

# A Method for Transforming a Broad Topic to a Focused Topic for Developing Research Questions

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**Abstract**—In this research-to-practice full paper, the results of an approach for transforming topic ideas into questions for developing research questions are presented. The first step in developing research questions is identifying an interesting topic. Once a topic is identified, the next challenge is to narrow the focus by formulating and asking questions that, when answered, will provide more depth to the topic. For the novice researcher, articulating what needs to be learned about a topic and what the reader should understand about the topic can be challenging. The purpose of this study is to assess students' perception of a method that is designed to challenge students to ask critical questions of their research topics to better understand what they know about the topic; what remains to be known and what their target audience should understand about the topic as a result of the research. An activity worksheet was designed to facilitate critical thinking about the process of questioning and posing questions as part of the developing research questions process. Students were asked to complete the worksheet then provide feedback on the usability of the activity worksheet. This work aims to answer the following research question, "How do students perceive the usability of the activity worksheet method for developing and evaluating questions about topic ideas?" The activity worksheet was completed by a 43 students across two sections of an undergraduate data visualization course in the Department of Computer Graphics Technology at Purdue University. After completing the worksheet students were asked to provide feedback on the usability of the worksheet, using a 5-point Likert scale: "1 - Strongly disagree," "2 - Disagree," "3 - Neutral," "4 - Agree," and "5 - Strongly Agree." Students' overall perception of the worksheet approach was favorable/positive. The implications of this work will help students build skills in questioning and posing questions. This research is significant because it helps students answer critical questions about their topic, and further clarify the significance of a topic beyond their own interests. The contribution of this work is in helping students pose questions and ask questions that will strengthen their critical thinking skills in the practice of engineering and computer science.

**Keywords:** *critical thinking, habits of the mind, research questions, inquiry-based*

## I. INTRODUCTION

This work focuses on helping students refine a topic to a manageable scope, then question it to find the makings of a problem that can guide their research [1]. The application of research skills to the acquisition of new knowledge requires asking a good question that can be answered in a reasonable manner and period [2]. The first aim of the study is to

introduce an activity worksheet approach for transforming broad topics to questions for developing research questions. This is intended to help students ask significant questions to better inform their future steps in the development of research questions. The second aim is to assess students' perception of the usability of the activity worksheet method. In this paper we examine, compare and present results from undergraduates who used the activity worksheet method to develop questions from topics of interest. This research is significant because it helps students answer critical questions about their topic, further clarifying the significance of the project. Understanding questions asked in the worksheet informs the next stage of developing research questions - developing a significant problem statement. The implications of this work will help students build skills in questioning and posing questions. The contribution of this work is in helping students pose questions and ask questions that will strengthen their critical thinking skills in the practice of engineering and computer science. Critical thinking and habits of the mind are the underlying constructs utilized in this work, specifically, the process of questioning and posing questions.

## II. BACKGROUND

### A. Critical Thinking

University education across all disciplines aims to produce thinking skills in students that reflect the principles and practices of scientific research and rigor [3]. Critical thinking is constituted by a variety of cognitive skills and dispositions to meet complex demands that make it possible to assess, evaluate, synthesize and interpret relevant information that is associated with a situation; and apply that information to solve a problem, to decide a course of action, to find an answer to a given question or to reach a well-reasoned conclusion [4]. It involves open-minded and self-regulated thinking about alternative solutions and perspectives as well as possible consequences. The development of critical thinking consisting of a variety of skills requires support, continuous feedback and long-term practice [5]. In the context of this work, we adopt the view of [1]:

If a writer asks no specific question worth asking, he/she can offer no specific answer worth

supporting. And without an answer to support, he/she cannot select from all the data he/she could find on a topic just those relevant to his/her answer. (pp 44)

You can start with the standard questions: who, what, when, and where, but focus on how and why. (pp 44)

In the context of this project, students focus on what they want to find out about their topic and what they want their reader to understand about the topic. The approach utilized in this work emphasizes the model of inquiry to help students develop a habit of inquiry so that they can learn to ask thoughtful questions [6]. In this inquiry-based learning model, students learn a skill for asking questions on their own [7]. An important feature of inquiry-based learning is that the students are not merely searching for correct answers to the instructor's questions; rather they are posing and answering questions that address their own lack of understanding, specific gaps in knowledge and particular misconceptions [6]. Questioning and posing problems are one of 16 Habit of the Mind behaviors that constitute a subset of thinking dispositions [8].

### B. Habits of the Mind

A Habit of Mind means having a disposition toward behaving intelligently when confronted with a problem to which the answer is not known [9]. Behaving intelligently refers to problem-solving behavior that is constructed by experience gained through social interactions [10]. Intelligent behaviors are the external outcomes of the interaction between our cognition and emotions; they are what we can observe unlike neurological processes [11]. These behaviors may provide clues about one's cognitive processes and functioning, skills, strategies, and one's disposition [12]. Costa and Kallick [13] list 16 Habits of Mind which include the following:

- 1) Applying Past Knowledge to Novel Situations
- 2) Creating, Imagining, and Innovating
- 3) Finding Humor
- 4) Gathering Data Through All Senses
- 5) Listening with Understanding and Empathy
- 6) Managing Impulsivity
- 7) Meta-cognition (Thinking About Thinking)
- 8) Persisting
- 9) Questioning and Problem Posing
- 10) Remaining Open to Continuous Learning
- 11) Responding with Wonderment and Awe
- 12) Striving for Accuracy and Precision
- 13) Taking Responsible Risks
- 14) Thinking and Communicating with Clarity and Precision
- 15) Thinking Flexibly
- 16) Thinking Interdependently

In the context of this work, we focus on critical thinking and Habit of Mind that refer to the process of questioning and posing critical questions about a research topic.

### C. Implications for Engineering and Computer Science

The cognitivist learning theory is the underpinning of the critical thinking and Habit of Mind elements for this work. The goal of the cognitivist approach is to develop the learner's capacity and skills for more effective self-directed learning [14]. Developing critical thinking through reflection is one of the most important components of the cognitivist learning orientation [15]. Studies about critical thinking in engineering have considered thinking in the context of engineering problem-solving [16]–[18]. Key elements of problem-solving are the ability to question, pose questions, to examine what is known and what is unknown [19], [20]. In this work, students are motivated to think critically and question the significance of topics they choose. The worksheet provides a mechanism to articulate, beyond bullet points, what the student wants to find out about a topic and what they want the reader to understand.

In this study, we assessed students' perception of the usability of the "Topics to Questions" worksheet in helping to narrow the scope of their topic and pose questions to provide more depth of understanding what they want their readers to know upon completion of the research guided by the topic. We address the following research question in this work, "How do students perceive the usability of the activity worksheet method for developing and evaluating questions about topic ideas?" To address this question we define the following sub-research questions:

- 1) Do students enrolled in an introductory data visualization course perceive the worksheet to be useful in helping to articulate what they want to find out about a topic?
- 2) Do students enrolled in an introductory data visualization course perceive the worksheet to be helpful in articulating what readers should understand once the research is implemented on a topic?

There continue to be no shortage of guides [21], books [1, 22] and efforts [23] to assist the novice researcher in the process of developing research questions. In fact, the approach detailed in this work is adapted from [1]. The worksheet approach was implemented after reading assignments failed to result in students' implementing content found in the material and student research questions that were either too broad, too narrow or the student could not articulate the significance of the project beyond his/her own interests. The worksheet approach was developed to address this problem and to actively engage students in the process.

### III. METHODOLOGY

The methodology for this work aligns with project aims. The first aim of the study is to introduce an activity worksheet approach for transforming broad topics to questions for developing research questions. This is intended to help students ask significant questions to better inform their future steps in the development of research questions. For this work, a one-page

worksheet, “Topics to Questions,” was created to help student articulate what they hope to find out about topics of interests that they choose for research projects. The objective of the worksheet, is that students will transition from a broad topic to a specific research question. Upon completing the worksheet, students will generate a description of their topic by answering the following questions: “who, what, when, whether, why, and how?” about their topic [1].

### A. Topics to Questions Worksheet

The worksheet consists of a total of three questions. The worksheet is designed to be used as a standalone document and as such, the first question asks students to describe, in their own words, the topic they have chosen to study. In response to the second question, students are asked to explain why they are interested in the topic. Students are given elements of a sentence that, upon completion of the worksheet, will generate content to complete the sentence.

In the first part of the second section, students engage their critical thinking and Habit of Mind behavior by answering and posing questions about their topic. To help initiate the self-inquiry, students are given prompts to facilitate the process. Students are asked to complete the following statement: I want to find out

- a) what
- b) why (the significance of the problem)
- c) how

about my topic.

Answering this indirect question indicates what is not known or understood about a topic and steers students toward thinking about why they are pursuing the topic. The idea is to use their answers to questions a) – c) to provide clarity to their statement.

The last question on the worksheet is intended to help student provide motivation for their topic by stating what they hope to help their reader understand. The aim is to explain [1]:

- 1) what you are writing about – I am working on the topic of . . .
- 2) what you don’t know about it – because I want to find out . . .
- 3) why you want your reader to know and care about it – in order to help my reader understand better. . .

A copy of the worksheet is provided in the Appendix.

### B. Participants

The research was implemented in a data visualization course at Purdue University in Fall 2019. The 16-week course is an introductory course in data visualization. The course meets twice a week with a lecture/lab format. The learning objective for the course is to introduce the data visualization process. Upon completing the course, students are required to demonstrate their proficiency in applying the data visualization process by presenting results from a research topic of their choosing with data and visualizations to support their conclusions.

The “Topics to Questions” worksheet was completed by students enrolled in an introductory data visualization course for undergraduates. The course consisted of two sections. Section A consisted of undergraduates majoring in STEM related fields and in their second year or higher of their degree programs. The second section (Section B) included students who were STEM and non-STEM majors, and consisted of freshmen, sophomores, juniors and seniors. A total of 43 students completed the worksheet: 20 students from Section A, and 23 students from Section B. Table I shows participant academic levels for each section. Fifty-six percent of all participants were sophomores. The majority of students in Section A (45%) were juniors, and 74% of students in Section B were sophomores.

TABLE I  
PARTICIPANTS ACADEMIC LEVEL

Academic Status	Combined Sections (n=43)	Section A (n=20)	Section B (n=23)
Freshman	2% (1)	0% (0)	4% (1)
Sophomore	56% (24)	17% (4)	74% (17)
Junior	30% (13)	45% (9)	17% (4)
Senior	12% (5)	20% (4)	4% (1)

Students in both sections possessed little to no research experience and even less experience with the practice of questioning and posing questions as a structured process for developing research questions to support a strong research focus.

### C. Data Collection

The data for the project consists of the completed “Topics to Questions” worksheet, and students’ self-assessment for the usability of the worksheet. Students were given the worksheet in week two of the semester and given one week to complete and submit the worksheet for review by the professor and teaching assistants. After completing the worksheet students were asked to provide feedback on their perception of the usability of the worksheet using a 5-point Likert scale: 1- Strongly disagree, 2- Disagree, 3-Neutral, 4-Agree, and 5-Strongly Agree. Students were asked to indicate their level of agreement, using the Likert scale, to two statements:

- S1 The worksheet helped me identify the significance of my topic by helping me articulate what I want to find out about the topic.
- S2 The worksheet helped me identify the significance of my topic by helping me articulate what I want my reader understand.

If students indicated strongly disagree or disagree, they were asked to provide a brief explanation. Students’ qualitative feedback will inform evaluation and refinement of the worksheet for future class offerings. Analysis of students’ qualitative responses is not covered in this paper. The Self-assessment survey is provided in Appendix B.

#### D. Data Analysis

Analysis of the data aligns with the second aim of the project: to assess students' perception of the usability of the Activity Worksheet Method in helping to articulate what the student hopes to learn about the topic and what they hope to help their reader to understand. For this work, only the student self-assessment data for the usability of the worksheet are analyzed. Data analysis of Likert-scale data was performed. The mean is used as the basic descriptive statistical indicator for each statement in the survey research instrument. T-test calculations are used to compare Likert scores by sections and by questions. Microsoft T.TEST function was used to calculate p-value using two-tailed distribution, for two-sample unequal variance. An alpha level of .05 was used for all tests to determine statistical significance.

### IV. RESULTS AND DISCUSSION

#### A. Comparing the Overall Mean Score by Sections

The main research question addressed by the work is: "How do students perceive the usability of the Activity Worksheet Method for developing and evaluating questions about topic ideas?" To answer this question, Likert-scales were used to capture students' perception of the usability of the worksheet. To assess students' responses to the worksheet as a whole, all responses from both sections were combined and analyzed. There were two questions answered by 43 students resulting in a total of 86 responses analyzed for the entire worksheet. The mean is used as a statistical indicator of students' perception. For this work, a mean value greater than three is considered favorable (agree or strongly agree), and a mean value less than three is considered unfavorable (disagree or strongly disagree). As seen in Table II, students' perception of the worksheet was favorable/positive. The calculated mean values for each section and for the combined sections was a value of 3 or higher, indicating both sections found the worksheet to be helpful.

TABLE II  
T-TEST RESULTS FOR COMPARISON BETWEEN SECTIONS

Mean			t-test
Overall (n=86)	Section A (n=40)	Section B (n=46)	p-value
3.69	3.70	3.67	0.84

As seen in Table II, a comparison of Likert scores by sections was performed using mean values and t-tests, to test the null hypothesis, that there are differences in perception between the two sections. A p-value less than 0.05 is considered statistically significant. Despite the overall favorable/positive rating for the overall mean of the worksheet, the t-test result (p-value = 0.84), indicates there is an eighty-four percent chance the sample differences are due to random variation and only a sixteen percent chance the sample differences are due to significant variation. The result shows the differences in responses (for the entire worksheet) between the two sections are not statistically significant.

#### B. Comparing the Usability Statements by Sections

Statistical indicators for statement one (S1, Table III) indicate overall, on average, both sections were neutral, but leaning towards positive (overall mean = 3.77) regarding their perception of the usability of the worksheet in helping to identify the significance of their topics. By asking students to think more deeply about their choices by thinking about what is known and what is unknown, we contend, students engage in another Habit of the mind: Metacognition (Thinking About Thinking).

TABLE III  
T-TEST RESULTS FOR S1:  
"THE WORKSHEET HELPED ME IDENTIFY THE SIGNIFICANCE OF MY TOPIC BY HELPING ME ARTICULATE WHAT I WANT TO FIND OUT ABOUT THE TOPIC."

Mean			t-test
Overall (n=86)	Section A (n=40)	Section B (n=46)	p-value
3.77	3.80	3.74	.73

Several strategies that enhance critical thinking are described by [24]. Metacognition has often been conceptualized as comprising two components [25]: the knowledge component refers to knowing one's cognitive processes, such as knowledge about oneself as a thinker, characteristics of existing task and about which strategies are required to carry out for effective performance; the regulation component refers to the actual strategies one applies to control cognitive processes, such as planning how to approach a task, monitoring understanding and comprehension, and evaluating progress and performance. According to [25] added meta comprehension, for example, knowing that you understood a question, is an important category of metacognitive knowledge. In the context of the "Topics to Questions" worksheet, prompting students to answer the series of informative questions (What?, Why? and How?) will help students to better understand their topic so that they can do the research. Metacognitive knowledge provides the basis for effective planning and determining the next steps to be carried out; both components supplement each other and are both essential for optimal performance [27].

Statistical indicators for statement two (S2, Table IV) are slightly lower than indicators for S1, but are consistent in mean values (3.6) for Section A, Section B and for the worksheet overall. The mean value for S2 (3.6) indicates, overall, students were "neutral" but leaning more towards agreement in their perception of the worksheet's role in helping identify the significance of the topic by helping them articulate what they want the reader to understand. The frequency responses for statements one and two, S1 and S2 respectively, seen in Table V, show 24% of responses were "neutral." When we examine frequency responses for the statements individually we see 10% of the responses for statement one (Table VI) and 11% of the responses for statement two (Table VII) were "neutral."

TABLE IV  
T-TEST RESULTS FOR S2:  
"THE WORKSHEET HELPED ME IDENTIFY THE SIGNIFICANCE  
OF THE TOPIC BY HELPING ME ARTICULATE WHAT I WANT  
MY READER UNDERSTAND."

Overall (n=86)	Mean		t-test
	Section A (n=40)	Section B (n=46)	p-value
3.6	3.6	3.6	.96

TABLE V  
FREQUENCY RESPONSE COUNTS FOR S1, AND S2

Likert Responses	All (n=86) Count (%)	Section A (n=40) Count (%)	Section B (n=46) Count (%)
Strongly Disagree	0 (0%)	0 (0%)	0 (0%)
Disagree	4 (5%)	1 (3%)	3 (7%)
Neutral	21 (24%)	11 (28%)	10 (22%)
Agree	59 (69%)	27 (68%)	32 (70%)
Strongly Agree	2 (2%)	1 (3%)	1 (2%)
	86 (100%)	40 (100%)	46 (100%)

### C. Comparing the Usability Statements by Sections

In hindsight, we acknowledge a limitation of the assessment instrument: it does not accurately capture what a neutral response could mean: "I don't know," "indifference," or a guess. Care will be taken to accurately capture a wider range of what a "neutral" response could represent.

We are encouraged by the overall favorable response to the worksheet; however, we acknowledge some limitations. In addition to the limitation mentioned above, the second limitation is the participant sample size. Fall 2019 was the first semester the "Topics to Questions" worksheet was utilized in the course. We anticipate more students will take the course in future offerings and will provide a larger participant base. Qualitative analysis of the feedback from students where responses were "strongly disagree" or "disagree" might provide useful insight. For this study, as seen in Table V, there were no "strongly disagree" responses; but collectively between the two sections, there were four "disagree" responses. Review of the qualitative

TABLE VI  
FREQUENCY RESPONSE COUNTS FOR S1

Likert Responses	All (n=43) Count (%)	Section A (n=20) Count (%)	Section B (n=23) Count (%)
Strongly Disagree	0 (0%)	0 (0%)	0 (0%)
Disagree	1 (2%)	0 (0%)	1 (4%)
Neutral	10 (23%)	5 (25%)	5 (22%)
Agree	30 (70%)	14 (70%)	16 (70%)
Strongly Agree	2 (5%)	1 (5%)	1 (4%)

TABLE VII  
FREQUENCY RESPONSE COUNTS FOR S2

Likert Responses	All (n=43) Count (%)	Section A (n=20) Count (%)	Section B (n=23) Count (%)
Strongly Disagree	0 (0%)	0 (0%)	0 (0%)
Disagree	3 (7%)	1 (5%)	2 (9%)
Neutral	11 (26%)	6 (30%)	5 (22%)
Agree	29 (67%)	13 (65%)	16 (70%)
Strongly Agree	0 (0%)	0 (0%)	0 (0%)

feedback to these responses show students' responses were either blank or "NA." These responses were interpreted as either the student(s) did not understand what was asked, or simply typed in "NA" for the answer.

## V. CONCLUSION

We presented results from the Activity Worksheet Method that is designed to help students transform a broad topic idea to questions in preparation for developing a research problem statement. The analysis of the data for the "Topics to Questions" worksheet shows that the difference in responses between the two sections is not statistically significant; however, we are encouraged by mean values for individual statements which show an overall favorable perception of the worksheet. Based on the data, students found the worksheet to be helpful in articulating what students want to find out (what they don't know) about a topic and figure out what they want their readers to understand about the topic (why is the research important). The Activity Worksheet Method, and its assessment instrument will be incrementally refined and informed by student feedback. Also, more data will be collected to assess if there is statistical significance between sections, to better inform usability of the Activity Worksheet for all students.

We identified the Activity Worksheet to be a tool to facilitate critical thinking and Habit of Mind behaviors that have implications for engineering and computer science students. The worksheet is designed as a standalone unit, but can be used in parallel with other teaching materials. The outcomes of this work shows the worksheet can be used to help students build skills in developing questioning strategies to produce data and asking questions that make causal connections and relationships [8]. The questions posed in the "Topics to Questions" worksheet are crucial not just for posing questions, but also for turning a question into a problem that readers think is worth solving [1].

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## VII. APPENDIX A

This section presents the content of the Topics to Questions worksheet. The worksheet includes statements about the goal, objective and expected outcome of the worksheet and an additional resource for students.

### Topics to Questions Worksheet

**Goal:** To articulate what the student hopes to find out about the topic of interest.

**Objective:** Students will transition from a broad topic to a specific question.

**Outcome:** Students will answer the following questions about their topic: who/what/when/where/whether/why/how.

You are no longer a mere data collector, but a researcher interested in understanding something better. List your topic of interest below in a complete sentence using the prompts below.

- 1) The topic I am studying is:
- 2) I want to find out:
  - a) What
  - b) Why (significance of this problem)
  - c) How
- 3) In order to help my reader understand

Additional information for transforming topics to questions is available in Chapter 3: Booth, W. C., Colomb, G. G., Williams, J. M., Williams, J. M. (2003). *The craft of research*. University of Chicago Press.

## VIII. APPENDIX B

### Self-Assessment

Using the Likert scale below, indicate your level of agreement.

Q1. The worksheet helped me identify the significance of my topic by helping me articulate what I want to find out about the topic.

Strongly Disagree  Disagree  Neutral  Agree  Strongly Agree

Q1a. If you answered Strongly Disagree or Disagree, please provide a brief explanation.

Q2. The worksheet helped me to identify the significance of my topic by helping me to articulate what I want my reader

to understand about the topic.

Strongly Disagree  Disagree  Neutral  Agree   
Strongly Agree

Q2a. If you answered Strongly Disagree or Disagree, please provide a brief explanation.