew is a graduate student in Computer Science with over eight years of experience in software engineering, full-stack web development, and database management. He has contributed to academic and industry projects involving research support, backend systems, and user-centered application design. Kingsley is currently engaged in research at Morgan State University, where he focuses on data analysis, software development, and educational technology. He is a member of several professional bodies including the Nigerian Computer Society and has received multiple honors for academic excellence and leadership in technology initiatives.

Dr. Ellen Wang Althaus, University of Illinois at Urbana - Champaign

Ellen Wang Althaus, PhD is the Assistant Dean for Strategic DEI Initiatives at The Grainger College of Engineering. She is a collaborative and innovative leader forging new initiatives and building alliances to foster diversity, equity, and inclusion (DEI) in science, technology, engineering, and mathematics (STEM) disciplines. In her current role, she is responsible for executing a college-wide strategy that infuses DEI throughout the unit. She collaborates with campus, college, and departmental leaders to identify needs and priorities; develop and implement evidenced-based strategies; and monitor and evaluate progress toward DEI. Ellen has served on the campus leadership team and cross-institutional steering committee for Big Ten Academic Alliance (BTAA) Advancing Women in STEM initiative. She is also Program Director/Co-PI for the NSF-funded Developing Equity-Minded Engineering Practitioners (DEEP) Center and Director/PI for the NSF Illinois ADVANCE grant initiative. She holds degrees in chemistry from Carleton College (BA), and Northwestern University (MS and PhD).

Dr. Ashleigh Wright, University of Illinois Urbana-Champaign

Ashleigh R. Wright, PhD is the Associate Director of the Institute for Inclusion, Diversity, Equity, and Access and Assistant Teaching Professor in the Department of Materials Science and Engineering at the Grainger College of Engineering. She is responsible for collaborating with college and departmental leaders and stakeholders to identify needs and priorities, developing and implementing evidence-based strategies, and measuring progress and effectiveness quantitatively against key metrics that promote diversity, equity, inclusion, and access to the undergraduate and graduate student communities. She also conducts research that analyzes trends, driving factors, barriers, and best practices to educate others and support organizational improvement. Prior to joining the University, Ashleigh managed and directed many training and pathway programs that support students from underrepresented backgrounds in STEM, and facilitated workshops that enhance the academic, personal, and professional development of students at North Carolina State University and Louisiana State University. She is a member of the National Organization for the Professional Advancement of Black Chemists and Chemical Engineers (NOBCChE) and Delta Sigma Theta Sorority, Inc. She holds degrees in chemistry from Wofford College (B.S.), North Carolina Agricultural and Technical State University (M.S.), and Louisiana State University (Ph.D.).

Dr. Lynford Goddard, University of Illinois Urbana-Champaign
Mr. Olorunfunmi Samuel Shobowale, Morgan State University

Olorunfunmi Shobowale is a graduate research assistant at Morgan State University, Maryland, pursuing a Masters degree in Advanced Computing. He has over nine years of experience in IT, edtech and STEM education. His research focuses on equitable engagement strategies and the integration of AI in learning environments.

Fusion of Observational Tools for STEM Classroom Engagement

Abstract

This research paper investigates how classroom observation tools can be effectively combined to promote engagement in STEM education. Specifically, it explores the integration of the Classroom Observation Protocol for Undergraduate STEM (COPUS) and a culturally responsive Classroom Observation Instrument (COI) to evaluate and improve teaching practices. COPUS, developed by Smith et al. [21], captures instructional dynamics and student-faculty interactions, while the Classroom Observation Instrument COI, created by Dr. Jennifer G. Cromley and the University of Illinois Urbana-Champaign (UIUC) Developing Equity-Minded Engineering Practitioners (DEEP) research team [6], focuses on observing and assessing culturally responsive -related instructional practices. At Morgan State University (MSU), a Historically Black University (HBCU), coders formally trained by the UIUC DEEP team used both tools to analyze classroom recordings of faculty who had undergone professional development in engaging pedagogy. Findings indicate measurable improvements and balanced engagement in the classroom. This fusion of COPUS and COI tools offers a replicable framework for enhancing inclusive STEM instruction and cultivating more equitable learning environments.

This work will be presented as a traditional lecture at the conference.

Keywords: STEM education, COPUS, culturally responsive, engaging pedagogy, classroom observations

Introduction

Creating inclusive and equitable learning environments in STEM education is essential to address the longstanding underrepresentation of marginalized groups. [1] Tools like the Classroom Observation Protocol for Undergraduate STEM (COPUS) have proven valuable in capturing teaching practices and student engagement, providing educators with data-driven insights into their classroom dynamics. Simultaneously, growing attention to cultural responsiveness in higher education has prompted institutions to develop frameworks for assessing inclusive pedagogy and student outcomes.

One such initiative is being advanced by the Developing Equity-Minded Engineering Practitioners (DEEP) Center, which has developed and implemented culturally responsive (CR) efforts through structured faculty development, including workshops and Communities of Practice (CoPs). These efforts aim to foster inclusive teaching practices across institutions by providing faculty with the tools and support needed to assess and improve classroom engagement.

The approach involves integrating the Classroom Observation Protocol for Undergraduate STEM (COPUS) with CR tools. The inclusion of CR tools ensures that classroom practices are assessed not only for engagement and interaction but also for their ability to support a diverse range of learners. This combined methodology aims to promote equitable engagement in STEM classrooms by aligning structured classroom observation techniques (such as COPUS) with inclusive pedagogical strategies, specifically designed to address the diverse needs of students from various racial, ethnic, and socio-economic backgrounds. The goal is to assess and improve classroom practices in a way that ensures all students have equal opportunities for participation, success, and engagement. Inclusive pedagogy is also central to this effort, as research highlights the detrimental impact of implicit biases and stereotype threats on student performance and participation in STEM disciplines [2]. Studies like Implicit Bias and Stereotype Threat in STEM [2] and Culturally Responsive Teaching and Faculty Workshops [3] can effectively raise faculty awareness of these challenges and motivate the adoption of inclusive practices to improve classroom climates. These efforts are critical for creating learning environments where all students, particularly those from underrepresented backgrounds, can thrive.

Despite increased awareness, systemic inequities in STEM education remain a significant barrier. Interventions like values affirmation, visual-spatial skill development, and racially inclusive STEM policies have shown promise in reducing achievement gaps, particularly related to race and gender [4][5]. However, their implementation requires sustained efforts from educators, policymakers, and institutions to drive meaningful change [6]. By combining the observational rigor of COPUS with the equity lens of COI, this study introduces a comprehensive framework that supports the transformation of STEM teaching and learning. This approach aligns with broader efforts to diversify the STEM pipeline and ensure that all students, especially those from historically excluded groups, have equitable opportunities to engage, participate, and succeed.

Research Questions

To evaluate the effectiveness of integrating COPUS and COI in fostering equitable classroom engagement, this study focused on the teaching practices of faculty trained in inclusive pedagogy. The professional development was delivered through Communities of Practice (CoPs) facilitated by the DEEP Center and designed to support faculty in embedding CR principles into their instruction. Classroom observations were conducted before and after the training to assess changes in engagement and inclusivity.

The following research questions guided this study:

1. What impact does the fusion of COPUS and COI tools have on addressing inequities in classroom participation?
2. In what ways do faculty professional development in experimental and inclusive pedagogies influence the effectiveness of COPUS and COI tools in promoting equity-centered teaching practices?
3. How can the proposed framework combining COPUS protocols, CR principles, and adaptive technologies be implemented to create a replicable model for equitable engagement in STEM education?

These questions shaped both the qualitative and quantitative data collection approaches used in this study. By analyzing classroom practices through the dual lenses of engagement and inclusion, the research aims to demonstrate how observation tools, when paired with equity - focused professional development, can drive meaningful instructional transformation.

Literature Review

The integration of the COPUS with COI tools represents a novel approach, building on existing research that highlights the need for diverse and inclusive educational environments, particularly in STEM fields where underrepresentation remains a significant challenge [5]. By combining COPUS, which provides a systematic way to observe and analyze classroom interactions, with CR strategies, educators can better understand and address the barriers faced by marginalized students. This fusion is crucial for fostering an inclusive learning environment that supports all students' success in STEM.

The Classroom Observation Protocol for Undergraduate STEM (COPUS)

It is a structured framework designed to assess teaching practices and student engagement in STEM classrooms. COPUS categorizes classroom activities into different types, such as lecture, group work, and individual work, allowing educators to evaluate the extent of active learning occurring in their classrooms. Using COPUS, educators can gain insights into their teaching effectiveness and identify areas for improvement. The benefits of implementing COPUS in STEM classrooms include enhanced student engagement, increased collaboration among students, and a greater focus on active learning strategies. By fostering an environment that encourages participation, COPUS contributes to more equitable STEM education.

COPUS provides a structured method to observe classroom dynamics, helping educators identify and address inequities in student participation and engagement. According to Ramos et al. [8], this tool can be used to assess the effectiveness of CR strategies in real-time classroom settings. By using COPUS, educators can gather data on student interactions and adapt their teaching methods to ensure equitable participation, thus supporting the goals of CR frameworks

CR/COPUS Fusion

Implementing CR-focused strategies in STEM education requires dismantling systemic barriers that limit teacher autonomy and agency, Which helps to empower teachers to make decisions based on their knowledge and goals for social justice is crucial for creating equity-centered classrooms The integration of CR principles into curriculum design, as demonstrated by the use of evidence-centered design (ECD), ensures that learning opportunities are accessible and relevant to diverse students, promoting engagement and success in STEM [9].

State of CR in the STEM Classroom

An effective curriculum and instructional methodology are designed to accommodate all learners without conferring undue advantages to any particular demographic group. The STEM Equity Framework, like the STEM Equity Pipeline, is designed to improve diversity and inclusion in STEM education by addressing systemic barriers and fostering supportive environments for underrepresented groups[10]. These frameworks typically advocate for the integration of inclusive practices throughout the curriculum, from instructional design to assessment. [11]. Three foundational principles, which are Equity in STEM Education, Student Engagement in Scientific and Engineering Practices, and Cultural Responsiveness, link student sensemaking within the

STEM classroom to culturally responsive pedagogical approaches aimed at fostering support for all learners [12]. Furthermore, this suggests that curricular and instructional strategies prioritizing student engagement in scientific and engineering practices possess "the potential to recalibrate science education towards more equitable, interactive, and participatory learning experiences for all students." This potential can be actualized if educators and learners are motivated to "challenge prescriptive notions of knowledge and practice in science" and are permitted to incorporate their diverse cultural backgrounds into their scientific endeavors. High-caliber instruction that incorporates cultural responsiveness can be nurtured through professional development opportunities, while well-designed curricular frameworks can underpin such educational practices. Learners, for instance, should have the opportunity to see their present and prospective identities represented within student-facing curricular resources. In the contemporary educational landscape, characterized by technological advancements and increasingly heterogeneous classrooms, it is progressively feasible for high-quality curricular resources to integrate multimodal/multisensory activities, thereby enabling students to engage with STEM along a spectrum of human abilities and experiences. Curricular resources that present multiple modalities for instructional delivery enable students to forge connections both within and among concepts, thereby enhancing the transferability of learning. By incorporating alternatives such as speech-to-text capabilities, collage creation, and interview presentations, educators can empower students to demonstrate their knowledge in diverse and accessible ways.

While these strategies offer a robust framework for enhancing equity in STEM education, challenges remain in their implementation. The need for sustained commitment from educators, policymakers, and communities is critical to overcoming barriers and ensuring that diverse voices are heard and valued in STEM fields. Additionally, ongoing research and adaptation of these frameworks are necessary to address the evolving needs of diverse student populations. The fusion of COPUS and COI tools offers a promising approach to equitable STEM education, while emphasizing the need for systemic changes in educational policies and practices. Addressing these challenges requires a collaborative effort among educators, policymakers, and stakeholders to create an inclusive and supportive learning environment for all students.

Theoretical Framework

Inclusive teaching practices play a crucial role in addressing the challenges of recruiting and retaining underrepresented groups in STEM fields [13]. Evidence indicates that workshops focusing on social identities and barriers, such as implicit bias and stereotype threats, can improve faculty attitudes and teaching practices [5]. The STEM Equity Model advocates for funding policies that support racially based collaborative STEM initiatives, emphasizing culturally responsive training for educators to bridge racial disparities in STEM [4].

The integration of the Classroom Observation Protocol for Undergraduate STEM (COPUS) framework and culturally responsive (CR) practices is anchored in educational theories that stress active engagement, inclusivity, and equity [14]. These foundational theories establish the intellectual basis for advancing equitable STEM education.

Active Learning and Social Constructivism are central to the COPUS framework. Active learning focuses on student-centered instruction, enabling learners to actively participate through discussions, problem-solving, and collaboration [15]. Social constructivism, introduced by Vygotsky, underscores the social nature of learning, where interactions with peers and instructors shape knowledge construction [16]. COPUS aligns with these theories by systematically documenting classroom interactions, allowing educators to refine teaching practices and ensure equitable student participation.

Critical Race Theory

Critical Race Theory (CRT) provides a vital lens for understanding and addressing systemic inequities in STEM education. It emphasizes the role of structural racism in shaping educational experiences, identifying how power dynamics, policies, and institutional practices perpetuate disparities [17]. By applying CRT, this study acknowledges the systemic barriers that underrepresented groups face in STEM classrooms, such as implicit bias and unequal access to resources. CRT's emphasis on counter-narratives is particularly relevant, as it centers on the lived experiences of marginalized students, highlighting their challenges and achievements as a foundation for transformative teaching practices.

In this study, CRT informs the development of inclusive STEM environments by guiding the integration of COI tools that challenge traditional pedagogical norms. For example, it underscores the necessity of addressing biases in faculty interactions and curriculum design, promoting equity

by recognizing the diverse cultural contexts of students. This approach aligns with the D-STEM Equity Model by providing actionable strategies for creating classrooms that actively dismantle inequities, ensuring that all students, regardless of background, can thrive in STEM disciplines.

Culturally Responsive Teaching

Culturally Responsive Teaching (CRT), as articulated by Gay, connects pedagogy to students' cultural contexts, affirming their identities and enhancing their engagement in STEM learning environments [18]. This approach emphasizes the importance of incorporating students' cultural knowledge, experiences, and learning styles into teaching practices, fostering a sense of belonging essential for their success. By bridging the gap between students' cultural contexts and STEM curricula, culturally responsive teaching empowers educators to create inclusive and engaging learning environments that reflect the diversity of their classrooms.

In the context of this research, culturally responsive teaching serves as a cornerstone for the CR framework, equipping educators with the tools to address the unique challenges faced by underrepresented groups. For instance, it encourages the inclusion of culturally relevant examples in STEM content, which can enhance student motivation and learning outcomes. This approach complements the COPUS framework by providing qualitative insights into classroom dynamics, ensuring that strategies for promoting engagement are not only evidence-based but also culturally attuned. Together, these tools create a feedback loop that refines teaching practices to promote equity and inclusivity in STEM education.

Synergy of COPUS and COI tools

Integrating COPUS and COI tools strengthens efforts to create equitable STEM learning environments. COPUS provides evidence-based insights into classroom interactions, while COI tools assess inclusivity by examining faculty awareness of implicit biases and the incorporation of culturally relevant content [18]. Together, these tools foster iterative improvement in teaching practices through feedback loops, identifying engagement gaps, implementing CR-informed interventions, and reassessing outcomes.

The fusion of these tools also aligns with equity-centered pedagogy, which seeks to dismantle systemic barriers in education [19]. COPUS highlights participation inequities, while COI tools

propose culturally responsive strategies to mitigate these challenges, enabling educators to tailor instruction to diverse student needs and promote inclusivity [20].

Framework for Equitable and Inclusive STEM Engagement

COPUS for Engagement Assessment: The COPUS framework enables the systematic documentation of classroom interactions, tracking engagement patterns, diagnosing barriers, and evaluating active learning strategies [21]. This approach enhances evidence-based decision-making in STEM classrooms.

CR Principles for Inclusivity: Incorporating CR principles addresses barriers faced by marginalized students. This includes culturally responsive teaching, equity-centered practices, and implicit bias mitigation, all aimed at fostering a welcoming classroom atmosphere and enhancing STEM identity for underrepresented groups [22].

Research Methodology

Research Design

This study employed a mixed-methods approach to evaluate the integration of the Classroom Observation Protocol for Undergraduate STEM (COPUS) and Diversity, Equity, and Inclusion (CR) tools in assessing and improving instructional practices in STEM courses at historically Black colleges and universities (HBCUs). The research was conducted across three courses - TRSS 301, CEGR 324, and CEGR 628 - and aimed to identify and address inequities in classroom instruction delivery while promoting equity-centered teaching practices.

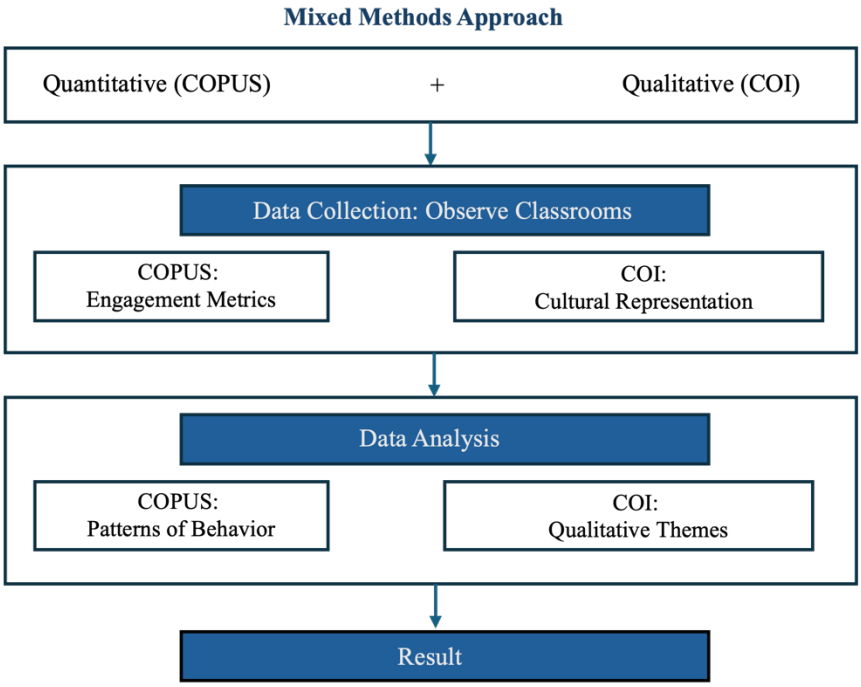


Figure 1: Our Mixed methods approach

Participants and Setting

This study was conducted across two Universities, one of which is a Historically Black Colleges and Universities (HBCUs) participating in the DEEP (Developing Equity-Minded Engineering Practitioners) initiative, a multi-institutional project funded by the National Science Foundation (NSF). The DEEP initiative aims to build more inclusive engineering education environments by equipping faculty with the tools to implement equity-minded teaching practices.

The participants included eight STEM faculty members from the participating institutions who voluntarily enrolled in a professional development program facilitated by the DEEP team for Morgan State University (MSU) faculty. These instructors taught undergraduate and graduate-level courses in engineering and transportation-related fields. They were selected based on their willingness to engage in long-term instructional improvement and their roles in courses where inclusive teaching practices could be implemented and observed.

The faculty participated in a Community of Practice (CoP) hosted during the summer of 2024 by the DEEP Center. This CoP was part of a broader professional development initiative aimed at

advancing equity in STEM classrooms through collaborative reflection, training, and experimentation. The program was structured over two intensive days and featured:

- Interactive workshops on inclusive and culturally responsive pedagogy;
- Case-based learning to explore real classroom challenges related to diversity and engagement;
- Group discussions to foster peer learning and share strategies for equitable instruction; and
- Development of individualized action plans, designed by each participant to guide implementation of CR strategies in their own classrooms.

Each faculty member participated in a 45–60-minute individual interview, where they reflected on their teaching philosophies, challenges with inclusive instruction, and anticipated changes to their pedagogical approach. These interviews informed the interpretation of classroom observations and offered deeper insight into how faculty internalized and applied what they learned through the CoP.

The courses selected for observation were core or advanced STEM courses: CEGR 628 (Bridge Engineering), TRSS 301 (Transportation Management), and CEGR 324 (Software for Structural Analysis and Design). These courses were chosen due to their diverse enrollment profiles and alignment with the instructional roles of the faculty participants.

It is important to note that while the classroom observation component of the study received IRB approval, the DEEP CoP itself was classified as professional development and did not require IRB review, as it did not involve human subject research.

By focusing on instructors actively engaged in reflective teaching and CR-centered training, the study aimed to capture both the challenges and potential of implementing inclusive pedagogy within the context of STEM education at HBCUs.

Procedure

The study was conducted in two phases - pre-training and post-training - to assess the impact of inclusive pedagogy training on faculty teaching practices and classroom engagement. Observations were carried out in three STEM courses across two institutions: *Bridge Engineering*

(CEGR 628), Transportation Management (TRSS 301), and Software for Structural Analysis and Design (CEGR 324).

Each course was observed once during the Spring 2024 and again during the Fall 2024 semester, allowing for comparative analysis of instructional strategies before and after the DEEP CoP training. These classroom sessions were video recorded and systematically analyzed using two complementary tools:

- COPUS was used to quantify classroom engagement by capturing instructor and student behaviors, such as lecturing, questioning, and group interactions.
- -COI was used to qualitatively evaluate classroom inclusivity by identifying positive and negative CR-related practices. These included attention to cultural responsiveness, equitable participation strategies, discouraging or stereotype-based language, and inclusive instructional design.

The pre-training phase involved baseline observations of classroom practices, which provided a snapshot of typical instructional methods prior to participation in the DEEP CoP. This phase was essential for identifying initial patterns in faculty-student interaction and the extent of inclusive engagement in STEM courses.

Following the summer 2024 training, the post-training phase captured changes in faculty teaching practices and classroom environments. In this phase, the same observational protocols were applied to assess whether instructors had implemented inclusive strategies from their CoP action plans and how these changes affected student engagement.

By comparing data across both phases, the study was able to evaluate the effectiveness of the training and the combined use of COPUS and COI as tools for identifying shifts in classroom equity and participation. Observers used structured coding sheets and reliability checks to ensure consistency and minimize bias during analysis.

Together, the procedure allowed for a comprehensive examination of how professional development in inclusive pedagogy can translate into measurable changes in teaching behavior and classroom culture.

Data Collection

To assess changes in faculty teaching practices and classroom engagement before and after the DEEP Community of Practice (CoP) training, a structured data collection process was

implemented across two academic semesters - Spring 2024 and Fall 2024. The data collection focused on three engineering-related STEM courses taught by participating faculty:

- **CEGR 628** - Bridge Engineering
- **TRSS 301** - Transportation Management
- **CEGR 324** - Software for Structural Analysis and Design

Each course was observed once during the spring semester (pre-training) and once during the fall semester (post-training), resulting in a total of six recorded classroom sessions. Observations were conducted using a dual-instrument approach that captured both quantitative and qualitative dimensions of teaching and learning.

COPUS Instrument (Quantitative Data)

The Classroom Observation Protocol for Undergraduate STEM (COPUS) was employed to document instructional behaviors and student engagement patterns in real time. Using a minute-by-minute coding scheme, trained observers recorded activities such as lecturing, posing questions, group discussions, student presentations, and interactive problem-solving. This allowed for a structured, data-driven snapshot of how class time was allocated and how students were engaged.

COI Instrument (Qualitative Data)

To capture inclusion-related practices and faculty-student interactions through a CR lens, the Diversity, Equity, and Inclusion – Classroom Observation Instrument (COI) - developed by Dr. Jennifer Cromley and the UIUC DEEP team - was used. Coders trained by the UIUC team used this tool to document both positive practices (e.g., culturally responsive instruction, affirming student voices, multiple modes of engagement) and negative practices (e.g., use of discouraging language, stereotypes, or rigid instructional approaches).

Each observed session was video recorded and independently coded by trained MSU observers who had completed reliability checks using mock sessions provided during their COI training. Observers completed structured coding forms aligned with each instrument and compared pre- and post-training sessions to track shifts in pedagogical strategies.

The combination of COPUS metrics and COI observations allowed for a comprehensive, triangulated understanding of classroom dynamics, capturing both what was happening in the classroom and how it was experienced by diverse learners.

A summary of the six observed course sessions is provided in the table below:

Table 1: Overview of Observed Courses with Corresponding Factors

Semester	**Course Code**	**Course title**	**Number of Sessions**
Spring 2024	CEGR 628	Bridge Engineering	1
Fall 2024	CEGR 628	Bridge Engineering	1
Spring 2024	TRSS 301	Transportation Management	1
Fall 2024	TRSS 301	Transportation Management	1
Spring 2024	CEGR 324	Software for Structural analysis and design	1
Fall 2024	CEGR 324	Software for Structural analysis and design	1

Data Analysis

Quantitative data from COPUS were analyzed to identify trends in engagement metrics, such as the percentage of class time spent on lecturing, student interactions, and questioning. Qualitative data from the COI tools were categorized into positive and negative practices, focusing on

elements such as cultural relevance and inclusivity. A comparative analysis of pre-and post-training data was conducted to evaluate changes in teaching practices and their impact on equitable classroom engagement.

Ethical Considerations

While the classroom observation protocol was approved by the institutional IRB, the DEEP CoP training itself did not require IRB submission or approval, as it was conducted as a professional development activity.

Discussion and Results

The analysis of classroom practices across three courses—CEGR 324(Software for Structural Analysis and Design), TRSS 301(Transportation Systems), and CEGR 628(Bridge Engineering)—revealed significant changes in teaching practices before and after instructors participated in the Community of Practice training during the summer of 2024.

Research Question 1: What impact does the fusion of COPUS and COI tools have, quantitatively and qualitatively, on addressing inequities in classroom participation?

The integration of the COPUS and COI tools provided a comprehensive evaluation of classroom dynamics in TRSS 301 and additional insights from CEGR 324 and CEGR 628, showcasing patterns in both positive and negative practices.

Before Training**:** The results of the COPUS observation shown in Figure 2 revealed that lecturing dominated instructional time, accounting for 56.5% in TRSS 301, with minimal student interaction - only 4.3% was spent on listening to and answering questions (AnQ). As shown in Figure 4, CR analyses across all three courses recorded frequent negative practices, such as reliance on stereotypes (5 occurrences in CEGR 628), discouraging language ("this is a weed-out class," 2 occurrences in CEGR 324), and rigid problem sets. Positive practices, including culturally responsive teaching or emphasizing help availability, were sparse, with no occurrences recorded in CEGR 628, as can be seen in Figure 6.

After Training: COPUS data showed significant increases in interactive teaching practices, with posing questions (PQ) rising to 18.2% and listening to/answering questions (AnQ) increasing to

13.6% in the TRSS 301 class. CR observations highlighted significant reductions in negative behaviors, such as discouraging language (0 occurrences in CEGR 324), and increases in culturally responsive practices, including linking content to underrepresented communities and providing multiple assignment formats, all occurring at different times in these classes.

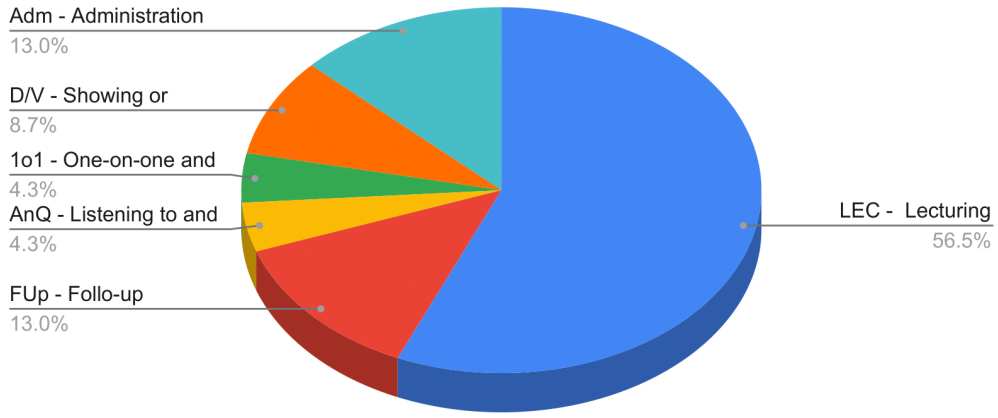


Figure 2: COPUS Observation of TRSS 301 Instructor's Class Activity before training

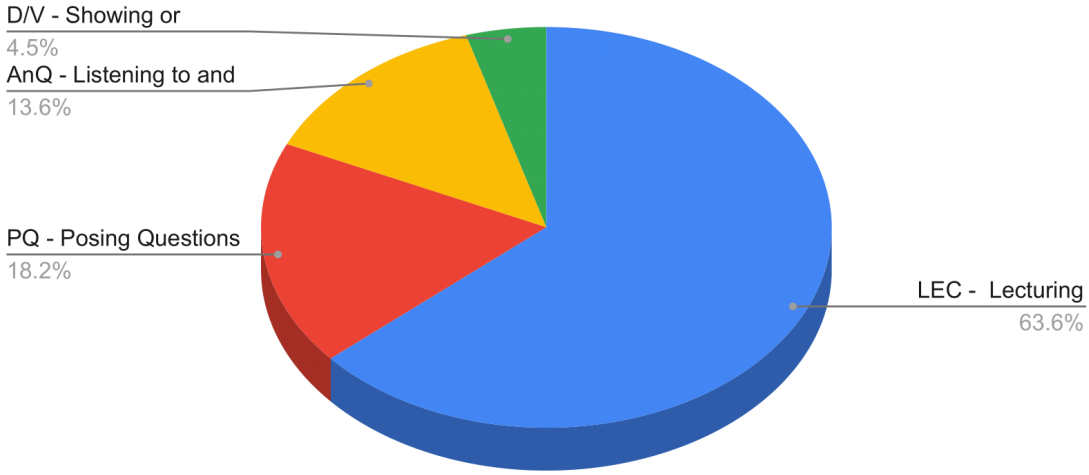


Figure 3: COPUS Observation of TRSS 301 Instructor's Class Activity After training

The results support the effectiveness of COPUS and COI tools in pinpointing classroom participation inequities and show that, after targeted training, there is a noticeable improvement in inclusive engagement for students from URM groups.

Research Question 2: In what ways does faculty professional development in experimental and inclusive pedagogies influence the effectiveness of COPUS and CR tools in promoting equity-centered teaching practices?

The Community of Practice training played an important role in improving teaching practices across all observed courses.

Shift in Practices: Post-training, faculty demonstrated increased adaptability and inclusivity. COPUS data reflected enhanced engagement strategies, with more time devoted to student interaction through questions and discussions, as shown in Figure 3. CR findings indicated enriched cultural responsiveness, such as using real-world examples relevant to underrepresented groups (Figure 7 showing occurrences in CEGR 324 and CEGR 628).

Reduction in Barriers: Negative practices, including rigid problem sets and discouraging communication, were significantly reduced across all classes. CEGR 324, for example, saw a marked decrease in stereotypical references and discouraging language, reflecting a shift toward inclusivity

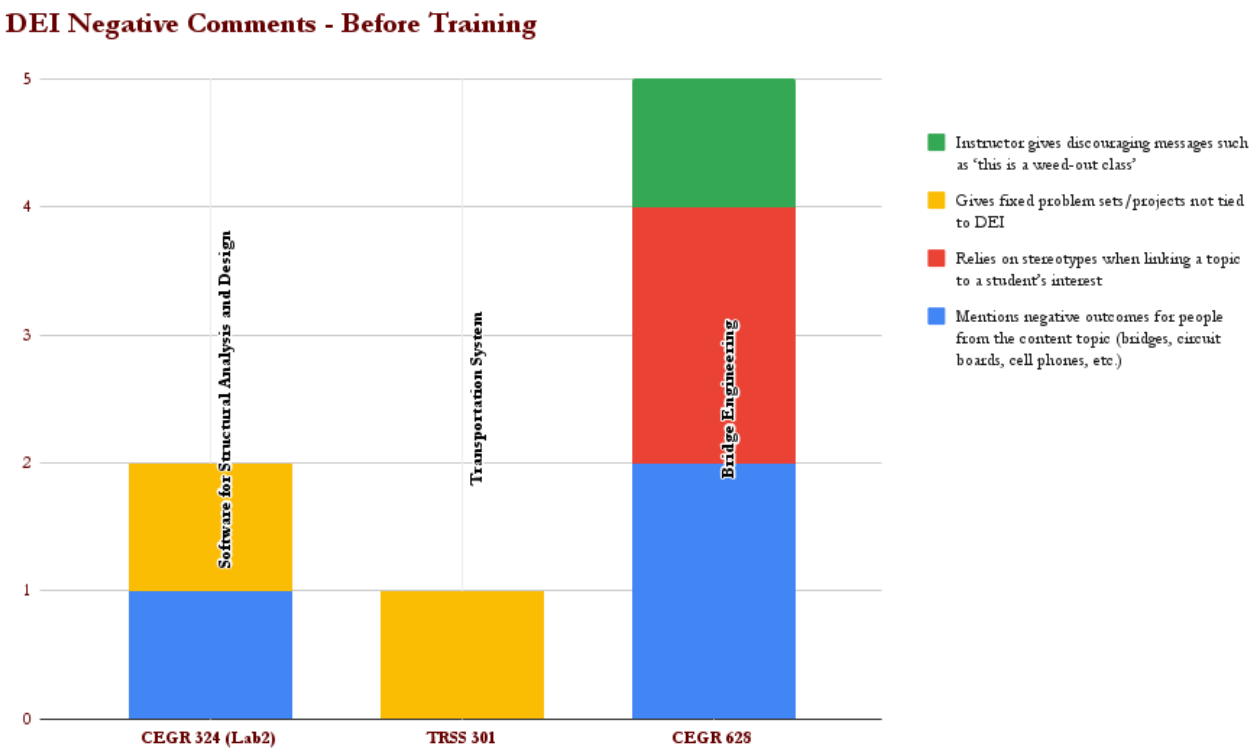


Figure 4: CR Negative Comments - Before Training

Figure 5: CR Negative Comments - After Training

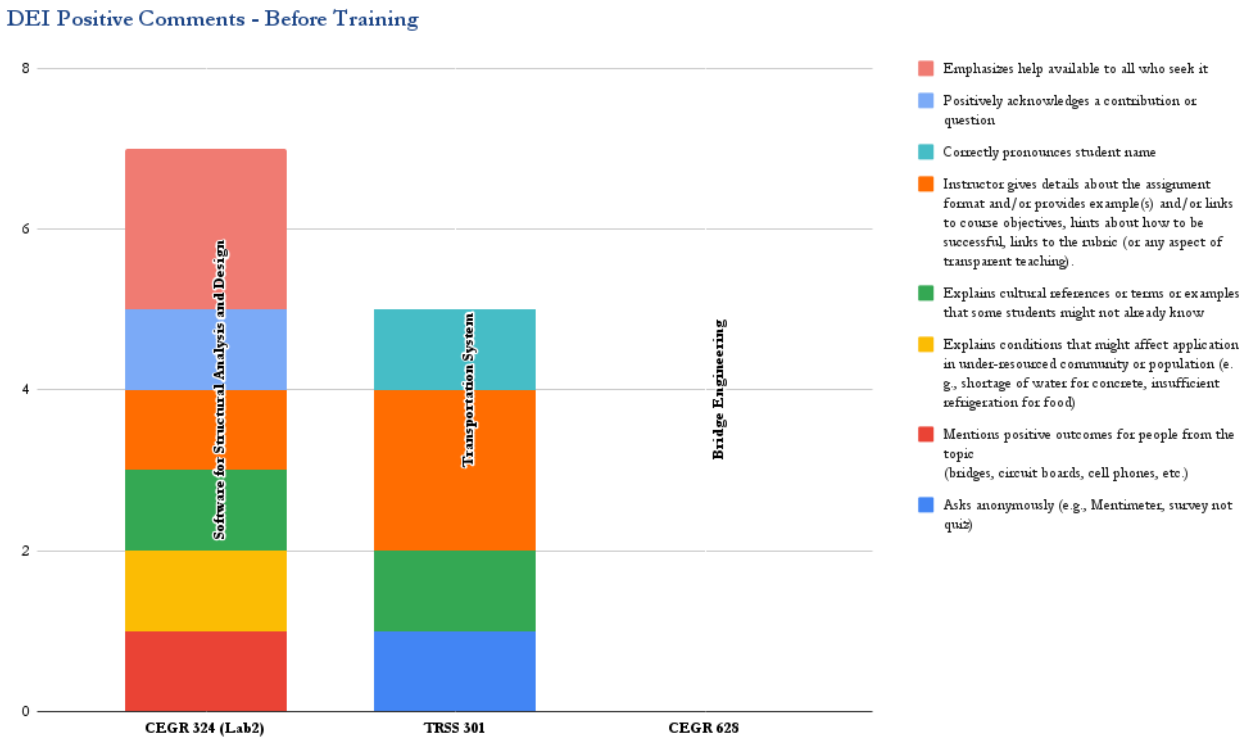


Figure 6: CR Positive Comment - Before Training

Figure 7: CR Positive Comments - After Training

As can be inferred from Figures 4-7, Faculty training enhanced the implementation of COPUS and CR tools, demonstrating their combined potential to promote equity-centered teaching practices tailored to diverse classroom dynamics.

Research Question 3: How can the proposed framework combining COPUS protocols, CR principles, and adaptive technologies be implemented to create a replicable model for equitable engagement in STEM education?

The findings from TRSS 301, CEGR 324, and CEGR 628 highlight the potential for a scalable and replicable framework combining COPUS and CR tools. By using COPUS to measure engagement quantitatively and CR tools to qualitatively assess inclusivity, this dual approach creates a holistic view of classroom dynamics. Prior studies, such as those by Cromley et al. [6] and Smith et al. [21], emphasize the importance of structured observations and inclusivity-driven pedagogies in achieving equitable classroom practices.

Implementation begins with professional development programs designed to bridge theoretical and practical applications of COPUS and CR methodologies. These programs should integrate adaptive technologies, such as real-time digital observation platforms, to provide immediate feedback and data-driven insights for educators. Such tools enable instructors to make iterative adjustments to their teaching strategies, fostering continuous improvement in classroom engagement. Research by Valdez et al. [7] further supports the use of digital aids in amplifying teaching efficacy within diverse classrooms.

Scalability requires sustained institutional support, with regular evaluation cycles to refine the framework's components. Establishing a culture of feedback and adaptation ensures the framework's relevance across various educational contexts. Drawing parallels with Smith et al. [21], the iterative refinement of teaching strategies through structured observation and professional development ensures replicability and sustained impact, especially when addressing systemic inequities in STEM education.

Limitations of the Study

Notably, we had observer bias, despite the use of structured assessment tools, which could have affected data interpretation, emphasizing the need for multiple independent raters in future

research. There was a limited sample size, restricted to two institutions, constraining the generalizability of the results, necessitating broader institutional representation. Variability in instructor participation and the degree of adoption of inclusive teaching strategies may have introduced inconsistencies, highlighting the importance of longitudinal studies to assess sustained pedagogical changes. Also, the study's short duration limits insights into the long-term impact of COPUS/CR, underscoring the need for extended research to evaluate the enduring effects of inclusive teaching practices on student engagement and success.

Conclusion

This study investigated the design, implementation, and results of integrating a COPUS and CR-based framework for assessing responses in STEM courses at significant HBCU institutions. Classroom dynamics in TRSS 301, CEGR 324, and CEGR 628 demonstrated marked improvements in instructional practices post-training, with increased interactive and culturally responsive teaching methods. Participation in the Community of Practice training played a pivotal role in equipping instructors with strategies to promote inclusivity and engagement, as evidenced by the reduction in negative practices and the enhancement of equitable teaching approaches.

By demonstrating the significance of infusing CR into course content to foster respectful, inclusive classroom environments, this study contributes to the broader discourse on equity in STEM education. The current study adhered to ethical guidelines to ensure the integrity of the study findings. Future research could focus on expanding this framework across broader contexts and integrating adaptive technologies for real-time feedback to enhance its applicability

Acknowledgment

This material is based upon work supported by the National Science Foundation Grant #2308531 and #2308532 titled "Collaborative Research: Track 4: Developing Equity-Minded Engineering Practitioners (DEEP)". We acknowledge the UIUC DEEP research team for their development of the COI instrument and for training Morgan State University coders in its application. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

References

[1] S. D. Castle *et al.*, "Systemic advantage has a meaningful relationship with grade outcomes in students' early STEM courses at six research universities," in *Proc. Int. J. STEM Educ. Conf.*, vol. 11, no. 1, p. 14, Feb. 2024, doi: 10.1186/s40594-024-00474-7.

[2] L. Farrell and L. McHugh, "Exploring the relationship between implicit and explicit gender-STEM bias and behavior among STEM students using the Implicit Relational Assessment Procedure," *J. Context. Behav. Sci.*, vol. 15, pp. 142–152, 2020, doi: 10.1016/j.jcbs.2019.12.008

[3] A. J. Samuels, "Exploring culturally responsive pedagogy: Teachers' perspectives on fostering equitable and inclusive classrooms," in *Proc. SRATE Journal Winter 2018 Conf.*, vol. 27, no. 1, pp. 22–30, 2018

[4] B. Dewsbury, and C. J. Brame, "Inclusive Teaching," *CBE—Life Sciences Education*, vol. 18, no. 2, article fe2, June 2019, doi: 10.1187/cbe.19-01-0021.

[5] S. L. O'Leary, M. L. Shapiro, and P. T. Toma, "Creating inclusive classrooms by engaging STEM faculty in culturally responsive teaching workshops," *International Journal of STEM Education*, vol. 7, no. 1, art. 11, Dec. 2020. doi: 10.1186/s40594-020-00230-7.

[6] Cromley, J., & Avent, C., & Jong, Jae J. (2025, April), DEI in Engineering Classroom instruction Observation Instrument (DEI-COI) User Manual & Technical Report v. 2, https://hdl.handle.net/2142/127969

[7] C. J. Valdez and N. C. Kelp, "Student perceptions of inclusive pedagogy in undergraduate STEM classrooms," *J. Microbiol. Biol. Educ.*, vol. 24, no. 3, Oct. 2023, doi: 10.1128/jmbe.00097-23.

[8] G. Ramos, C. Ponting, J. P. Labao, and K. Sobowale, "Considerations of diversity, equity, and inclusion in mental health apps: A scoping review of evaluation frameworks," *Behaviour Research and Therapy*, vol. 147, no. 147, p. 103990, Oct. 2021, doi: https://doi.org/10.1016/j.brat.2021.103990.

[9] N. Alozie, P. Lundh, K. Laguarda, C. Parker, and R. Fujii, "Designing for Diversity Part 1 Where is Equity and Inclusion in Curriculum Design?," 2021. Available: https://files.eric.ed.gov/fulltext/ED615692.pdf

[10] N. Nixon, Y. Lin, and L. Snow, "Catalyzing Equity in STEM Teams: Harnessing Generative AI for Inclusion and Diversity," *Policy Insights from the Behavioral and Brain Sciences*, Feb. 2024, doi: https://doi.org/10.1177/23727322231220356.

[11] R. Januszyk, E. Miller, and O. Lee, “Addressing Student Diversity and Equity,” *Science and Children*, vol. 053, no. 08, 2016, doi: https://doi.org/10.2505/4/sc16_053_08_28.

[12] M. Bang, B. Brown, A. C. Barton, A. Rosebery, and B. Warren, "Toward more equitable learning in science, expanding relationships among students, teachers, and science practice," in *Helping Students Make Sense of the World through Next Generation Science and Engineering Practices*, C. V. Schwarz, C. Passmore, and B. J. Reiser, Eds. Arlington, VA: National Science Teachers Association, 2017, pp. 33–58.

[13] J. Miller, “The Scales Lifted from My Eyes”: How an Equity Lens Can Inspire Teachers to Differentiate for Their Gifted Students, Doctoral dissertation, Northeastern University, Boston, MA, USA.

[14] Addy, T. M., Younas, H., Cetin, P., Rizk, M., Cham, F., Nwankpa, C., & Borzone, M. (2022). The development of the protocol for advancing inclusive teaching efforts (PAITE). Journal of Educational Research and Practice, 12(0), 65–93. https://doi.org/10.5590/JERAP.2022.12.0.05

[15] C. C. Bonwell and J. A. Eison, *Active Learning: Creating Excitement in the Classroom*. ASHE-ERIC Higher Education Report No. 1, Washington, DC: George Washington University, 1991. [Online]. Available: https://files.eric.ed.gov/fulltext/ED336049.pdf

[16] L. S. Vygotsky, *Mind in Society: The Development of Higher Psychological Processes*. Cambridge, MA: Harvard University Press, 1978. [Online]. Available: https://doi.org/10.2307/j.ctvjf9vz4

[17] R. Delgado and J. Stefancic, *Critical Race Theory: An Introduction*, 3rd ed. New York: NYU Press, 2017. [Online]. Available: https://leftychan.net/leftypol/src/1624076630977.pdf

[18] G. Gay, *Culturally Responsive Teaching: Theory, Research, and Practice*, 3rd ed. New York: Teachers College Press, 2018. [Online]. Available: https://eric.ed.gov/?id=ED581130

[19] B. I. Adeika, A. Ariyibi, P. O. Abiodun, and O. A. Owolabi, “Breaking Barriers: Promoting Motivation, Engagement, and Learning Success among Biology Undergraduates from Minority Backgrounds,” in Proc. ASEE Annu. Conf. Expo., 2024, Paper ID #42964.

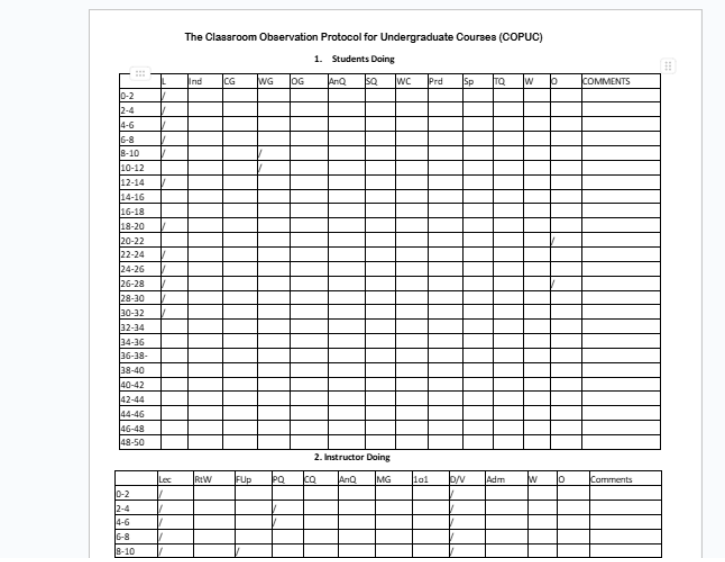
[20] K. Gutiérrez and E. Rogoff, "Cultural Ways of Learning: Individual Traits or Repertoires of Practice," *Educational Researcher*, vol. 32, no. 5, pp. 19–25, Jun. 2003. [Online]. Available: https://doi.org/10.3102/0013189X032005019

[21] M. K. Smith, F. H. M. Jones, S. L. Gilbert, and C. E. Wieman, "The Classroom Observation Protocol for Undergraduate STEM (COPUS): A New Instrument to Characterize University

STEM Classroom Practices," *CBE—Life Sciences Education*, vol. 12, no. 4, pp. 618–627, Dec. 2013. doi: 10.1187/cbe.13-08-0154.

[22] G. Ladson-Billings, "Toward a Theory of Culturally Relevant Pedagogy," *American Educational Research Journal*, vol. 32, no. 3, pp. 465–491, Sep. 1995. [Online]. Available: https://doi.org/10.3102/00028312032003465

Appendix: COPUS Observation Sample



The Classroom Observation Protocol for Undergraduate Courses (COPUC)

1. Students Doing

	L	Ind	CG	WG	OG	AnQ	SQ	WC	Prd	Sp	TQ	W	O	COMMENTS
0-2	/													
2-4	/													
4-6	/													
6-8	/													
8-10	/			/										
10-12				/										
12-14	/													
14-16														
16-18														
18-20	/													
20-22													/	
22-24	/													
24-26	/													
26-28	/												/	
28-30	/													
30-32	/													
32-34														
34-36														
36-38-														
38-40														
40-42														
42-44														
44-46														
46-48														
48-50														

2. Instructor Doing

	Lec	RtW	FUp	PQ	CQ	AnQ	MG	1o1	D/V	Adm	W	O	Comments
0-2	/								/				
2-4	/			/					/				
4-6	/			/					/				
6-8	/								/				
8-10	/		/						/				

COI Tool: Can be provided upon request