Clarifying Your Project: Supporting Interns' Understanding of Mentored STEM Projects

Institute for Scientist and Engineer Educators Report

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Abstract

This report focuses on the Akamai Internship Program's *Clarifying Your Project* scaffold, which is designed to support interns' understanding of their mentored STEM project. The report presents an analysis of responses on *Clarifying Your Project* (CYP) worksheets from a group of ten interns and mentors (five each) from the summer 2015 cohort. Findings include the identification of four challenges associated with the CYP worksheets: intern attribution, purpose clarification, user interpretation, and comprehensive scientific explanation. A variety of considerations are shared for Akamai staff to discuss including text and format changes to the CYP worksheet as well as the creation of staff and user guides.

Introduction

The Akamai Workforce Initiative is dedicated to building Hawaii's scientific and technical workforce in such a manner that this workforce reflects the diverse population of the state (https://akamaihawaii.org/about/). As part of its efforts to achieve this mission, the Initiative operates the Akamai Internship Program which places science, technology, engineering and mathematics (STEM) undergraduates in positions at observatories and STEM industries on the Big Island and Maui. Akamai interns complete a mentored project for seven weeks during the summer. As part of this program, Akamai staff and instructors provide a variety of supports to help interns complete a "productive" project, namely, one that makes a valued contribution to the host institution while at the same time engages the intern in a positive learning experience.

This report explores the nature and value of one such support – the *Clarifying Your Project* (CYP) scaffold. Here the term "scaffold" refers to a "cognitive [temporary supporting structure] to promote complex thinking, design, and learning" (Bransford, Brown, Cocking, 1999, p. 214; Berland & McNeill, p. 771). The CYP scaffold includes a writer (i.e., intern or mentor) completing a document called the CYP worksheet along with a discussion between the writer and an Akamai staff member about the writer's responses on the CYP worksheet. This write/discuss cycle typically happens twice during the span of the eight-week Akamai internship.

Subsequent sections of this report chronicle the origin of the CYP scaffold, describe its use within Akamai, discuss challenges with its use, and present considerations for future use. The penultimate section is based on an analysis of CYP worksheet responses from a subset of interns and mentors during the 2015 Akamai internship. As the phrase "consideration for future use" implies, the overall intent of this report is to serve as a catalyst for discussion among Akamai staff, not to present a specific set of recommendations for implementation.

Entering into writing this report, the general consensus among Akamai staff was that the CYP scaffold is a useful tool for *assessing* interns' understanding of their projects. It also is useful for interns with respect to *gathering* information about their projects and highlighting their contribution to or agency with carrying out and completing the project. However, the CYP should not be used as a template for interns to *prepare presentations* about their projects.

When reading this report, two frames are important to keep in mind. First, in creating and using the CYP scaffold, the overall goal for Akamai staff is to have interns more deeply *understand* their projects as a precursor to being able to cogently *explain* their projects (e.g., to a technical audience during an end-of-program symposium). Second, an overarching concern is how do Akamai staff use supports such as the CYP scaffold in ways that enhance the goal of "understanding" without getting bogged down in terminology or formatting?

The Akamai Context

The Akamai Workforce Initiative is one of several programs overseen by the Institute for Scientist and Engineer Educators or ISEE. ISEE's mission is to advance highly productive science, technology, engineering and mathematics (STEM) professionals who contribute to making the STEM workforce more diverse and inclusive. ISEE is structured around three major themes, each of which is described briefly below (further details at http://isee.ucsc.edu/programs/pdp/themes.html and http://isee.ucsc.edu/about/publications/index.html).

- Inquiry ISEE has developed a framework that includes six elements it considers essential to inquiry, namely, (1) cognitive STEM practices, (2) foundational STEM content, (3) intertwined content and practice, (4) mirroring authentic research and design, (5) ownership of learning, and (6) explaining using evidence (Metevier, Hunter, Seagroves, Kluger-Bell, Quan, & Barnes, 2015).

- Equity & Inclusion ISEE has developed four research-informed "focus areas" in Equity and Inclusion that provide practice-oriented lenses for viewing the design and implementation of STEM learning environments: (1) multiple ways to participate, (2) learners' goals, interests, and values, (3) beliefs and biases about learning, achievement, and teaching, and (4) developing an identity as a STEM person (Seagroves, Hunter, Metevier, Barnes, & Quan, 2015).

- Assessment ISEE has developed research-informed "focus areas" in assessment that move beyond traditional tests to assessment for learning and for evaluating the learning outcomes that are most important: (1) assessment as a driver of iterative design and teaching, (2) making learners' thinking visible, and (3) assessing content understanding through learners' explanations (Hunter, Kluger-Bell, Seagroves, Metevier, Barnes, Norton, & Quan, 2015).

In their own ways, all ISEE programs operationalize the above themes. For Akamai, they have been translated into concrete strategies, design principles, and behaviors within the Initiative's two main efforts: the Akamai Internship Program and the ISEE/Akamai Mentor Program. The former places STEM undergraduates in workforce positions while the latter works with the mentors (STEM professionals) who supervise Akamai interns. Each program has multiple components. For example, the internship program includes a multi-day PREP course prior to an intern's placement at a job site and the mentor program includes a day-and-a-half workshop focused on designing a productive project several weeks prior to the start of the internship (http://isee.ucsc.edu/programs/mentor/index.html).

Both the Internship program and the Mentor program emphasize the *Inquiry* theme in terms of cognitive STEM practices, mirroring authentic research and design, and ownership of learning. The focus for the *Equity & Inclusion* theme is on developing an identity as a STEM person, while for *Assessment* it is on making learner's thinking visible. The CYP scaffold relates to all of these focus areas: while making their thinking (i.e., understanding) about a project visible in writing, users are called upon to identify of focal STEM practice. Documenting their engagement with an authentic workplace task is intended to help develop an intern's identity as a STEM person. Finally, Akamai staff encourage interns to do this documentation in a way that shows the choices and challenges they faced while completing the project. In ISEE terms, these are key ingredients for establishing learner ownership (Metevier et al. 2015, page 8).

The *Clarifying Your Project* Scaffold: A Brief History

As with other Akamai program supports, the CYP scaffold came about in response to an identified need. For many years, Akamai staff recognized interns' and mentors' recurring struggle with understanding and articulating the essential features of an intern's project. This lack of comprehension and/or communication was most evident around the two times when interns give presentations on their projects: mid-way through the summer internship in July and the end-of-program symposia in August. Akamai staff coach interns through practice-runs of both presentations prior to their formal delivery to a technical audience (e.g., job site colleagues for the mid-point talk and program-wide mentors and industry representatives at the symposia).

While effective in giving feedback to interns, Akamai staff lacked a formal framework or schema – i.e., "organized conceptual structure that guide[s] how problems are represented and understood," (Bransford, Brown, & Cocking, 1999, p. 33) – to serve as a shared frame of reference for the conversations. They initially turned to an existing resource in the K-12 science education research literature.

Known as Claim-Evidence-Reasoning or CER framework, this framework helps guide educators and learners in crafting evidence-based scientific explanations (McNeill 2011; McNeill & Krajcik 2007; McNeill & Krajcik 2008; McNeill, Lizotte, Krajcik, & Marx 2006; Zembal-Saul, McNeill, & Hershberger, 2013). Akamai's version of the CER has added components such as context and focal science practice (see ISEE Inquiry theme element number 1; Metevier et al., 2015) and is referred to as the "Explanation Articulation Framework."

Akamai's Explanation Articulation Framework was an effective support for science-oriented projects, i.e., those in which an intern is ostensibly tasked with answering a scientific question. However, over time there has been a trend of intern projects being increasingly engineering-focused, i.e., the intern is tasked with solving a problem. Finding a lack of an appropriate support in the literature, Akamai staff developed their own engineering-focused framework based on the style and format of the CER. First known as the "Engineering Solution Framework" (circa 2010), it was later renamed as the "Solution Articulation Framework" (Arnberg, 2014).

To help support interns and mentors develop deeper understanding of their projects, Akamai staff translated both the Explanation Articulation Framework and the Solution Articulation Framework into *Clarifying Your Project* worksheets (see Appendices A and B). Both versions are living documents, subject to ongoing revision as deemed necessary by Akamai staff.

Anatomy of a CYP Worksheet
As can be seen in Appendices A and B, each type of CYP worksheet has the sections listed below in order of appearance.

<u>Engineering CYP</u>
HEADING: intern, site, mentor, project (i.e., title of project)
SOULTION ARTICULATION FRAMEWORK Components: Context, Need, Requirements, Constraints, Solution, Justification, Focal Engineering Practice

<u>Science CYP</u>
HEADING: intern, site, mentor, project (i.e., title of project)
EXPLANATION ARTICULATION FRAMEWORK Components: Context, Question, Claim, Evidence, Reasoning, Focal Science Practice

Each framework component is accompanied by clarifying text/prompts to help users understand the brief titles. For example, the clarifying text for Context is as follows:

Background information necessary to understand the need.
(Give others a sense of where your project fits in with the host institution's big picture.)
Why does the host organization value this project? What contribution does it make?

Writers may complete a hard or soft copy (e.g., fillable pdf) version of a CYP worksheet. Both versions provide space for writing in responses (note that a condensed version, i.e., without space for responses, is shown in the Appendices). On average, a fully completed CYP worksheet is about three pages in length.

CYP Scaffold Use in the Akamai Internship Program

The Akamai Internship Program model begins with a preliminary 1-week PREP course for interns prior to their completing a mentored project over 7 weeks at a STEM job site. The internship component ends with regionally based symposium during which interns give succinct, ten-minute presentations on their projects. There is an ongoing Communication Course that spans the entire 8 weeks including the PREP course and mentored project. After completing those components, Akamai provides ongoing Career Development such as occasional workshops, assistance with conference presentations and networking. These elements are graphically portrayed in Figure 1.

Figure 1. Akamai Internship Program Model

During the PREP course, Akamai staff work with interns on skills and behaviors that prepare them to be successful during the internship (e.g., problem-solving as a team, strategies for communicating with mentors). Akamai staff meet face-to-face separately with each intern her or his mentor at their job site mid-way through the internship (e.g., week 3 of 7). This mid-point check-in includes gauging interns' progress on and understanding of their project. The latter has a very concrete application in the mid-point presentation interns practice in front of Akamai staff as a precursor to giving the same talk at their job site. Akamai staff also meet with regionally based groups of interns on "coaching days" immediately prior to a region's symposium date. Again, the staff provide feedback on draft verbal presentations which provide insights as to how well an intern understands her or his project.

Akamai staff have had both interns and mentors complete CYP worksheets at various stages in the program. Given the fact that certain information is not known until the end of a project (e.g., a final solution or answer to a question), use of the CYP scaffold has evolved to the following phased process:

I. Based on a preliminary project description provided y the mentor, interns complete the Heading and Context and Question (science) or Context and Need (engineering) sections during the pre-internship PREP course. Akamai staff help interns understand the various sections and provide verbal feedback on the written responses.

II. After experiencing the first few weeks of the actual internship and as part of the ongoing Communication Course, interns revisit and revise as needed the information provided in Phase I, and add Evidence – anticipated or actual (science) or Requirements and Constraints (engineering). This phase of the CYP scaffold is designed to help interns prepare for their mid-point presentations. Akamai staff again provide verbal feedback on the responses as well as interns' practice presentations.

III. After completing the internship and as part of preparing their symposium presentations, interns revisit and revise previously written responses and complete the entire worksheet. On coaching days, Akamai staff may refer to responses on the CYP worksheet directly or indirectly (e.g., how that information is portrayed in the presentation's slides).

In addition to the thinking done by writers completing the worksheets, the conversations between Akamai staff and the writer greatly contribute to the negotiation of meaning and deepened understanding for the involved parties.

Anecdotally, staff, interns, and mentors all feel that there is value in the CYP scaffold. That said, Akamai staff feel the need for improvement to prevent unintended unproductive trends such as intern use of the CYP worksheet as a template for symposium presentations. This report aims to shed light on productive areas in which to make fruitful improvements.

Methodology

In the summer of 2015, the author conducted a study with a small cohort of Akamai interns and their mentors (five pairs). As part of this study, each intern-mentor pair completed a CYP worksheet twice; first at the internship's midpoint in July, and again just prior to the end-of-program symposia in August. These ten CYP worksheets constitute the main source of data for this report.

As part of the data collection, the author also interviewed each intern and mentor individually twice – once when the midpoint CYP worksheet was completed and again when the end-of-program CYP worksheet was completed. Direct reference to completed CYP worksheets (e.g., seeking clarification of written responses) was made during the interviews. These interviews were recorded and the audio files transcribed. These transcriptions served as a secondary data source for this report.

The CYP worksheets were reviewed as pairs in sequence, i.e., reviewing an intern and her/his mentor's midpoint CYP worksheet together, then reviewing their end-of-program CYP worksheets together, proceeding pair-by-pair in alphabetical order of the intern's last name. This review resulted in a comprehensive document containing both the unedited source data (i.e., unaltered intern and mentor CYP worksheet responses) and the author's initial observations (e.g., patterns, questions, reactions) (Shaw, 2016). Annotations were made in the summary review document including any references made to the transcript data.

The summary review document then was examined in a process of "content analysis," defined as "any qualitative data reduction and sense-making effort that takes a volume of qualitative material and attempts to identify core consistencies and meanings," (Patton, 2002, p. 453). The guiding query for this analysis was, "What do these data tell us about how Akamai staff can better support interns and mentors when using the CYP?"

Data Set

As stated above, the primary data set for this report consists of a total of ten CYP worksheets completed twice each by five Akamai interns and their five mentors during the summer of 2015. In terms of type, by their choice, one intern-mentor pair completed the Science CYP worksheet and the other four pairs completed the Engineering CYP worksheet. Four of the intern-mentor pairs were based on the Big Island while the remaining pair was based on Maui. Two intern-mentor pairs were based at the same institution on the Big Island but the individuals did not have much interaction.

In both this report and the summary review document, the CYP worksheet data are referred to with the coding scheme shown in Table 1.

Table 1.
Coding Scheme for 2015 Clarifying Your Project *Data*

CODE	DESCRIPTION
I1	Intern for first Intern/Mentor pair
I2	Intern for second Intern/Mentor pair
I3	Intern for third Intern/Mentor pair
I4	Intern for fourth Intern/Mentor pair
I5	Intern for fifth Intern/Mentor pair
M1	Mentor for first Intern/Mentor pair
M2	Mentor for second Intern/Mentor pair

M3	Mentor for third Intern/Mentor pair
M4	Mentor for fourth Intern/Mentor pair
M5	Mentor for fifth Intern/Mentor pair
MP	Mid-Point *Clarifying Your Project* worksheet
EP	End-of-Program *Clarifying Your Project* worksheet

Sample reference: I4EP27

Translation: Intern #4's End-of-Program *Clarifying Your Project* worksheet, page 27 in the Review of 2015 *Clarifying Your Project* Data source document (Shaw, 2016).

Given the nature of the data, this report addresses the CYP worksheet component of the overall CYP scaffold. This focus is in no way intended to diminish the importance of the writer-staff discussion aspect of the scaffold.

CYP: Challenges

Analysis of the summary review document (Shaw, 2016) yielded several points of interest regarding the guiding question, "What do these data tell us about how Akamai staff can better support interns and mentors when using the CYP?" In this report, these points of interest are referred to as "challenges." Unless noted otherwise, all sample responses are taken verbatim from source documents, such as an intern's or mentor's completed CYP worksheet. Due to space and time limitations, only those deemed most salient by the author are presented here (see list in Table 2 below). Readers may review the summary document themselves to gain a sense of other points of interest that arose.

Table 2.
Summary of Clarifying Your Project Challenges

Challenge	Description
1. Intern Attribution	Lack of explicit indication of what the intern did/contributed to the project.
2. Purpose Clarification	Ambiguous project focus – what exactly is it intended to accomplish?
3. User Interpretation	Response provides information other than that intended by the developers.
4. Comprehensive Scientific Explanation	Lack of any or all: direct claim statement, empirical evidence, reasoning that explicitly connects the evidence to the claim using scientific principles.

As a precursor to discussing the challenges, consider the following analogy. In the Akamai program, the final symposium presentation is akin to a newspaper article. A reporter (intern) needs to present the Who, What, When, Where, How, and Why in a succinct yet compelling manner. A reporter has a space limitation (e.g., two columns of a newspaper page) while an intern has a time limitation (10 minutes). The purpose of the CYP worksheet is to help an intern *understand* the WWWWHW of her or his project. Crafting the actual presentation is a related yet distinct task with its own set of supports (e.g., pre-symposium Coaching Days).

Challenge #1: Intern Attribution
This challenge refers to a lack of indication or specification of the type of action being done by the intern. CYP worksheets may contain several statements describing a project without any indication of what the intern's role is or what sort of activity the intern actually undertook. The lack of this information is critically important as one of ISEE's goals is to help interns develop identity as a person in STEM, and having an intern be clear about her or his role or agency in the project helps develop such identity (http://isee.ucsc.edu/programs/pdp/equity-inclusion.html).

This challenge was most evident in project titles. Given that titles are typically the first slide in an intern's symposium presentation, it is important that the information on the slide give a sense of the "What" of a project – what action or sort of activity was done. While presenting, the intern can verbally ascribe attribution/agency/ownership –by stating "I did *X*." Nevertheless, for those not present at the symposium or for anyone reviewing the presentation's slides at a later date, the title should convey some of the "How" along with the "What." Here are titles that solely present the "What."

- Efficacy of Flue Gas for Cellana's Open Pond N. oceanica Cultivation [I1MP1]
- Plate Coil Thermal Management: Carousel Cooling System [I2MP6]
- Mechanized Telescope Balancing System [M3MP13]
- Temperature Control for MOIRICS [I5MP24]

Here are examples of titles that present both the "What" and the "How"("How" words have been italicized).

- Carbon Dioxide Utilization Efficiency in Microalgae Systems: *Evaluating* the use of flue gas to grow microalgae [M1MP1]
- DKIST Carousel Cooling System Design *Validation* [M2MP6]
- *Improving* the Counter-Balance System for Keck I and Keck II [I3MP13]
- MOIRCS Instrument Temperature Controller *Upgrade* [M5MP24]

This challenge may also be related to the Focal Science or Engineering Practice section at the end of the CYP worksheet. While an intern likely engages in several STEM practices while completing a project, Akamai staff ask both mentors (e.g., during the Mentor Workshop) and interns to identify a single practice that interns will engage with most directly or frequently, especially in a manner that is challenging to the intern (e.g., an unfamiliar skill) and with which the intern, through repeated practice and guidance, gains a relative degree of competency. The lack of such focused activity may be detrimental to an intern's ownership of learning and development of an identity as a STEM person.

On the CYP worksheets in the data set, the majority of interns and mentors (three out of the five pairs) listed the same practice on their respective worksheets – "analyzing data" for pair 1, "justifying solutions" for pair 2, and "prototyping" for pair 4. For pair 3, the intern listed "prototyping" while the mentor listed "defining requirements" and "conceptual design." The mentor of pair 5 wrote "defining problems" while the intern left that section blank. The challenge here is more on the part of the reader, i.e., Akamai staff member, attempting to make sense of this information or lack thereof. Do the mentor and intern define that designated practice in the same way? Did the intern leave the section blank due to lack of understanding or running out of time? Other than designating a focal STEM practice, the CYP worksheet gives no indication of the how the writer understands or defines that practice, nor the manner in or extent to which the intern actually engaged in the practice. Having the writer provide information along those lines could help that person as well as the reader better understand what an intern actually did and even promote some realization on an intern's part of his or her agency and learning.

Challenge #2: Purpose Clarification

In reading through the CYP worksheets, it was often difficult to identify the "Why?" for a given project. Without really knowing this information, it is challenging for an intern to tell or a staff member to decipher the rest of the story about the project.

In CYP worksheet terms, this information was intended to be found in the "Need" or "Question" section. Below is an example of a Question and its accompanying Title and Claim that show a well-sequenced path, a clear story line.

TITLE: Carbon Dioxide Utilization Efficiency in Microalgae Systems: Evaluating the use of recycled CO2 as flue gas to grow microalgae

QUESTION: How does the algae N. oceanica grown with flue gas [i.e., recycled CO2[1]] compare in growth performance, biochemical composition, nutrient use, and cost to N. oceanica grown with pure carbon dioxide? [I1MP1]

CLAIM: Cellana's flue gas system may be effective in the large scale cultivation of algae because the flue gas system produced algae that meets growth performance and quality standards and costs less to produce than algae grown using conventional methods. [I1EP3]

Here is an example of an intern-mentor pair working to clarify the "Why." Text in italics show additions made to a Mid-Point CYP response on the End-of-Program CYP.

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[1] Text in brackets added for readers of this report.

Intern CYP Text [I2EP8-9]

TITLE: Plate Coil Thermal Management: Carousel Cooling System

NEED: To ensure that the plate coil design will meet specifications, data will be collected from the test rig. This data will then be used to perform calculations that can be compared to the theoretical data. *Data needs to be gathered and analyzed so that comparisons can be drawn between the design specifications and the actual test data.*

The above text indicates the intern's attempt to clarify what his project was about and why he was doing it. The response begins by making reference to the need (verifying that the cooling system design actually works on the actual installation site) and provides additional procedural details.
Mentor CYP Text [M2EP8-9]

TITLE: DKIST Carousel Cooling System Design Validation

NEED: The application of the plate coils for the DKIST enclosure is innovative, however, the lack of previous experience requires the need to verify analysis findings. A simplified single plate coil CFD thermal analysis has been performed in order to study its thermal behavior and needs to be experimentally verified with seasonal data. *Summer data sets will need to be collected. Once all seasonal data sets are gathered, thermal analysis need to be made to validate the heat dissipation from the plate coils.*

This response shows that the mentor has a specific shorthand for referring to the process the intern was to undertake, namely "validation" of the cooling system. It is unclear if the intern grasped that he was engaging in an established technical process that had a name that he could use when discussing the project with others in the field.

Terminology aside, both intern and mentor appear to share an understanding of the steps involved: gathering additional data, performing comparison analyses, using the results to determine whether or not the cooling system's design will work in reality. As seen in the modified Need responses shared above, the specific focus of the project became increasingly clearer over the span of the internship. The CYP worksheet may have played a role in this process, at least in terms of having the intern and mentor express their understanding of the Need in writing.

Based on information in other sections of their CYP worksheets, the Need for this project can be described hierarchically. At the highest level, there was the need to <u>verify the cooling system's design</u>. The verification process required two data sets: one theoretical (previously generated) and one empirical (i.e., seasonal – summer season data were lacking). Thus, one level down was the need to <u>complete the</u>

seasonal data set. A test rig and procedure for its use already existed. Given complete data sets, there was a need to do a computer-based comparison of the theoretical data (i.e., the intern's "design specifications") and empirical (i.e., seasonal) data to see if the actual cooling system (represented by the test rig) would perform as predicted by the theoretical model. The desired output was previously specified but the code to run the comparison needed to be written and the results explained. This hierarchy of needs is graphically portrayed in Figure 2 below.

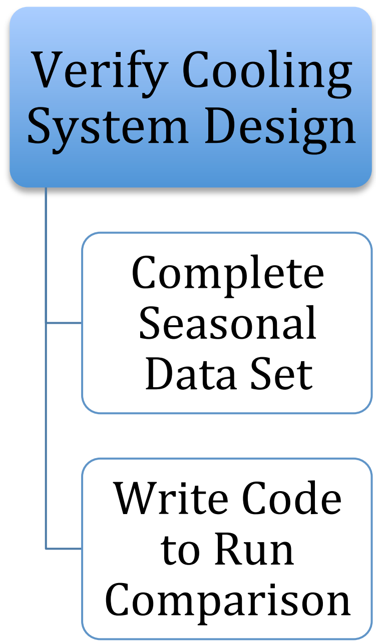

Figure 2. Hierarchy of Needs in Cooling System Validation Project

Challenge #3: User Interpretation

There were several instances in which the writer's response deviated from that intended by the CYP scaffold's developers. As discussed below, this challenge was most evident in the following sections of the CYP worksheet: Context, Requirements, and Solution.

Context

As stated in the clarifying text for this section, the Context should provide "background information necessary to understand the need" (See Appendix B). Below is an example of an on-target Context response. It is preceded by the corresponding Need statement to facilitate reader comprehension.

Need

The goal of this project is to generate two to four mechanized telescope balancing system concept designs, evaluate the feasibility of each approach and to recommend the optimal system design concept for further study. The main hazards of the current system that are to be addressed are the risk of dropping heavy weights from the

Nasmyth deck to the dome floor far below, risk of bodily injury and length of time needed to properly balance the telescope. [M3MP13-14]

Context
The Keck telescopes are massive structures, weighing more than 300 tons each, but the motors that rotate it up and down, pointing it between the horizon and straight up at zenith, are relatively small. This is only possible if the telescope is sufficiently balanced around the pivot axis. The original method of balancing the telescope, which was designed over twenty-five years ago, is still being used today and consists of manually removing or bolting heavy steel plates onto the telescope. This is not only a hazardous operation for the personnel, but it is also rather crude, sometimes requiring time consuming iterative adjustments to meet the balancing requirements. [M3MP13]

Other writers provided information less relevant to understanding the Need, such as steps or procedures to follow in addressing the Need.

Need
Subaru MOIRCS focusing programs are outdated, difficult to maintain, and not always accurate when finding best-fit curves. [I4MP19]

Context
One of the Subaru Telescope's scientific instruments, MOIRCS, uses a variety of cumbersome and hard-to-maintain computer programs to establish the "best focus" telescope configuration for the instrument. The first goal of this project is to re-write the focusing programs in the Python computer language so as to make them more modern and easier to maintain. The second goal is to develop a graphical user interface (GUI) for the focusing operation and integrate the GUI into the Subaru Observation Control System. [M4MP19]

As the above examples show, some writers associated goal statements with either the Context or the Need. Depending on how it is written, a goal statement may be relevant for either section.

Requirements
Engineering requirements are a complex topic. There are multiple definitions of the term "requirements," with distinctions commonly made between functional and non-functional requirements. Non-functional requirements themselves have been divided into eight subcategories (Robertson & Robertson, 2012). Previous ISEE-sponsored research has identified intern struggles with articulating a project's requirements, such as identifying constraints as requirements, identifying non-functional requirements as functional requirements, and not stating functional requirements in a verifiable manner (Arnberg, 2014).

To address these issues, in 2015 Akamai staff created a handout on engineering requirements that was shared with interns in that summer's PREP course (see Appendix C). Based on Arnberg's findings and insights from mentor workshop discussions, this document uses "generic" language to describe requirements (i.e., main requirements – what a solution must do or accomplish, and other requirements – actions/characteristics a solution may or may not need to address the problem) and provides examples of different requirement statements. As recommended by Arnberg, the handout makes the distinction between "verifiable" and "non-verifiable" requirements, the difference being whether or not you tell if the requirement has been met. Examples of the former are requirement statements with measurable target values and units.

These insights are reflected in the engineering CYP worksheet. For example, the Requirements section simply uses the word "requirements" with no modifier, and the clarifying text refers to "target values and units." Nevertheless, the following discrepancies were evident in both intern and mentor responses to this section.

Vague Requirements

The presence of ambiguous adverbs such as "clearly" or "effectively" is a common indicator of this issue.

It must be written as concisely and clearly as possible, making the programs easier to maintain. [I4MP19]

Effectively keep the temperature of MOIRCS at 77 degrees Kelvin. [I5MP24]

Requirements statements also may lack measurable targets with units when other sources (e.g., a different CYP worksheet or interview transcript) show this information to have been available.

The new system must accurately balance the telescope along the z and y axes. [I3MP14]

Ability to balance about the telescope about its Y and Z axes so that the drive motor currents necessary to move the telescope are less than 5 amps. [M3MP14]

Inclusion of Procedural Information with Requirements

Some writers placed how-to as well as what-must-do information in this section.

The experimental data collected using an existing test rig shall be combined with previous seasonal data and used to determine, analyze and compare the accuracy of design models used for the DKIST carousel cooling system. Data collected should verify if the plate coils satisfy the requirements specified in the Carousel Cooling System Analysis Report. [M2MP7]

Inclusion of Constraints as Requirements

Constraints, i.e., limits on tasks and resources used to reach a solution (such as available staff, money, and equipment), often were written in the Requirements section.

Must use the data collection tools provided. [I2MP7]

Ultimately, the lack of clear requirements statements hinders understanding of how to solve a problem as well as how to defend one's proposed solution to a problem. The latter is called for in the Justification section of the engineering CYP worksheet.

Solution

Akamai staff intended responses to this section to provide a description of the solution, proposed or actual, to the previously specified need or problem. For example…

The focusing programs were rewritten in Python using Python libraries such as AstroPy, NumPy, MatPlotLib, and SewPy. Using an existing (more general) plugin (FocusFit) as a guideline, the focusing programs were reworked into the plugin format and added to the list of fitsview plugins. [I4EP22]

In contrast, as the examples below show, some writers responded with descriptions of the procedure, i.e., steps taken to determine a solution.

In order to see if the plate coil is performing to standard, tests will be performed with the test rid and data will be collected from those tests. This data was input into a MatLAB code that I wrote. The code is designed to take the collected data and perform all required calculations. It will output the results and let me know where certain issues occur. The data is recorded on an excel sheet that can be imported to the MatLAB script. This automates the process and allows all future testing and analysis to be done efficiently. [I2EP29]

Set up schedule for data collection. Set up plate coil on summit and left the chiller charged to reduce set up time. [M2EP29]

The conflation of procedural information with solution description may be the result of different interpretations of the section's clarifying text, "A way to address the need." It is reasonable for a writer to interpret "way" as "how," i.e., procedure.

In sum, user interpretation challenges may point to confusing text on the CYP worksheets themselves. The underlying issue may be related more to grappling with CYP terminology and formatting (e.g., getting the desired information in the "right" CYP section) rather than actual comprehension of what a project is about.

Challenge #4: Comprehensive Scientific Explanation

As mentioned earlier, the Science version of the CYP is based on the well-researched claim-evidence-reasoning framework in the K-12 science education literature (see, for example, McNeill 2011). To provide a context for the discussion of this challenge, consider this example of an elementary school experiment investigating plant growth (Zembal-Saul, McNeill, Hershberger, 2013, p. 30) shown in Figure 3 below.

QUESTION	Do bush bean plants grow better in sunlight?
CLAIM	Bush bean plants grow better in sunlight.
EVIDENCE	The plant in direct sunlight grew 16cm, and the plant with less sunlight grew 11cm. The plant in direct sunlight had 6 leaves, and the plant with less sunlight only had 3 leaves. Finally, the plant in direct sunlight was a dark green, and the plant with less sunlight was pale green.
REASONING	Height, number of leaves, and color are all important indicators of a plant's health. Since the plant in direct light was taller, had more leaves, and was dark green, that means it was able to grow better.

Figure 3. Elementary Level Claim-Evidence-Reasoning Example

Note how the Claim is a simple, direct answer to the Question. Note the inclusion of quantitative empirical data (e.g., grew 11 cm) in the Evidence. Also note how the Reasoning explains how the evidence *categories* (height, number of leaves, and color) relate to the claim. Using the scientific principle that greater height, more leaves, and darker color indicate better growth, since the plant grown in direct sunlight had those attributes in comparison to the plant grown with less sunlight, it is logical to conclude that the plant grown in direct sunlight "grew better."

Consider the same components from the one intern who completed a Science CYP worksheet.

QUESTION	Is Cellana's flue gas system effective in the large scale cultivation of algae?
CLAIM	Cellana's flue gas system may be effective in the large scale cultivation of algae because the flue gas system produced algae that meets growth performance and quality standards and costs less to produce than algae grown using conventional methods.
EVIDENCE	Early results show that algae grown with flue gas did not significantly differ from control algae in biomass productivity, growth rate, pH, and nutrient use. Flue gas grown algae used less pure carbon dioxide than the control algae, and consequently cost less.
REASONING	Algae grown at Cellana must meet quality, and growth performance standards. Growth rate, biomass productivity, pH, nutrient use, and biochemical composition are all measures of quality and growth performance.

Figure 4. Intern Science CYP [I1EP3]

Note how the Claim is an extended, as opposed to simple, answer to the Question. This is likely due to the scaffolding text for the CYP worksheet's Claim component which states the following:

A statement or conclusion that answers the question.
(The answer is X because…)

Note how the Evidence lacks reference to quantitative empirical data which were readily available. As with the plant growth example, the intern's Reasoning does mention evidence *categories* (growth rate, biomass productivity, pH, nutrient use and biochemical composition) but does not connect actual evidence in those categories in support of the Claim. A more complete reasoning statement could have included the following:

> Since the microalgae grown with CO2 from the flue gas system had a growth rate, biomass productivity, pH, nutrient use and biochemical composition comparable to microalgae grown with purchased CO2, that means flue gas CO2 may be effective in the large-scale production of algae.

Now consider the same components from the one mentor who completed a Science CYP worksheet.

QUESTION	Using flue gas as a source of CO2 will affect the growth and composition of algae similarly to that of using pure CO2.
CLAIM	The flue gas affects the growth of algae similarly to pure CO2 because the growth rates are the same between control and experimental ponds.
EVIDENCE	Data on CO2 usage. Data on growth rate.
REASONING	Data from this project are currently based on one round of experiments and may, or may not, present a possible trend. However, data based on first round do appear to indicate a potential positive effect of using flue gas.

Figure 5. Mentor Science CYP [M1EP3-4]

The first thing to note is that the mentor stated the Question as a declarative hypothesis statement. This is not necessarily a challenge as it is an acceptable way of describing an experiment in the scientific community. Given such a hypothesis, it is understood that the experiment is designed to prove or disprove that statement.

Given this question-as-hypothesis scenario, the first half (up to the word "because") of the mentor's Claim statement is also scientifically acceptable. However, as with the intern's response, it also goes beyond a simple "answer" to the hypothesis continuing on with a rationale (from "because" to the end of the sentence). Again, this is likely due to the scaffolding text encouraging the inclusion of a "because" clause.

Note also how the mentor makes cryptic reference the actual empirical quantitative Evidence. Thus, both intern and mentor failed to include actual empirical quantitative data in their CYP worksheet responses.

With respect to Reasoning, rather then mentioning evidence *categories*, the mentor refers to the need for multiple trails to be able to make a stronger claim. The mentor's statement substantiates the intern's qualified claim of "*may* be effective" (I1EP3, emphasis added). Thus, intern and mentor Reasoning statements show complementary ways of applying scientific principles to support a claim. A comprehensive reasoning statement would refer to both the intern's growth-indicator principle and the mentor's multiple-replication principle.

In sum, the challenge with scientific explanations inherent in the Science CYP worksheet was manifested in three ways: (1) extended versus concise Claim statements, and (2) lack of inclusion of empirical quantitative Evidence, and (3) incomplete Reasoning statements (e.g., not directly connecting the evidence – or evidence categories – back to the claim, or not referring to other scientific principles that directly relate to the claim).

CYP: Considerations for Improvement

This section presents topics for Akamai staff to consider as they deliberate revisions to the CYP scaffold. While sometimes written in declarative statements for ease of expression (e.g., Change X text to say Y…), these considerations are offered as catalysts for discussion, not specific action items.

Taken altogether, the above-described challenges suggest two broad courses of action: (a) revisions to the CYP worksheets themselves, and (b) ideas about how to *use* the CYP.

Changes to the CYP worksheets
Presented below are potential changes to both the language and formatting of the CYP worksheets. They begin with referencing changes to the two types of worksheets separately (i.e., science then engineering), and close with considerations that affect both worksheets as a whole.

<u>Changes to the text on the Science CYP</u>

1. CLAIM: Delete scaffolding text "The answer is X because…" It inappropriately encourages the writer to include reasoning language when a direct statement of the claim (i.e., answer to the question) is sufficient.
2. REASONING: Provide clarifying text about "Scientific Principles." How does Akamai define that phrase, what are some examples?

Changes to the text on the Engineering CYP

3. SOLUTION: Come up with alternative scaffolding text to replace "A way to meet the need" that avoids confusion with requesting procedural information.

Changes to the text on both CYPs

4. WORKSHEET TITLE: Change the name of the worksheets to "Understanding Your Project" (UYP) to emphasize the intended focus on comprehension and not presentation.
5. PROJECT: Revise to read "Title of Project" and adding clarifying text that cues the writer to include a "How" verb in the title.
6. CONTEXT: Delete this section entirely. The intended information may naturally surface in the other sections. Thus, removing this section may remove some redundancy along with confusion over what goes where. Context information also may be more relevant to presenting rather than understanding a project, so better to be addressed when assisting interns with actual presentations (e.g., during pre-symposium Coaching Days).
7. FOCAL STEM PRACTICE: Enhance this section to include the writer providing a description of the identified practice and how the intern engaged with the practice.

Reformatting the CYP

Discrepancies in what information writer's place where are likely due to lack of understanding of CYP terminology as well as the actual arrangement of text on the worksheets. The textual changes listed above partially address the former issue. A more complete solution may be to reformat the documents in a way that breaks up the current linear progression through the sections and reflects the *relationships* between sections. For example, imagine a graphic in which the Need is located inside a circle that is connected by an arrow to another circle containing the Solution. Underneath the connecting arrow is a two-column table in which individual Requirements are listed on the left and information on how they were or were not met (i.e., Justification) is listed side-by-side on the right (see Figure 6 below). Such an arrangement graphically conveys the direct connection between Need and Solution, and how a Solution must be based on meeting Requirements.

A more radical reformatting action is to consider creating a single *Understanding Your Project* worksheet that solicits the essence of what is needed for a writer or Akamai staff member to comprehend a project, whether or not it is considered science or engineering. Fitting intern projects into one framework or the other is an ongoing debate among Akamai staff. Having a single framework for all projects could render this debate mute. Returning to the two frames shared in the introduction to this report, the focus of the CYP scaffold should be on *understanding* a project, not getting distracted or confused by terminology or formatting. Having users choose between a science or engineering CYP worksheet may be an unproductive mental exercise that draws their attention away from more essential pursuits such as coming up with a fundamental description of a project's purpose and how it was addressed. Creating a universally applicable CYP or UYP may not be realistically achievable. However, the idea is worth considering.

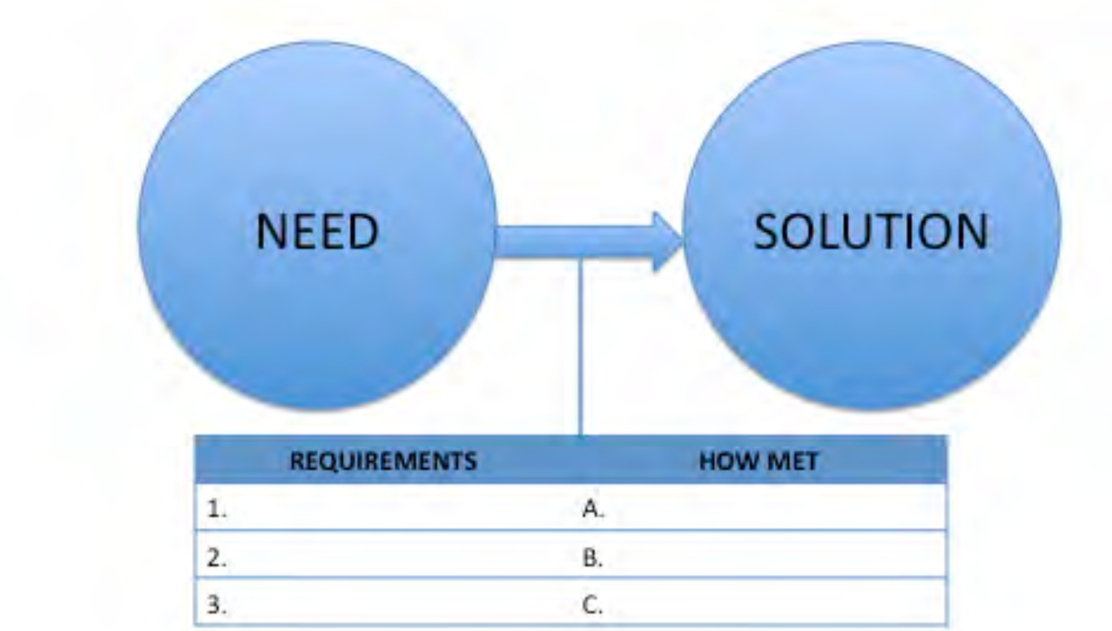

Figure 6. Solution Articulation Framework Graphic

Ideas for future use of the CYP Scaffold

Regardless of language or format, Akamai staff should consider ways to make ISEE Theme focus areas such as development of identity as a STEM person more explicit for the writer, be that person an intern or mentor. An example would be to coach interns to include "How" verbs in the title for their project so that it is clear to the intern as well as a reader or audience member what STEM-related action the intern engaged in (e.g., validation, upgrade, optimization).

Another use-oriented consideration is to place greater emphasis on the Focal STEM Practice section of the CYP worksheets. Currently, Akamai staff spend relatively little time discussing this response with interns and mentors. This is understandable given that gaining clarification on higher priority items (such as requirements and justification for engineering or evidence and reasoning for science) consume most of the available time. However, connecting the focal STEM practice to discussions of these items can help promote intern ownership of learning as well as development of identity as a STEM person.

To effectively implement the above and other considerations that arise or are not mentioned here, Akamai staff should consider creating supporting documentation for the CYP scaffold. Such documents could be of two different kinds: one for staff and the other for users (i.e., those who fill out a CYP worksheet).

CYP Staff Guide. This supporting document could take the form of a staff guide such as those used by Akamai staff for Initiative presentations such as sessions for the PREP course or Mentor Workshop. This guide could lay out a typical session for working with interns on completing a CYP and include a discussion of the nuances associated with such a task as well as specific prompts to use during such a session.

CYP User Guide. This supporting document for interns or mentors could take the form of "Cliff Notes" (i.e., concise statements that get to the essence of a topic or issue). The User Guide could mirror some of the information in the Staff Guide but without background information. For example, in relation to the Intern Attribution challenge, the User Guide would contain examples of titles that do and do not show intern attribution while the Staff Guide would the same information enhanced with excerpts from the "Developing an identity as a person in STEM" section of the ISEE Equity & Inclusion Theme document (Seagroves et al., 2015) along with discussion or coaching prompts.

A final consideration

Whatever becomes of the CYP and related documents, the author strongly encourages Akamai staff to have these items available in soft-copy and readily accessible on the Internet. For the past two years Akamai staff have experimented with providing the CYPs as fillable pdf's for interns and mentors to use. While this approach was not without it's own challenges (e.g., determining the proper "coding" for the fillable text boxes), it was an overall improvement in terms of ease of use as well as collection and archiving of responses. A next step might be a web-based Google Form which may be even easier for users to complete and more readily accessed by staff.

In closing it is worth repeating that Akamai staff have an admirable history of providing a variety of supports to program participants. Oftentimes, these strategies are passed on informally among existing staff, with little documentation of lessons learned or nuances to their effective use. This report represents an attempt to bridge that gap as well as provide a formal foundation on which to further improve the CYP scaffold.

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Appendix A.

Clarifying Your SCIENCE Project

Intern: ______________________ Site: ______________________

Mentor: ______________________ Date: ______________________

Project: ____

EXPLANATION ARTICULATION FRAMEWORK Components

CONTEXT

Background information necessary to understand the need.
(Give others a sense of where your project fits in with the host institution's big picture.)
Why does the host organization value this project? What contribution does it make?

QUESTION

The *specific* question or hypothesis about the phenomenon.

CLAIM

A statement or conclusion that answers the question.
(The answer is X because…)

EVIDENCE

Scientific data that support the claim. The data need to be **appropriate** and **sufficient**.

REASONING

How the evidence is linked to the claim through scientific principles.
Why the data count as evidence. (May be a chain of reasoning.)

Focal SCIENCE PRACTICE (circle or specify):
Generating Questions Analyzing Data Developing Explanations
Planning and Carrying Out Investigations Developing Theories Other:

Appendix B.

Clarifying Your ENGINEERING Project

Intern: ______________________ Site: ______________________

Mentor: ______________________ Date: ______________________

Project: ____

SOLUTION ARTICULATION FRAMEWORK Components

CONTEXT

Background information necessary to understand the need.
(Give others a sense of where your project fits in with the host institution's big picture.)
Why does the host organization value this project? What contribution does it make?

NEED

The *specific* problem being addressed.

REQUIREMENTS

What the solution must **do** or **accomplish**.
(May have measurable **target values and units**.)
If the solution does not do ______________, then it's not solving the problem at all.

CONSTRAINTS

Limits on tasks and resources used to reach the solution.
(Examples include available staff, time, money, equipment, materials)

SOLUTION

A way to address the need.

JUSTIFICATION

Support for the solution that addresses each requirement (among other things).

Focal ENGINEERING PRACTICE (circle or specify):
Defining Problem Analyzing Tradeoffs Defining Requirements Identifying Constraints
Prototyping Justifying Solutions Troubleshooting Other

Appendix C.

ENGINEERING REQUIREMENTS

The phrase "engineering requirements" has many different meanings. We provide the information and examples below to help us have a common language when discussing this important topic.

MAIN REQUIREMENTS

What the solution must do or accomplish. (May have measurable target values and units.)

The solution must get and process 5K bytes of data from the server in real time.

OTHER REQUIREMENT(S)

Other actions / characteristics the solution may or may not need to do or have in order to solve the fundamental problem or address the essential need.

Type	Description	Example
Look and Feel	Related to the solution's appearance	• The exterior should be painted in earth tones
Usability	Related to the solution's ease of use	• Have an extremely intuitive user interface
Performance	How fast, safe, accurate, etc.	• Reduce cooling costs • Protect racks from seismic events
Operational	Related to the solution's operating environment	• Integrated with existing infrastructure
Maintainability / Portability	Related to expected changes and the time needed to make them	• Be accessible for future troubleshooting and maintenance
Security	Related to security and confidentiality	• Minimize security risk
Cultural / Political	Related to concerns / issues that arise because of the people involved	• Respect traditional sacred sites
Legal	Related to applicable laws / industry standards	•

VERIFIABLE REQUIREMENTS

Whether or not you can tell if the requirement has been met.

Non-Verifiable	Verifiable
• Continue operations	• Provide employees with continued access to company servers
• Align the file systems	• Align the file systems with array vendors best practices
• Filter data views	• Filter data views into separate folder