Abdul Rauf (He/Him)

845 W. Taylor St, Office 4500 SES
Chicago, IL 60607
arauf4@uic.edu, 773-575-1004

Webpage: https://ryu.lab.uic.edu/profiles/abdulrauf/
LinkedIn: https://www.linkedin.com/in/abdulrauf1103
Scholar: https://scholar.google.com/citations?hl=en&user=zwhVd2EAAAAJ
Research Gate: https://www.researchgate.net/profile/Abdul-Rauf-93
American Chemical Society: https://acs.digitellinc.com/b/sp/abdul-rauf-334955

EDUCATION

University of Illinois at Chicago (UIC) *2021- Present*
PhD Chemistry
- Specialization in *Chemistry Education Research (CER).*
- ***Advisor:*** *Prof. Minjung Ryu*
- ***Relevant Courses:*** *Research in Chemistry Education; Educational Research: Designs and Analyses; Cultural, Social, and Gender issues in Chemistry Education; Essentials of Quantitative Inquiry in Education; Essentials of Qualitative Inquiry in Education; Advanced Organic Chemistry; Biochemistry.*

Lahore University of Management Sciences (LUMS) *2019 - 2021*
MS Chemistry
- Specialization in organic chemistry.
- **Advisor:** *Prof. Muhammad Saeed*
- **MS Thesis:** *Synthesis and Anti-Covid-19 Evaluation of 1,3-Benzothiazinones (BTZs) Derived from Schiff Bases.*

University of Sargodha, Sargodha *2014 – 2019*
BS Chemistry
- Specialization in organic chemistry.
- Attended exchange semester at University of St. Francis, Joliet IL under fully funded scholarship offered by U.S. Department of State (*Dec 2016 – May 2017).*

LICENSURES & CERTIFICATIONS

- Collaborative Institutional Training Initiative (CITI Program)- **IPS for Researchers.**
- Collaborative Institutional Training Initiative (CITI Program)- **IRB Reference Resource.**
- Collaborative Institutional Training Initiative (CITI Program)- **Group 2. HSP, Social / Behavioral Research Investigators and Key Personnel.**

EXPERIENCE

University of Illinois at Chicago (UIC)
Graduate Research Assistant *May 2022 – Present*
- *Research Focus: Chemistry Education Research, Collaborative Action Research, Organic Chemistry Education Research, Models and Modeling, Teachers' Professional Development.*

Graduate Teaching Assistant Aug *2021 – Aug 2022*
- *General Chemistry (CHEM 122); Taught a total of 3 times.*
- *General Chemistry lab (CHEM 123); Taught a total of 3 times.*

Lahore University of Management Sciences (LUMS)
Graduate Research Assistant *Aug 2020 – June 2021*

- *Research Focus: Synthetic organic chemistry.*
- Project: Development of COVI9-19, SARS-CoV-2 Main Protease M^{PRO} inhibitors using synthetic organic and chemistry and molecular modeling.

Graduate Teaching Assistant *Aug 2020 – May 2021*

- *Courses Taught: Organic Chemistry (CHEM-231).*
- *Organic Chemistry lab (CHEM-230).*

Northwestern University, Chicago IL., Science in Society
Science Club Mentor (volunteer position) *Sep 2024 - Present*

Midtown Metro Achievement Centers, Chicago
Math and Science Tutor (volunteer position) *October 2022- Dec 2023*

LUMS Society of Chemical Sciences and Engineering
Assistant Director, Department of Publications *2019-21*
Director, Department of Publications *2020-21*

U.S. Department of State *Jan 2018 – Feb 2019*

- Worked on three projects under *Community Development Initiative (CDI)* grants awarded by U.S. Department of State via International Research and Exchanges Board (IREX).

International Research and Exchanges Board (IREX), Washington D.C. *Dec 2016 – May 2017*

- Worked as Student Ambassador of Pakistan under *Global UGRAD Student Exchange Program.*
- Placement at University of Saint Francis, Joliet, IL.

Lincoln Corner, University of Sargodha (A Project of U.S. Embassy in Pakistan)
Member of Board of Advisors *Jan – Aug 2019*

- Worked to promote interactive science learning and project-based learning at University of Sargodha.
- Conducted Statement of Purpose (SOP) writing sessions for US College admissions.
- Mentored teams to write research proposals for Pak-U.S. Alumni Network annual grants.
- Organized academic writing workshops.
- Organized hands-on workshops on software including ChemDraw, EndNote and Origin Pro and SPSS Data packages.

RESEARCH PROJECTS

Working as Graduate Research Assistant on the Project "*Institutional Transformation Through Curriculum and Faculty Development to Serve the Modern Chemistry Student*" (IUSE ICT) **NSF-DUE 211144**

Empowering Graduate Teaching Assistants in STEM: The Role of Collaborative Action Research in Professional Agency Development. **NSF-DUE 211144**

Beyond Arrows: Organic chemistry students' understanding of electron pushing formalism as scientific modeling: Independent Research Project for PhD Dissertation.

Development of COVI9-19, SARS-CoV-2 Main Protease M^{PRO} inhibitors using synthetic organic and chemistry and molecular modeling (*MS thesis work under the supervision of Dr. Muhammad Saeed*).

SCIENTIFIC CONFERENCES AND PRESENTATIONS

Rauf, A., Ryu, M., Wink, D.J. (2024, July 29). Engaging College Chemistry Faculty in Collaborative Action Research for Professional Development. Biennial Conference on Chemical Education **(BCCE)** 2024, Lexington, Kentucky. DOI: http://dx.doi.org/10.13140/RG.2.2.25764.90247

Rauf, A., Ryu, M., (2024, July 29). Beyond Arrows: Organic chemistry students' understanding of electron pushing formalism as scientific modeling. Biennial Conference on Chemical Education **(BCCE)** 2024, Lexington, Kentucky. DOI: http://dx.doi.org/10.13140/RG.2.2.32475.78884

Rauf, A., & Ryu, M. (2024, March 17). Empowering Graduate Teaching Assistants in STEM: Role of Collaborative Action Research in Professional Agency Development. National Association for Research in Science Teaching **(NARST)** 2024 Annual International Conference, Denver, CO. DOI: 10.13140/RG.2.2.34732.48005

Rauf, A., Ryu, M., Wink, D.J. (2023, March 27). Oral talk: Institutional transformation through curriculum and faculty development to serve the modern chemistry student: Action research as a professional development strategy, American Chemical Society (**ACS)** Spring 2023 International Conference, DOI: http://dx.doi.org/10.13140/RG.2.2.21310.70723

Rauf, A., Ryu, M., Wink, D.J. (2023, March 27). Poster presentation: Institutional transformation through curriculum and faculty development to serve the modern chemistry student: Action research as a professional development strategy. SciMix, American Chemical Society (**ACS)** Spring 2023 International Conference, Indianapolis, IN. https://doi.org/10.1021/scimeetings.3c00062

Organized international symposium on Antiviral Drug Discovery and Design" under supervision of Dr. Muhammad Saeed, Department of Chemistry & Chemical Engineering, SBA School of Science & Engineering, LUMS, Lahore. (October 10, 2020).

Member of student organizers committee for 2nd International Conference on Nanoscience and Nanotechnology. *(Organized by Department of Chemistry & Chemical Engineering, SBA School of Science & Engineering, LUMS, Lahore, the School of Chemical and Materials Engineering, NUST, Islamabad, and the Preston Institute of Nano Science & Technology, Preston University, Islamabad, November 1-2, 2019)*

PEER REVIEW

Reviewed journal manuscript for *The Science Teacher.* Manuscript ID 2024-Feb-TST-R-2215.R1, entitled "Is That Really True? Evaluating Science-related Claims Using Brief Bellringers.

National Association for Research in Science Teaching (NARST) International Annual Conference 2024: Reviewed 3 conference papers.

PROFESSIONAL MEMBERSHIPS

American Chemical Society (ACS); Membership ID: 33098617
National Association for Research in Science Teaching (NARST); Membership ID: 71955963
American Educational Research Association (AERA); Membership ID: 1106674
American Association for the Advancement of Science (AAAS); Membership ID: 60833777

GRANTS AND FUNDING

Graduate Research Assistant funding, NSF-DUE 211144; **$ $2,510**	May – Jun 2022
Graduate Research Assistant funding, NSF-DUE 211144; **$1505**	Jun – Aug 2022
Graduate Research Assistant funding, NSF-DUE 211144; **$10,040**	Aug – Dec 2022
Graduate Research Assistant funding, NSF-DUE 211144; **$10,040**	Jan – May 2023
UIC Graduate College Conference Award 2023; **$600**	Jun 2023
Graduate Research Assistant funding, NSF-DUE 211144; **$7530**	May – Aug 2023
Graduate Research Assistant funding, NSF-DUE 211144; **$10,442**	Aug – Dec 2023

Graduate Research Assistant funding, NSF-DUE 211144; **$10,442**	Jan – May 2024
UIC Graduate College Conference Award 2024; **$500**	Jun 2024
Graduate Research Assistant funding, NSF-DUE 211144; **$7831**	May – Aug 2024
Graduate Research Assistant funding, NSF-DUE 211144; **$10,756**	Aug – Dec 2024

HONORS AND AWARDS

- Selected as Judge for Chicago Public Schools Annual STEM symposia, 2023
- 100% Merit scholarship awarded by LUMS for MS Chemistry (2019)
- Selected by USEFP (Fulbright Commission) for fully funded scholarship to study in the US.
- Former Student Ambassador of Pakistan at U.S. Department of State acknowledgement certification by U.S. Department of State.
- Undergraduate exchange certification from University of St. Francis, Joliet, IL.
- Awarded by Prime Minister of Pakistan with laptop prize under "Prime Minister's Laptop distribution scheme for talented students.

RESEARCH SOFTWARE EXPERTISE

- SPSS Data Packages for quantitative data analysis
- Atlas.ti for qualitative data analysis
- MAXQDA for qualitative data analysis
- NVivo for qualitative and mixed-methods research
- InqScribe for qualitative data transcription
- EndNote and Mendeley for reference management
- Microsoft office
- Topspin and MestReNova for NMR analysis
- PyMOL for molecular visualization
- AutoDock Vina for molecular modeling simulations

LANGUAGES

- Urdu (native speaker), English (fluent), Punjabi (Fluent), Hindi (Advance), Arabic (Basic)

RESEARCH SUMMARIES

My research focuses on making the instruction and learning of chemistry more effective, contemporary, and engaging. Specifically, my work aims to meet two major goals: **first,** integrating curricula with real-world applications and contemporary research addressing, and **second,** addressing the critical national need for improving retention rates in STEM courses, particularly in challenging courses like general chemistry and organic chemistry. To that end, my current research involves three main projects:

Project 1

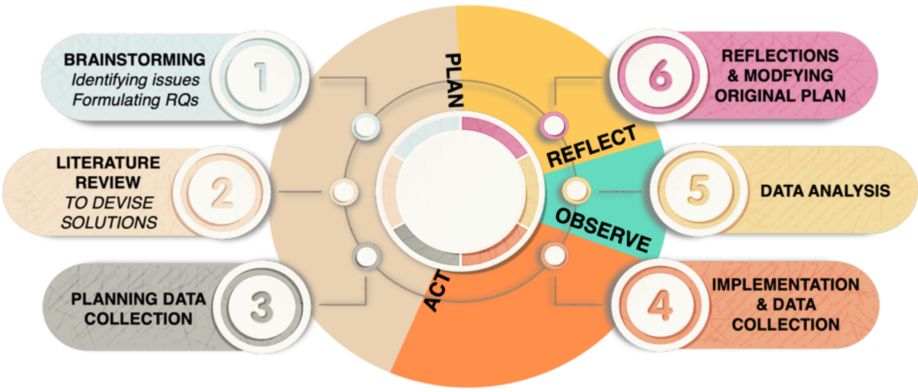
Project title:	*Action Research component of project "Institutional Transformation through Curriculum and Faculty Development to Serve the Modern Chemistry Student* **(IUSE ICT)**"
Country:	United States
Source of Funding:	National Science Foundation (NSF): NSF DUE 2111446
Problem Statement:	This project addresses three major problems. Firstly, it tackles the persistent issues associated with the instruction and learning of introductory chemistry courses, which are often labeled as "weed-out" courses due to their high rates of student failure, withdrawal, and poor performance (DWF rates). These ongoing struggles highlight the need for a deeper understanding of instructional practices and learning processes in these courses. By identifying and implementing evidence-based practices, the project aims to enhance student outcomes in introductory

	chemistry and STEM courses more broadly, thereby reducing DWF rates and improving overall student success. Secondly, the project addresses the lack of preparedness among students for modern-day skills and demands. This problem underscores the importance of integrating contemporary research and societal issues into chemistry curricula. Such integration is crucial for preparing students to apply their knowledge to real-world problems effectively. The current disconnect between classroom learning and the practical skills needed in professional settings hampers students' ability to transition smoothly from academic environments to their future careers. By incorporating relevant and current research topics into the curriculum, the project seeks to bridge this gap and better equip students with the knowledge and skills required in the modern scientific and professional landscape. The third problem addressed by this project is the unique dynamics and hierarchical structures inherent in university-based settings, where instructors hold various designations such as tenured professors, non-tenured lecturers, and graduate teaching assistants (GTAs). These differing roles and statuses can complicate collaborative processes, including Collaborative Action Research (CAR). The project recognizes the need for studies that examine how CAR and other collaborative methodologies function within such complex academic environments. By investigating the distinctive partnership dynamics and effectiveness of CAR in university settings, the research aims to develop strategies that foster effective collaboration across these hierarchical structures. This, in turn, can lead to more cohesive and productive efforts in improving instructional practices and student outcomes. **Why is this research different from other research already done in the field?** It integrates the use of Collaborative Action Research (CAR) within the specific context of university-level chemistry education. While CAR has been widely utilized in K-12 education to foster continuous improvement in teaching practices, its application in higher education, particularly within the hierarchical and diverse instructional environment of universities, remains underexplored. This project uniquely addresses this gap by examining how CAR functions among chemistry instructors with varying designations, such as tenured faculty, non-tenured lecturers, and graduate teaching assistants. This focus on the distinct dynamics of higher education settings provides a novel perspective that has been largely overlooked in prior research.
Project Summary:	In response to contemporary challenges and the expanding scope of scientific inquiry, enhancing STEM education is paramount, particularly in its capacity to integrate current research and societal issues. This integration is essential for better preparing students to apply their knowledge to contemporary problems. To address this need, the University of Illinois Chicago's Department of Chemistry launched a National Science Foundation (NSF) supported project in 2021. This initiative, titled Institutional Transformation through Curriculum and Faculty Development to Serve the Modern Chemistry Student (IUSE ICT), is focused on evidence-based research of instructional practices, course and curriculum revisions, and faculty development. A key component of the IUSE ICT project is the incorporation of collaborative action research (CAR), where chemistry education researchers collaborate with chemistry course instructors through an iterative process of identifying issues related to the instruction and learning of chemistry,

	designing evidence-based and literature-based interventions, collecting data, analyzing data, and reflecting retrospectively. As a graduate research assistant specializing in chemistry education, I collaborate with a team of instructors on this action research endeavor. My research within this context aims to examine the process of CAR and understand how collaboration functions in the higher education setting, noting that while CAR has been extensively used in K-12 settings, its application in higher education is less explored. By examining the process and distinctive partnership dynamics inherent in CAR within university-based collaborations, my research evaluates the effectiveness of the CAR process between university-based chemistry instructors and chemistry education researchers. Specifically, my research questions are: 1) How does the collaborative action research process work between university-based chemistry instructors and chemistry education researchers? 2) How can collaborative action research be used as a tool to improve the instructional practices of university-based chemistry instructors? I draw upon the Communities of Practice (CoP) framework by Etienne Wenger (1999) to examine the collaborative processes in CAR. CoP is defined as a group of individuals who share a common interest and engage in a collective process to enhance their practice (Wenger-Trayner & Wenger-Trayner, 2014). Within the CoP framework, three crucial elements are highlighted: domain, community, and practice. The domain pertains to the shared interest in advancing chemistry education through evidence-based practices and action research. Regular interactions, which form the community aspect, include meetings, workshops, and collaborative sessions that foster ongoing dialogue and the exchange of ideas. The practice element involves developing a shared repertoire of resources such as instructional strategies and evidence-based interventions to enhance learning. This repertoire is continually refined as members contribute their expertise and experiences, ensuring the community's growth and the sustained improvement of instructional practices. The CoP framework offers a lens to analyze how chemistry instructors and chemistry education researchers form and sustain a community focused on improving chemistry education. This community is characterized by collaborative learning processes, knowledge sharing, and a collective goal of enhancing instructional practices and curriculum design.
Important Articles:	**Conference Presentations by me:** • <u>Rauf, A.,</u> Ryu, M., Wink, D.J. (2024, July 29). Engaging College Chemistry Faculty in Collaborative Action Research for Professional Development. Biennial Conference on Chemical Education **(BCCE)** 2024, Lexington, Kentucky. • <u>Rauf, A.,</u> Ryu, M., Wink, D.J. (2023, March 27). Poster presentation: Institutional transformation through curriculum and faculty development to serve the modern chemistry student: Action research as a professional development strategy. SciMix, American Chemical Society (**ACS)** Spring 2023 International Conference, Indianapolis, IN. https://doi.org/10.1021/scimeetings.3c00062 • <u>Rauf, A.,</u> Ryu, M., Wink, D.J. (2023, March 27). Oral talk: Institutional transformation through curriculum and faculty development to serve the modern chemistry student: Action

research as a professional development strategy. American Chemical Society (**ACS)** Spring 2023 International Conference, DOI: http://dx.doi.org/10.13140/RG.2.2.21310.70723

The figure below shows unique 4 phases and 6 stages approach for Collaborative Action Research, developed my me.



I have also developed a toolkit of techniques used in brainstorming and problem identification. These techniques included reflective interviews, analytic discourse and graphic representations. As of Spring 2024, I have sequentially conducted CAR with three instructional teams—organic, inorganic, and biochemistry—each in a different semester. This collaboration has included a diverse group of instructors, including a graduate teaching assistant, three tenured faculty members, and two non-tenure track faculty members. Each team underwent a process of identifying potential issues they wanted to address, reviewing literature to identify solutions, formulating research questions, developing and submitting IRB application, designing data collection, collecting and analyze data.

Table: Key activities conducted under Collaborative Action Research Project

Semester	Course	Collaborative Action Research Activities
Spring 2023	Chem- 314 Inorganic Chemistry	• Identified the issue of underperformance and diminished motivation in Walsh Diagram Lab. • Designed a Prelab activity based upon Moozeh et al. (2019) Prelaboratory Learning Framework. The Prelab comprised of a video, worksheet, and formative assessment components. • Received IRB approval. • Collected data using exit slips, entrance surveys, interviews, field notes and students’ lab reports over spring 2023 and fall 2023. • Analyzed the data. • The manuscript focusing on design and outcomes of intervention in progress.

Fall 2023	Chem- 455 Biochemistry	• Identified students' difficulty in grasping the objective and experimental design of the wet-lab project, which encompasses three intertwined experiments i.e., Site-Directed mutagenesis of TEM-1 DNA, expressing it in E.coli, and functional analysis of the mutant proteins. • Revised the instructional strategy focusing on providing clearer picture and rationale of conducting these experiments and conducting office hours to respond to better engage students. • Received IRB approval. • Collected data over fall 2023. • Analysis in progress.
Spring 2024	Chem- 232 Organic Chemistry	• Identified students' difficulty in writing reaction mechanisms in organic chemistry. • We have designed a unique Peer Learning Assistant (PLA) model and in-class, small teams activities using problem-solving worksheets. • Formulated research questions. • Received IRB approval. • Recruited 20 PLAs • Designed and conducted PLAs pedagogy training.

Project 2

Project title:	*Empowering Graduate Teaching Assistants in STEM: Collaborative Action Research and TA's Professional Agency*
Country:	United States
Source of Funding:	National Science Foundation (NSF): NSF DUE 2111446
Problem Statement:	Graduate Teaching Assistants (GTAs) occupy a distinctive position within higher education settings, aptly noted by Muzaka (2009) as an 'ambiguous niche'. The multifaceted role of GTAs as teachers, researchers, students, and employees presents unique challenges related to agency and recognition. Literature shows the contributions of GTAs to teaching provision are often undervalued and they are usually relegated to the status of mere "cheap labor". This is vividly captured by Park and Ramos (2002), who described TAs' experience as "donkey in the department", highlighting the disproportionate balance between their workload and autonomy. These challenges underscore the need for innovative professional development approaches that empower GTAs in their teaching roles. Collaborative Action Research (CAR), with its emphasis on instructor ownership in decision-making and the promotion of reflective practice, can be used as an effective method for empowering GTAs. It shifts their role from passive participants to active, engaged contributors within the educational system. In our study, we engaged a senior GTA in a semester long CAR project to offer professional development and to examine1) how GTA navigate and exercises his professional agency within his teaching role? And 2) what is the impact of CAR on professional agency of a graduate TA? **Why is this research different from other research already done in the field?**

This research distinguishes itself from previous studies by focusing on the application of CAR to enhance the professional agency of GTAs. While prior research has acknowledged the challenges faced by GTAs, there has been a lack of comprehensive studies examining how structured, participatory approaches like CAR can transform these challenges into opportunities for professional growth and agency. By engaging a senior GTA in a semester-long CAR project, this study not only provides professional development but also closely examines the nuances of how GTAs navigate their roles and exert their agency. The theoretical framework employed, based on Eteläpelto et al. (2013), offers a subject-centered socio-cultural perspective on professional agency, emphasizing the situated nature of agency within socio-cultural and material contexts. This approach allows for a nuanced understanding of how GTAs' lived experiences, professional identity elements, knowledge, and competencies serve as resources for exercising agency.

Project Summary:

Graduate Teaching Assistants (GTAs) occupy a distinctive and multifaceted role within higher education, balancing responsibilities as teachers, researchers, students, and employees. This complex position, described by Muzaka (2009) as an 'ambiguous niche,' presents unique challenges related to agency and recognition. The literature consistently highlights the undervaluation of GTAs' contributions to teaching, often relegating them to the status of "cheap labor" (Park & Ramos, 2002). This dynamic vividly captures GTAs' experiences as akin to being a "donkey in the department," underscoring the disproportionate workload they carry relative to their autonomy and recognition. Such challenges highlight the critical need for innovative professional development approaches that empower GTAs in their teaching roles. One promising method is Collaborative Action Research (CAR), which emphasizes instructor ownership in decision-making and the promotion of reflective practice, effectively shifting GTAs from passive participants to active, engaged contributors within the educational system. This study engaged a senior GTA in a semester-long CAR project to offer professional development and examine two primary questions: how GTAs navigate and exercise their professional agency within their teaching roles, and the impact of CAR on the professional agency of a GTA.

Our study is anchored within a theoretical framework of professional agency from a subject-centered socio-cultural perspective, as outlined by Eteläpelto et al. (2013). This framework posits that professional agency is inherently situated within, and responsive to, the socio-cultural and material contexts of the workplace. It views professional subjects as agentic beings whose lived experiences, professional identity elements (such as commitments, ideals, motivations, interests, and goals), knowledge, and competencies serve as resources for exercising professional agency. This agency drives creative initiatives, professional growth, renegotiation of work-related identities, and the shaping of work environments. The study's methodology involved engaging an inorganic chemistry GTA in the CAR process. Qualitative data were utilized to capture the nuances of the GTA's professional agency and understand the impact of CAR. The analysis began with a deductive approach, coding the data using codes derived from Eteläpelto et al.'s (2013) professional agency framework. Relationships between codes were then closely examined to identify patterns and connections, which led to the emergence and refinement of overarching themes representing synthesized insights from the coded data. Each theme was reviewed and refined to ensure coherence and meaningfulness, without significant

	overlap. This process involved multiple revisits to the original data to validate that the themes accurately reflected the GTA's experiences. Preliminary findings from this project demonstrate that the GTA leveraged their personal interest in education, experience, and work history as a GTA to assert influence and take ownership within the action research process. This proactive involvement was evident in several key activities: leading the team of GTAs, making collaborative decisions, and designing intervention materials. Moreover, the GTA actively sought feedback from other inorganic chemistry instructors to refine the developed interventions. The analysis also revealed significant challenges encountered by the GTA, particularly the pervasive lack of engagement from other GTAs in their teaching responsibilities. This disengagement led to inadequate preparation for lab sessions, which in turn contributed to unresolved student confusions during labs. Participation in the CAR project catalyzed a transformative shift in the GTA's perspectives in two critical areas. First, there was a notable shift from attributing student disengagement to individual student deficiencies, to recognizing and addressing curricular issues—such as unclear language in the laboratory manual and cognitive overload during lab sessions—as root causes of student demotivation. Second, there was a significant change in the GTA's valuation of student feedback, transitioning from undervaluing it to acknowledging and incorporating student feedback as a crucial element of pedagogical improvement. These findings underscore the efficacy of CAR in enhancing professional agency among GTAs, facilitating a deeper understanding of the complexities of teaching and learning environments, and promoting a more reflective and responsive educational practice. This study contributes to the ongoing discourse on the importance of empowering GTAs and offers a practical, evidence-based approach to achieving this goal through CAR.
Important Articles:	**Conference Presentations by me:** • <u>Rauf, A.,</u> & Ryu, M. (2024, March 17). Empowering Graduate Teaching Assistants in STEM: Role of Collaborative Action Research in Professional Agency Development. National Association for Research in Science Teaching **(NARST)** 2024 Annual International Conference, Denver, CO. DOI: 10.13140/RG.2.2.34732.48005

<u>**Project 3**</u>

Project 3:	*Beyond Arrows: Organic Chemistry Students' Understanding of Electron Pushing Formalism as Scientific Modeling*
Country:	United States
Source of Funding:	Independent project for PhD
Problem Statement:	Despite being a prerequisite for various STEM majors, introductory organic chemistry is notorious for its high Drop, Fail, and Withdraw (DFW) rates, reflecting the significant struggles students face in this subject. This high attrition rate is unsurprising, considering that organic chemistry is markedly different from other branches of chemistry. It is often regarded as a "second language" due to its heavy reliance on visualization and representation skills; For example, in understanding stereochemistry or the intricate details of how reaction mechanisms work and how bonds are

	broken or formed. Modeling, which involves the ability to understand and represent the underlying phenomena through physical representations like mechanistic arrows and molecular orbital diagrams, is crucial to develop expertise in organic chemistry, yet it remains inadequately addressed in current textbooks and curricular designs and not explicitly taught. It's akin to learning a new language without first mastering its alphabet. Padalkar and Hegarty (2015) indicated: "*Students have poor attitudes toward using models, which stems in part from a lack of understanding of the ontological status of models in science. Specifically, students often perceive models as copies of scientific phenomena rather than as tools for understanding these phenomena or solving problems*". This calls for an explicit teaching of models and modelling before teaching higher order concepts in organic chemistry. As highlighted by Passmore et al. (2013*), it is essential for educators to understand and explain the core features of the subjects they teach, including the nature of models*. They argue that "*an explicit exploration of the epistemological underpinnings of modeling is vital not only for discussions on the nature of science and scientific inquiry but should also be a key element of classroom practice*" In the context of teaching visualizations and 'epistemological underpinnings of modeling', Cooper et al., 2019 indicated that there is no evidence-based consensus for how visualizations should be introduced or used. **Why is this research different from other research already done in the field?** This research distinguishes itself from existing studies by adopting a novel perspective on modeling in organic chemistry, specifically positioning EPF as a 'model for' explaining and predicting chemical phenomena rather than a static 'model of' electron movement. Previous research has largely treated EPF as an academic exercise or heuristic tool, without delving into its potential as a dynamic, agent-centric model that fosters epistemic agency among students. By conceptualizing EPF as an interactive tool used actively by scientists and students to achieve specific epistemic goals, this study emphasizes the role of students as active participants in their learning journey, rather than passive recipients of information.
Project Summary:	This research project focuses on the construct of models and modeling in organic chemistry. Despite being a prerequisite for various STEM majors, introductory organic chemistry is notorious for its high drop, fail, and withdraw (DFW) rates, reflecting the significant struggles students face in this subject. This high attrition rate is unsurprising, considering that organic chemistry is markedly different from other branches of chemistry. It is often regarded as a "second language" due to its heavy reliance on visualization and representation skills, such as understanding stereochemistry or the intricate details of how reaction mechanisms work and how bonds are broken or formed. Modeling, which involves the ability to understand and represent the underlying phenomena through physical representations like mechanistic arrows and molecular orbital diagrams, is crucial to developing expertise in organic chemistry. However, it remains inadequately addressed in current textbooks and curricular designs and is not explicitly taught. It is akin to learning a new language without first mastering its alphabet. As highlighted by Passmore et al. (2013), it is essential for educators to

understand and explain the core features of the subjects they teach, including the nature of models. They argue that an explicit exploration of the epistemological underpinnings of modeling is vital not only for discussions on the nature of science and scientific inquiry but should also be a key element of classroom practice.

Recognizing this critical need, I investigate how students utilize representations in ways that may be unintentional but are meaningful for understanding complex phenomena, such as chemical reactions, and for problem-solving in organic chemistry. My study employs an asset-based approach, focusing on what students can do instead of emphasizing what they cannot do. More specifically, I explore students' conceptualizations of models and use that understanding to identify opportunities for enhancing the instruction of modeling in introductory organic chemistry courses, with a particular emphasis on the epistemological foundations of modeling.
I employ the 'model for' framework by Gouvea and Passmore (2017), which conceptualizes models as dynamic tools for explanation and prediction, actively used by scientists for specific investigative purposes. This perspective places students at the center of the learning process, empowering them to engage actively with models to achieve their epistemic goals. Within this context, I have identified Electron-Pushing Formalism (EPF) as a promising starting point for understanding and addressing the challenges in the instruction of models and modeling in organic chemistry for two main reasons. First, students begin using EPF early in the course, particularly in units on structure and reactivity, where they study the nature of acids and bases and draw resonance structures. Second, many scholars have linked students' competency in writing reaction mechanisms to their understanding of Electron-Pushing Formalism.

Given the notoriously high DFW rates in organic chemistry courses, this research and its practical applications have significant implications for improving student outcomes. By addressing barriers to learning in organic chemistry and ultimately reducing DFW rates, my work aligns with national priorities to enhance retention in STEM disciplines.

Important Articles:

Conference Presentations by me:

- Rauf, A., Ryu, M. (2024, July 29). Beyond Arrows: Organic chemistry students' understanding of electron pushing formalism as scientific modeling. Biennial Conference on Chemical Education (BCCE) 2024, Lexington, Kentucky.

ResearchGate **LinkedIn** **Google Scholar** **Webpage**