



**PURM**

Perspectives on Undergraduate  
Research & Mentoring

## Use of Creative Inquiry as a Model for Undergraduate Research Mentoring: Co-Curricular and Curricular Approaches

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### **Introduction and Background**

The impetus of this article is to show how the creative inquiry process can be used as an engaging tool in directing and mentoring undergraduate research. Importantly, this process was used by a first-year graduate student in the Master's program, Kelsey Richards, who had performed undergraduate research during the previous year, to successfully mentor two undergraduate students who had just joined Professor Lisic's research group through a special topics course that satisfied one of Kelsey's Master's degree requirements for graduation. Kelsey helped these students initiate their research in the Spring 2017 semester and disseminate their findings later in the same semester at the university's Research and Creative Inquiry Day poster session. The process worked so well that one of the undergraduates tied for first place out of 35 other posters in the undergraduate research Chemistry Department division. Using some of her procedures and methods, Kelsey assisted Dr. Amanda Carroll in finalizing a new Introduction to Research Methods class that was designed to utilize the creative inquiry process to teach undergraduate students the skills and knowledge needed to conduct undergraduate research in the Chemistry Department. The following is an account of our team's work through their personal perspectives.

Tennessee Tech University (TTU) has just recently passed its 2016-2017 Southern Association of Colleges and Schools Commission on Colleges (SACSCOC) accreditation process, with no findings with our new quality enhancement plan (QEP) in its pilot year (Tennessee Technological University, 2016). Our five-year QEP is named EDGE: Enhanced Discovery through Guided Exploration with the theme of creative inquiry. One of the issues with our last QEP on critical thinking was that it was not as useful or applicable to students in some disciplines, such as art, because of the emphasis on critical thinking and nothing on creativity. With this in mind, the topic selection committee at the university decided that creative inquiry was the best topical theme for our institution.

Creative inquiry has been defined by TTU's QEP (2016) as the process of exploring issues, objects, or works through the collection and analysis of evidence, including combining or synthesizing existing ideas, products, or expertise in original ways to answer an open-ended question or achieve a desired goal. The goal of our QEP is to enhance student learning by infusing creative inquiry throughout the undergraduate experience.

Once the topic was decided, the next steps at the University level were to determine appropriate student learning outcomes (SLOs), along with a rubric scale to grade them. The task in our Chemistry Department was to translate the SLOs, which are presented in Table 1, for the creative inquiry process into our undergraduate research efforts in a usable fashion in order to take advantage of the creative inquiry experience for our students. Detailed SLOs that are tied directly to institutional

needs have been crafted to address the principal elements of creative inquiry while simultaneously including all disciplines.

**Table 1**

**TTU QEP EDGE Program's SLOs**

SLO 1	Students will effectively use digital information search tools.
SLO 2	Students will formulate a creative inquiry question or problem.
SLO 3	Students will explore a creative inquiry question or problem. 3.1 Choose an appropriate discovery process to address the problem. 3.2 Collect information relevant to the problem. 3.3 Assess collected information in a discipline-appropriate manner.
SLO 4	Students will create an original scholarly or creative project. 4.1 Applying critical thinking skills and/or 4.2 Applying creative thinking skills
SLO 5	Students will communicate their findings/creations/art/inventions in a discipline-appropriate manner.

TTU's QEP definition of creative inquiry is founded on learning via inquiry, but it accentuates creativity in the inquiry process. Inquiry-based learning (IBL), or inquiry-guided learning (IGL), has been implemented in various ways, but its main feature is the promotion of active learning "through guided and increasingly independent investigation of complex questions and problems, often for which there is no single answer" (Lee, 2004, p. 9). Later, Levy et al. (2011) drew upon the work of Justice et al. (2002) and modeled inquiry as a cyclic process with one pass of the cycle leading to new and additional questions. This aspect of inquiry-based learning is of interest due to the implied comparison to the cyclic hypothesis format of the scientific method. Justice et al. (2002) said that reflection is a product of the process as well as "an enabler of success at every stage" (p.5).

The advantages to students who perform undergraduate research have been well documented in the literature. But this work focused on one of the problems in advancing undergraduate research in the TTU Chemistry Department, i.e., time limitations expressed by faculty who already have time-consuming teaching loads. Limitations such as this are not new and have been discussed in the literature (Zydney, Bennett, Shahid, & Bauer, 2002). Amongst many possible options there are two viable ways at TTU to alleviate the problem, without reducing teaching loads. They are to 1) use graduate students as research mentors and 2) to incorporate undergraduate research into classes.

There are advantages and limitations of using graduate students as undergraduate research mentors as reported by Jordan and Brooks (2013). Their study concluded that much of the success of the project depends on the abilities and passion of the graduate student mentor. The student perspective below describes the inclusion of creative inquiry model using a graduate student as an undergraduate research mentor.

In the classroom, any undergraduate research project depends primarily on the factors involved in the actual research being done, which is hard to duplicate in different classes, or from year to year. On the other hand, literature shows that successful teaching about research methods in a classroom setting can be highly beneficial to both faculty and students (Ingebretson, Sjoberg, & Larson, 2014), but can be limited in the student experience if no actual research or inquiry is performed. To this end, Dr. Amanda Carroll has wanted to institute a research methods class for over a year and finally got departmental approval. Her faculty perspective below shows the effort at using the creative inquiry

approach to teach about undergraduate research through the SLOs. This article describes the efforts and highlights the perspectives on using this new creative inquiry model to mentor undergraduate researchers in both co-curricular and curricular class settings at Tennessee Technological University.

#### **Aspects of Research Mentoring: Faculty Perspective, Dr. Edward Lisic**

The creative inquiry definition and the accompanying set of five student learning outcomes present a unique opportunity to enhance and evolve TTU's undergraduate research efforts. Kelsey is an extraordinary chemistry student who has held leadership roles in our American Chemical Society Student Chapter as an undergraduate at TTU, and also performed undergraduate research at TTU before becoming a Master's student. As my graduate student, Kelsey embraced the idea of working with two undergraduate students, who were excited to get the chance to do undergraduate research with Kelsey as their immediate mentor. Neither of the two students actually knew Kelsey beforehand, so I was happy to see the way all three of them got acquainted and began to work.

When I presented the creative inquiry model to Kelsey with the student learning outcomes (Table 1), her mind apparently clicked with the components of the task. She immediately started turning the general SLOs into specific activities that she and "her/our" students would accomplish. By the next day she had worked out all of the activities and the SLOs that would be tagged for each activity. Part of Kelsey's success was that she envisioned and used SLO 2 as a hypothesis statement for the research. It followed that SLO 3, with its component portions, was actually the experimental work that needed to be accomplished in order to test the hypothesis or hypotheses. With that in place, it was easy to assign SLO 1, 4, and 5. The SLO 1 is about using digital information search tools. Therefore Scifinder Scholar was our primary choice since it is such a specific chemistry journal search program that allows students to not only search for general topics but it allows students to search for specific chemicals and authors. We also used ChemDraw, which is a chemical drawing program that allows users to interface with the internet to search for information on the chemical drawn, as Dr. Carroll discusses in her section later in this manuscript. The SLO 4 and 5 are easy to assign because, for us, SLO 4 is "Students will create an original scholarly or creative project," which for us is either a PowerPoint poster and/or a report or publication. The SLO 5 is "Students will communicate their findings/creations/art/inventions in a discipline-appropriate manner presenting the research" so the presentation of the poster to the public fulfills this SLO. My chemistry research is actually very iterative, so I knew that I could provide the two undergraduates a chance to make some new molecules by using an old synthesis technique with new substrate starting materials. They then could analyze the products using the Chemistry Department's state-of-the-art nuclear magnetic resonance (NMR) spectrometer. Kelsey not only had already obtained her skills as a NMR user, but was accomplished at presenting her work in a variety of methods, including a recent journal article of her undergraduate work (Carroll, et al., 2017), as part of the joint work of a student and faculty team. I deem myself extremely lucky to have found a student who had such latent talent to reveal in her mentoring work.

#### **Aspects of Research Mentoring: Student Perspective, Kelsey Richards**

As part of the Master's program at TTU, students are encouraged to do a special topics course with their research advisor. Students in these classes are typically working together to write a literature review or are learning the intricacies of an instrument to run an experiment. However, when I met with Dr. Lisic to discuss my special topics class, he had a different approach in mind. His goal was to think of a project that would be beneficial for my growth as a future employee, and would also further the progress of his research group. With that in mind, he proposed the idea that I mentor two of his incoming students in different class standings who had never done research before. Given that the Lisic Research Group has 17 students, it can be difficult to continually give each one a structured, streamlined, and hands-on experience. This class was set out as a pilot project for a model to alleviate that issue. To name this special topics course, we came up with the title "Aspects of

Research Mentoring.”

Once the idea of the class was settled on, I used the EDGE program’s SLOs to devise a plan for the semester. While the SLOs were established to broaden the undergraduate research topics at TTU, as a chemistry student I immediately drew the connection between them and the scientific method. Having recently done my proposal for my own graduate research, the scientific method was fresh on my mind, which allowed me to quickly assign the SLOs to tangible tasks. These assignments of SLOs to tasks are shown along with the timeline of implementation in Table 2.

**Table 2**

**Timeline of Events throughout the Semester of Mentoring**

Week	Calendar Date	Accomplishments and Tagged SLOs
1	January 23	<ul style="list-style-type: none"><li>• Discussed semester goals (SLO 2 and SLO 3)</li><li>• Completed safety training</li><li>• Notebook tutorial</li><li>• Prepared a prelab together (SLO 2 and SLO 3)</li></ul>
2	January 30	<ul style="list-style-type: none"><li>• Ran a reaction with verbal assistance (SLO 3)</li><li>• Documented all observations (SLO 3)</li></ul>
3	February 6	<ul style="list-style-type: none"><li>• Prepared NMR samples with verbal assistance</li><li>• Completed NMR training</li><li>• Ran NMR samples (SLO 3)</li></ul>
4	February 13	<ul style="list-style-type: none"><li>• Prepared prelab individually with necessary adjustments learned from the previous reaction</li><li>• Ran a reaction with less verbal assistance (SLO 3)</li><li>• Abstract writing tutorial and submission (SLO 2 and SLO 4)</li></ul>
5	February 20	<ul style="list-style-type: none"><li>• Prepared NMR sample with provided written steps and no verbal assistance</li><li>• Ran sample on NMR with provided written steps (SLO 2 and SLO 3)</li></ul>
6	February 27	<ul style="list-style-type: none"><li>• Data analysis tutorial</li><li>• Write-up tutorial</li><li>• Poster assembly tutorial (SLO 3 and SLO 4)</li></ul>
-	March 6	SPRING BREAK
7	March 13	<ul style="list-style-type: none"><li>• Continued data analysis (SLO 3 and SLO 4)</li><li>• Continued poster preparations (SLO 4)</li><li>• Primary literature search tutorial (SLO 1)</li></ul>
8	March 20	<ul style="list-style-type: none"><li>• Continued data analysis (SLO 3 and SLO 4)</li><li>• Continued poster preparations (SLO 4)</li></ul>
9	March 27	<ul style="list-style-type: none"><li>• Poster pickup</li><li>• Presentation practice (SLO 4 and SLO 5)</li></ul>
10	April 5	<ul style="list-style-type: none"><li>• Research day poster presentations (SLO 4 and SLO 5)</li></ul>
11	April 10	<ul style="list-style-type: none"><li>• Debriefing of research day (SLO 4 and SLO 5)</li></ul>

My focus then became getting the students well-equipped and comfortable with the plan before trying to do an experiment. I stressed the importance of safety and keeping good records as we worked together to prepare their notebooks and talked about what observations would be important to document. When it was time to conduct an experiment, I verbally assisted them through the procedure while they gathered the materials needed from the labeled drawers throughout the lab. Along the way, I shared with them techniques like how I hold certain glassware, the easiest way to do certain tasks, and what steps should be done with extra care.

Following the experiment and data collection we worked on data analysis. This was an interesting part due to one student having seen this type of data before in a classroom setting, while the other having not previously encountered this type of data analysis. The situation proved positive though, because the student that had seen it before felt like they finally fully understood the data treatment, and the one who had not seen it caught on quickly in a non-classroom environment with less stress. When data analysis was complete, we started working on how we would disseminate the work to a supervisor or for future reference in the project. I showed them how to write up reports of their work and use the results to decide what to do next in the lab. Then, we ran another experiment where I supervised and assisted verbally just when needed. They made minor changes to the procedures, completed data collection for this experiment, and then began the presentation work.

My main goal of the semester was to have the students present their work at the TTU Research and Creative Inquiry Day. To do so, they had to submit an abstract, complete a project, and create a poster to display the work. During the process of abstract writing, they were given guidelines and tips to aid in the process. Preparation of the posters was a taxing experience. The nuances of the PowerPoint and ChemDraw software programs that are used in the process were new to most students. Therefore, it became an extremely hands-on process. Using a TTU Research Day poster grading rubric for what was expected to be displayed, they created a poster that represented the reason for the project, how it was carried out, and what the data revealed about the work. Their ideas on formatting and design were encouraged throughout the process to give them a sense of ownership and confidence about the work.

To prepare for the event, I talked with them about what to wear and asked the students questions that judges or attendants might have. Research and Creative Inquiry Day is a competitive event. With 36 students competing in the chemistry division, we were extremely pleased that one of our students tied for first place. We were thrilled to even have them ready to present the work, so a win was a great testament to how effective this model was. These two students were the first of the Lisic Research Group to begin a project and present at Research and Creative Inquiry Day in the same semester.

After all the work put in during the semester, I compiled a survey for the two mentees to take. This survey was designed to gauge how well they thought the model of graduate student mentoring was for their introduction to research. When asked what their favorite part of the system was, they answered, "My mentor was always present if I needed assistance, but she gave me the freedom and confidence to work by myself if I was up to it", and "I loved how confident my mentor made me feel in my abilities." In an effort to make this system even better for the next group, we asked the students what they would have changed to our mentoring model. Both responded with wanting more time, whether it be meeting more times a week or meeting with the faculty advisor more often. Based on these results, the model will be used for future co-curricular endeavors in the Lisic Research Group.

Along with the success of the student mentees, this was also an incredible learning experience for me as a graduate student. I enjoyed passing on the lab techniques and knowledge to up-and-coming

scientists, and it helped me build on my teaching and management skills moving forward. Working with Dr. Lisic in this tiered mentoring model has prepared me in ways that normal classwork could not, and moving forward I think this model is a valuable experience for all involved.

#### **Introduction to Research Methods: Graduate Student Perspective, Kelsey D. Richards**

One of the reasons that I was so passionate about the Aspects of Research Mentoring class was because I knew Dr. Lisic had big ideas for how it could be used. Around the time when we were starting the process, another member of my Master's committee, Dr. Amanda Carroll, was in the final stages of developing a course called Introduction to Research methods for undergraduates. The class was designed to use guidelines from the American Chemical Society (ACS) Committee on Professional Training (CPT). But after talking with her about our plan for this semester, we saw a possible way to tie the two ideas together. I shared with her the SLO breakdown that I had done, as well as the worksheets that I had prepared for the students to guide them through the process. When she saw the correlation between what each of us was trying to accomplish, she incorporated the SLOs into her syllabus to be presented to the University Curriculum Committee. It was voted on positively and was chosen to be funded as a creative inquiry intensive class through the QEP committee for Fall 2017. This is the first class at TTU to be designed from its origin to utilize the creative inquiry model and the EDGE SLOs, as most other courses funded by QEP EDGE grants are currently being taught and are redesigned to incorporate the creative inquiry approach. The first offering of the course is in Fall 2017.

Having completed my undergraduate work at TTU, this class is one that I wish had been offered. While I had great mentors throughout my experience, it was all done outside of the classroom. The fact that her students will have a structured environment to learn all the types of work that go into research without having to fit it in as an extra component of their schedule is one that will make them better equipped when they begin lab work. I look forward to seeing how the students respond to the assignments she has designed and how beneficial the mentoring roles are going to be.

#### **Introduction to Research Methods: Faculty Perspective, Dr. Amanda J. Carroll**

At TTU, large numbers of undergraduate students participate in research projects in the Chemistry Department. Although our department has a long history of making opportunities available to any student who would like to pursue research, the department has not had a mechanism for providing consistent instruction on how to work within a research lab setting. As the number of undergraduates conducting research in the Chemistry Department continues to increase, and as ACS modified its requirements for undergraduate professional education in chemistry, the department sought to incorporate essential skills and the updated ACS CPT guidelines into a course. This course helps students develop the desired skills needed to work successfully in a research lab, while also meeting the updated ACS CPT guidelines through mentoring opportunities. These CPT guidelines promote excellence in chemistry education for undergraduates (American Chemical Society, 2015). This course is entitled "Introduction to Research Methods" and teaches students the skills and knowledge needed to work in a chemistry research lab setting by using the creative inquiry process and satisfying the EDGE program SLOs.

The SLOs provided by Tennessee Tech's QEP were considered carefully when designing the course content and activities. There is significant overlap between the ACS CPT guidelines and the creative inquiry based learning method promoted by TTU's QEP program. Introduction to Research Methods strives to provide



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students with intellectual, experimental, and communication skills necessary to become scientific professionals. Students will explore topics and combine knowledge from several aspects of Chemistry to propose hypothesis statements about a topic, as well as ways of testing their hypothesis statements. The assignments in this course are geared towards several of the SLOs in the TTU QEP program.

To complete SLO 1, students will learn to use TTU library databases to search for chemical literature articles and structures. Students will gain experience with SciFinder Scholar and Google Scholar for finding peer reviewed literature articles, and will learn to use RefWorks to manage citation sources. They will learn to use ChemDraw, which is a chemical structure drawing program. The use of ChemDraw allows chemical structures to be searched in databases, along with keywords and topics. Students will also learn to properly cite data and references in presentations.

SLO 2 will be satisfied by having students propose a research question and hypothesis statement working in groups of 2-3. The question and hypothesis can be based on a lab experiment or concept they may have encountered in General Chemistry or Organic Chemistry. They may also pose a question and hypothesis related to any undergraduate research project they will work on, as long as it is not the exact project they are currently conducting, and the question and hypothesis are posed by themselves rather than a faculty mentor.

Using the research question and hypothesis posed in SLO 2, the student groups will propose a set of experiments and methods that can be conducted to test their hypothesis to meet SLO 3. They must propose a methodology that could be conducted, what variables will be held constant, and what variables will be changed. Experiments must be proposed and detailed in a manner that the students could go into a lab setting and test their hypothesis statements.

The completion of SLOs 4 and 5 will be accomplished in tandem. Students will prepare a PowerPoint presentation over their research question, hypothesis statement, and proposed methodology from SLO 2 and 3 (SLO 4). The students will incorporate ChemDraw structures into their presentations if chemical structures need to be represented. The presentation should showcase the critical thinking skills utilized in SLO 2 and 3. The students will present the PowerPoint they prepared to satisfy SLO 4 to the class (SLO 5). The presentation should be given in a professional manner and will be judged based on focus, organization, and clarity. The feasibility of their methodology will also be analyzed.

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Incorporating the TTU QEP SLOs and the ACS CPT guidelines provides an effective way to mentor students in a classroom setting on skills and knowledge needed to become successful in a chemistry research lab setting. The course will provide this mentorship through several different methods. The course will have an instructor to provide the lecture materials and speakers needed to introduce the course content. A graduate student will also be utilized to assist the instructor and provide assistance to students outside of the class on topics such as research notebooks, ChemDraw assignments, abstract writing, literature searches, and other course topics. An undergraduate student will serve as a peer mentor to the students in the course. The undergraduate and graduate students will help with the preparation of the class presentations. Both the undergraduate student and the graduate student will assist the instructor with grading assignments and evaluating the class presentations. Mentorship will be provided to the students in different forms and levels: faculty, graduate student, and undergraduate student. The instructor will

also provide mentorship to the graduate and undergraduate student in how to help and guide the students in the course. The graduate student will also help mentor the undergraduate student in how to work with the course students.

The development of this course serves several purposes within the TTU Chemistry Department, the TTU academic institution, as well as providing mentoring opportunities to many people serving in various roles.

### **Conclusions**

We believe that the framework of SLOs provided by our unique creative inquiry process has proven to be an invaluable tool for undergraduate research mentoring in both co-curricular and curricular settings. The creative inquiry process, as envisioned by our team, gives undergraduate students experience in using primary literature sources, familiarization of health and safety rules pertinent to the research, and the tools needed to perform their research tasks. Furthermore, undergraduate students also use their own research hypotheses to direct their experiments and to understand how their research is hypothesis driven.

We have also employed a graduate student to serve as a direct mentor to two undergraduate researchers working within a large lab group to apply the TTU QEP EDGE program's SLOs to the mentoring of undergraduates through a co-curricular approach. This personal, hands-on approach proved beneficial to both the graduate student mentor and the undergraduate mentees. These mentees were able to begin a research project and successfully present it within the same semester, which would have been unlikely in the absence of the graduate student mentor. The graduate student mentor was able to not only complete an independent study course requirement for her Master's degree, but also gain valuable insights into ways of applying the SLOs to the mentoring process, which allowed her a distinct way of reaching her career goals.

The practical knowledge gained by the graduate student through the mentoring process was then passed on to another faculty member in the final stages of developing an undergraduate research methods course, which was then applied to the new course's curriculum. This resulted in the development of a new course that not only satisfied departmental needs and ACS CPT requirements for the TTU Chemistry Department's accreditation, but also incorporated creative inquiry into the course, satisfying the university's current QEP. Another addition to the course included the involvement of an undergraduate peer mentor and a graduate student mentor to assist with the course materials and project. This addition would not have occurred without the prior experience of Kelsey and her undergraduate mentees. This dual approach involving co-curricular and curricular aspects of incorporating SLOs allowed our team to explore different unique ways of influencing the outcomes of undergraduate researchers working within the Chemistry Department at TTU.

This work shows that the use of the creative inquiry model and its SLOs can be incorporated into undergraduate research not only outside the classroom in co-curricular settings, but also within the classroom in departmental course offerings that enrich the learning experience for our undergraduate students in a more efficient, yet detailed, manner. Even though this work is developed in the specific field of chemistry, we believe that this approach can easily be used by others in all fields of endeavor.

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