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Assessing creative productivity

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ABSTRACT

This research investigated the potential for curricula at the intersection of the arts and the sciences to develop creative productivity of students. The purpose of this research was to develop a series of rubric assessments to evaluate the content and creative and higher order thinking on a variety of teacher-made lesson plans and student-made products. The research used an iterative process to identify the criteria for the rubrics. The content validity process involved the use of experts in the domains of art and science education, assessment, and creativity to identify important themes from the research base of each domain. Then the process continued to teachers of cross-curricular lesson plans, to provide insights into usefulness of the constructs in practical contexts. The final instrument was used to evaluate cross-disciplinary student products. These works of art were evaluated by a sample of art teachers with over 5 years of experience. The art teachers had attended professional development offered by the Innovation Collaborative evaluator on arts integration and the rubric. The resulting inter-rater reliability estimates ranged from moderate to excellent, for each of the four rubrics. The resulting rubrics can be used to assess work in research or classroom environments.

KEYWORDS
Creativity; assessment; rubric; arts integration; content validation

Leaders in both industry and education have emphasized the importance of creativity and innovation in development (Craft, 2008). While commercial and business leaders have underscored the utility value of creativity and innovation to produce profits and maintain strategic edge over competitors in a global marketplace (e.g., Harvey & Novicevic, 2002), educators have attempted to address this call to action through the development of creative thinking skills in students (e.g., Sternberg, 2003). The development of creative thinking skills in schools has taken many forms, through creative problem-solving protocols (e.g., Treffinger, Isaksen, & Stead-Dorval, 2005), brainstorming and idea-generating activities (e.g., Paulus & Paulus, 1997), extracurricular activities (e.g., Future Problem Solvers, Destination Imagination, and robotics clubs) and through the development of creative ideas in discipline-specific activities (Plucker, 1998). More recently, there has been a movement in education to investigate the types of thinking and learning that occurs at the intersections of the STEM fields (i.e., Science, Technology, Engineering, and Mathematics) and the Arts and Humanities (e.g., Piro, 2010). This intersection is often called "STEAM" and has demonstrated promise as a vehicle for the development of creative thinking (e.g., Kim & Park, 2012; Wilson & Presley, 2018).

As education initiatives have focused to a greater extent on the creative thinking processes used by students (e.g., Treffinger & Isaksen, 2005), there have been fewer ways to evaluate and assess the creative and critical thinking that is occurring in those activities. Similarly, as education leaders have adopted a focus on STEAM-integrated lessons, there has been little instrumentation developed to measure effectiveness of arts integration in lessons or in student work. As the field moves forward with these ideas, and it becomes important to the individual growth of students as well as the overall growth of industry and innovation, it is vital that research focus on how to assess and evaluate best practices in these areas.

The purpose of this study is to describe the process of development and evaluation of four rubrics designed to measure the creative and critical thinking skills and the integration of the arts with math and

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science of both lessons developed by teachers and the products created by students in the context of arts classrooms. This study focuses on the development of each rubric separately, so future studies can investigate the relationship between the rubrics to provide further support for the constructs.

Background

This study is grounded in a framework of research connected with the development of creativity and creative and critical thinking skills through purposeful classroom design and implementation of activities with students. This development of student thinking is also connected to the research and theory of models of arts instruction that consider arts integration as a continuum (Frodeman, Klein, & Mitcham, 2010).

Creative productivity

Creative Productivity was first introduced as a conception of giftedness by Renzulli in 1978, and has since been updated and become one of the most cited conceptions of giftedness and creativity in the field (Renzulli, 2016). Creative Productivity uses Csikzentmikhayi's (1996) definitions of creativity, implying that unequivocal creativity occurs when people make innovations that change a field of study. Thus, creative productivity in a gifted individual implies the ability to interpret and make advances in areas of interest in new and unique ways. Thus, in order to foster creative productivity in students, schools must provide opportunities for exploration of ideas in which students are engaged and have task commitment, ability, and prior knowledge and skills to produce innovative products (Renzulli, 2016).

Arts integration and creativity

In thinking about ways in which schools, programs, and teachers can develop creative productivity among students, the integration of arts into the curriculum is one way in which researchers have proposed to increase creative thinking (e.g., Wilson, 2009; Wilson & Presley, 2018). By asking students to synthesize two disciplines and make connections across content areas, this strategy is particularly appropriate for gifted learners (Wilson, 2009) and the development of creative thinking skills. Specifically, the STEAM movement has emphasized design-thinking and innovation within the more traditional STEM fields, providing greater context for creativity to flourish within school curricula (Wilson, 2009). However, few studies have been conducted to formally study this relationship among K-12 learners (Kim & Park, 2012) and this was the impetus for the development of the rubrics documented in this study.

Assessing creative productivity

While there are numerous measures for creativity as a thinking skill, such as the Torrance Test of Creativity (TTCT) which demonstrate strong evidence of validity and reliability (Runco, Millar, Acar, & Cramond, 2010), there are fewer published instruments (e.g., rubrics) to assess creative products. Those that do exist for practical use in the classroom tend to be connected to a specific product, such as a poster, diorama, or science project (e.g., Karnes & Stephens, 2009).

On the other hand Amabile (1982, 1996) developed an approach to evaluating creative products from the perspective of social psychology, the Consensual Assessment Technique (CAT). In this technique, a group of evaluators (experts, teachers, or other raters) assess a set of products of the same type (e.g., paintings, poetry, or collages in the Amabile, 1982 original studies) on an overall mutually agreed-upon understanding of creativity. This overall understanding of creativity can then be tentatively broken down into sub-parts which may be related to the product type and work that is done by professionals (Amabile, 1982, 1996). Overall, this approach has shown to have high levels of reliability in research settings, evaluating such products as childrens' music compositions (Hickey, 2001), sentence captions (Kaufman, Lee, Baer, & Lee, 2007), and geometric shape drawings (Chen et al., 2002). In more recent research, the technique has been expanded to less tightly controlled setting, such as a panel of experts reviewing essays from a variety of prompts from the National Assessment of Educational Products (Baer, Kaufman, & Gentile, 2004). Additionally, research using this approach indicates that experts rate products significantly differently than non-experts and with much higher rates of interrater reliability (Kaufman, Baer, & Cole, 2009; Kaufman, Baer, Cole, & Sexton, 2008).

Rubrics have been used to effectively assess and measure creativity in specific contexts and within specific domains, such as landscape design (Clary, Brzuszek, & Fulford, 2011), creative writing (Mozaffari, 2013), and formative creativity in mathematics (Savic, Karakok, Tang, El Turkey, & Naccarato, 2017). These studies, perhaps, speak to a larger interest in the assessment of creativity and the tension between a prescribed rubric and the nurturing of creative thinking among students (Chapman & Inman, 2009; Young, 2009). Much of the existing literature regarding rubrics in the assessment of creative thinking or creative products is domain-specific, relying on the assessment of the product itself, and does not lend itself to cross-disciplinary study.

In this current study, documenting the development of rubrics that measure both critical and creative thinking and the level of arts integration, an overall score of creativity is generated from expert raters, along with other elements that demonstrate deep levels of thinking and engagement with the content, on the rubrics. Thus, this study was designed to look at the ways in which a student product could demonstrate creative and critical thinking across a variety of product types and developmental levels using specific rubrics designed for both research and classroom use. In addition, another set of rubrics developed in this study can assess the lessons developed by teachers that might elicit these products, in alignment of the theoretical framework (Renzulli, 2016).

Methods

This section outlines the context for the study, and then the process of the development of the rubrics and the content validation of the rubrics. Finally, it describes the methods for the analysis of the interrater reliability of the scoring of the products and lessons. The purpose of this study is to not only describe the final product of the rubrics, and their validity, but to also describe the process in which they were developed for other practitioners to potentially use as a model.

Context: innovation collaborative

This study was developed through the work of the Innovation Collaborative. The Innovation Collaborative is a nonprofit organization that works at the intersection of the arts, science, engineering, and use of technology. The organization works to provide information about effective integration of these content disciplines in formal and informal educational settings through identification, execution, and dissemination of research. The Innovation Collaborative provided the organization for the study.

By investigating the arts integrated activities, it became apparent that there was a need to evaluate the student products in quality as it related to the discipline-specific tasks (e.g., arts and sciences), but also to the types of thinking skills that were used by the students. In addition, because the studies were implemented across grade levels, content areas, and in a variety of school demographic contexts, an evaluation tool was needed that could assess the products by the ways in which students were thinking deeply (creatively and critically) without being dependent on product type (e.g., painting, sculpture, invention, etc.). The methods for developing the resulting rubrics are described in the following paragraphs.

Development of rubrics

One of the research foci of the Innovation Collaborative was to investigate if the implementation of arts integrated lessons increased the critical and creative thinking of students. Therefore, the first step, therefore, in the process was to theoretically define, and then operationally define, the constructs to be evaluated.

Development of the discipline specific criteria

The first identified constructs were the discipline-specific criteria including high-quality content areas and integration of the content areas. The research team worked with the Innovation Collaborative board that included experts from national arts, science, education, and museum organizations to identify a framework for understanding arts integration. Through discussions during monthly teleconference calls and quarterly in-person meetings, the board determined to adopt the arts integration framework from Frodeman et al. (2010) was adopted.

This framework describes curricular integration on a continuum from single disciplinary to transdisciplinary to characterize the degree to which activities incorporate multiple content areas. In single disciplinary learning experiences, there is a superficial integration in which each area is taught independently of each other and combined at the conclusion of the project (Frodeman et al., 2010). In multidisciplinary integration, the two subjects are taught simultaneously, yet separately, and one could be taught independently of each other (Frodeman et al., 2010). Interdisciplinary learning experiences, on the other hand, also include simultaneous instruction, but the interaction between the subjects is systematically planned from the beginning and occurs throughout the project. However, the disciplines are not dependent on each other (Frodeman et al., 2010). Finally, in transdisciplinary learning experiences, the activities are fully integrated, in a way in which all content areas are dependent on each other and contribute in meaningful understandings (Frodeman et al., 2010). It should be noted that while these levels of arts integration are hierarchal, indicating that, perhaps, transdisciplinary learning would be the most desirable for lesson planning, future research will have to determine whether or not this level of integration results in higher levels of creativity and/or thinking from students.

In order to further operationalize these areas, the research team developed a table of examples (see Table 1) for each of the levels of arts integration proposed by Frodeman et al. (2010). These illustrative examples were then later incorporated as part of the rubrics.

Development of thinking skills criteria

The next step was to define the goals for critical and creative thinking skills to be assessed by the rubric. This was an iterative process that began by convening a group of research thought leaders funded through a grant funded by the National Endowment for the Arts in 2016. These thought leaders were identified experts in the major areas of focus of the Innovation Collaborative (Arts, Sciences, Neuroscience, Creativity, and the Arts/Science Intersections). In this meeting, domains of thinking skills were defined. From this initial work, the Research Thought Leaders have continued to collaborate and provide important recommendations and insights used in the research projects. The 14 thinking skills criteria developed in the initial meeting are outlined in Table 2.

Development of rubrics

The next step in the process was to develop rubrics from the identified constructs. In the first iteration of the rubrics, one rubric was designed to assess both thinking skills and arts integration of student products. Each of the 14 thinking skills outlined as well as arts integration and content areas were separate criteria on the rubric.

This version of the rubric was evaluated by a group of expert practitioners who had been successful at designing and implementing arts integrated lessons. This group was comprised of 8 teachers in elementary (n = 5) and secondary (n = 3) schools. They taught a variety of subjects including art, science, and engineering design. These practitioners provided feedback through teleconferencing and through in-person professional development surrounding the rubrics. This feedback and discussion amongst the practitioners led to several changes to the rubric.

Primarily, the teachers found that the number of criteria to be cumbersome to use, and that it was unlikely for any product to demonstrate all of these criteria. Teachers and evaluators utilizing the rubric had difficulty distinguishing among the various criteria and making sense of them, even if instructed that not all thinking skills would be demonstrated in every lesson or with every product. Thus, attempts were made to combine and simplify the list of thinking skills to a manageable list that would be useful for teachers in the field. This included collapsing the various steps of problem solving into one category, conceptualizing that the problem-solving process of the production of a product may include some, or all, of these steps.

Additional areas deemed important to the teachers that emerged from earlier projects conducted by the Innovation Collaborative included: persistence and visual thinking skills. In particular, visual thinking skills were determined to be instrumental to the project in that they demonstrated additional modalities for students to understand and interpret information and process that information to make a product. This was particularly relevant to the arts-integrated approach. Through their experience in implementing arts integrated lessons, and working with students as they developed critical and creative thinking skills, the teachers also identified persistence as an important skill for students. They viewed persistence as more than a disposition; rather a skill that could be

Table 1. Levels of integration with examples.

Level	Explanation	Example
Single Disciplinary	Lesson provides opportunities for students to work on individual disciplines which are combined at the end on a superficial level.	Decorating a car that they created in science class
Multidisciplinary	Lesson provides opportunities for students to plan toward a common goal but work on different disciplines separately, combining them at the end to enhance each discipline. Each discipline could have been addressed separately without impacting the other discipline	Students create and decorate a car in separate science and art classes and combine their products at the end.
Interdisciplinary	Lesson provides opportunities for integration throughout, but is structured so that students work within separate disciplines. Students plan on the integration throughout, but work within separate disciplines. They could be successful in one discipline and not the other. However, when combined, the disciplines enhance each other, but are not dependent on each other for success.	Students plan in both art and science how to create an art/science car at the end. However, they work separately in each discipline toward the art/science goal.
Transdisciplinary	Lesson requires students to work on disciplines interdependently, seeing that one discipline can*not* complete the task without the other. The lesson helps the students understand that the disciplines rely on each other to contribute to a meaningful understanding of the other in order to address their problem.	Students create an art/science car where art thinking and concepts inform the scientific/engineering aspects of the car and the scientific/engineering aspects of the car inform the esthetic choices. Neither could succeed without the input of the other. This is all framed around solving a given problem.

Levels of Integration (Frodeman et al., 2010)

Table 2. Thinking skills criteria.

Thinking Skill	Description
Observing and asking questions	Students observe objects, phenomena and experiences and communicate questions that those observations raise.
Defining/clarifying a problem	Students define a problem, then narrow the problem to feasible parameters.
Acquiring and evaluating necessary knowledge	Students acquire knowledge that relates to their problem and evaluate its relevance and validity. This includes: 1) carrying out investigations in disciplinary and cross-disciplinary areas that address questions they have raised and 2) interpreting what they discovered using evidence.
Generating ideas	Students generate a number of ideas concerning the problem, with an emphasis on out-of-the-box ideas.
Changing perspectives	Students think about content and concepts in different ways or from different points of view.
Abstracting	Students explore theoretical concepts and/or form generalizations from concrete experiences.
Transforming	Students modify and adapt ideas and content.
Synthesizing	Students combine disparate ideas to form new conceptualizations.
Comparing/Contrasting	Students explore similarities and differences between ideas, experiences, or content.
Evaluating ideas or statements	Students evaluate ideas or statements and then select the most appropriate ideas based upon criteria.
Collaborating	Students collaborate with others to deepen the process of learning, thinking, and understanding.
Creating	Students design, build or invent something new based on what the student has learned or information that (s)he has been given. This can include models, concepts, or other works that help explain disciplinary concepts.
Communicating	Students communicate through a variety of means what they have learned/discovered in this process. They are able to select the necessary information to explain their findings/products using discipline-specific argumentation.
Responding	Students view other people's work or important concepts, knowing what to look for and how to make meaning. They see how the work or concepts connect to other subjects or to their own lives, and use criteria to evaluate them.

developed, and foundational to the growth of students' capabilities.

This conversation led to the discussion regarding the types of lessons that would elicit the demonstration of thinking skills in student products. It became increasingly apparent that it would be necessary and useful to assess both the lessons created by the teacher and the products created by the students.

Table 3. Interrater reliability statistics.

Rubric	*N* of Raters	Two-Way Average Measures Intraclass Coefficient
Lesson Content Rubric	7	0.961
Lesson Thinking Skills Rubric	7	0.699
Student Work Content Rubric	7	0.911
Student Work Thinking Skills Rubric	7	0.565

Finally, through conversations between the research team and the teachers, the distinction between the two constructs (i.e., content-related criteria and thinking skills criteria) emerged. As the future research goals were further defined to look at the possible correlation between these two constructs, developing separate rubrics for each seemed sensible. This separation was also perceived by the teachers to make each rubric more useful for purposes outside of the specific research projects associated with the project.

Thus, moving into the next step of the rubric development, there were four separate rubrics to evaluate: Content of Lesson, Content of Student Product, Thinking Skills of Lesson, and Thinking Skills of Student Product.

Content validation

The process of content validation of the rubrics was an iterative process, working with both the groups of practitioners and the Research Thought Leaders to elicit feedback and make revisions to the final products. After simplifying the thinking skills from the list of 14 initially proposed by the Research Thought Leaders for the purposes of the rubric, the rubric was sent to the group for feedback. This group proposed changes to the wording and grouping of some of the items.

After these changes were made, the rubric was discussed by the group of expert teachers. These practitioners then discussed the practical applications of the rubrics to their classroom practices and their experiences with arts integration and development of skills among students. They emphasized the need for the inclusion of collaboration as an important skill that was developed through the process, for both teachers and students. They also had the opportunity to utilize the updated and revised rubrics in their classrooms to self-evaluate their own lessons and their students' products.

Interrater reliability

The expert teachers participating in the research project submitted photographs of student work and their lesson plans. They were asked to select 9 representative examples of the student work: 3 of exemplary work, 3 of typical work, and 3 of underdeveloped student work. They also submitted a copy of their lesson plan to accompany the work. For each of the examples of student work, they completed the Thinking Skills and Content Student Evaluation Rubrics. They also assessed their lesson plans using the Thinking Skills and Content Lesson Evaluation Rubrics.

A panel of seven experienced art teachers evaluated the student work and lesson plans separately. This panel of experienced teachers had not been a part of the Innovation Collaborative's previous work, but were selected for their experience as teachers in the field and were part of a school district partnership with the research team associated with a separate professional development opportunity. These scores were analyzed, and inter-rater reliability was calculated for each item on the rubric. Two-way mixed intraclass correlations of absolute agreement on the average measures were calculated to measure the inter-rater reliability (ICC[2,*k*]) of the seven expert teachers on the 4 rubrics (Koo & Li, 2016) for one lesson and 3 examples of student work. The expert teachers only reviewed a subset of the available data (lesson plans and student work) as their review was part of a district partnership agreement and limited by resources of time. The results of the interrater reliability analysis canbe found in Table 3.

Results

This process resulted in 4 rubrics: Content of Lesson, Content of Student Product, Thinking Skills of Lesson, and Thinking Skills of Student Product. (See Appendix A for full copies of each rubric.)

Final rubrics

Content rubrics

Two content rubrics were developed, one for the evaluation of lessons, and one for the evaluation of student products. Each of these rubrics had the same criteria with descriptors modified for each evaluation. The content rubrics consisted of three criteria with four levels; (see Appendix).

Thinking skills rubrics

Similarly, two thinking skills rubrics were developed for lessons and student products. Each of these rubrics had six matching criteria, with descriptors tailored to the context and four levels of performance; (see Appendix).

Quantitative results

Intraclass correlations were calculated to measure the inter-rater reliability of the expert teachers on each of the four rubrics. The two content rubrics had excellent inter-rater reliability (Lesson Content, 0.961; Student Work Content, 0.911; Koo & Li, 2016). The two thinking skills rubrics had moderate levels of inter-rater reliability (Lesson Thinking Skills, 0.699; Student Work Thinking Skills, 0.565; Koo & Li, 2016). As the rubrics have also been through content validation and inter-rater reliability, the rubrics have statistical evidence that they are performing well. The outside teachers' evaluation of the student products also matched the students' own teachers' evaluation of the student products, who grouped the students into "high," "average," and "low" categories. Thus, providing additional content validation support.

Discussion

Description of art integration rubrics

There are three criteria on the Content Rubrics with four levels of performance from "Beginning" to "Expert." Degree of Integration refers to the level of integration of the content areas, based upon the theoretical framework which delineates multi-, inter-, and transdisciplinary forms of integration (Frodeman et al., 2010). The examples were created by the research team as part of the content validation process. In addition, examples of each level of integration were provided in the student rubric. STEM Content and Arts or Humanities Content refers to the content knowledge and understanding that is presented by the lesson learning experience or demonstrated by the student. These criteria were developed in response to the emphasis on high-quality content knowledge in integrated lessons learning experiences.

Description of thinking skills rubrics

There are six criteria on the Thinking Skills Rubrics, with the same four levels of performance as the Content Rubrics.

Synthesis and transformation

This section describes skills related to creativity, innovation and imagination. Specifically, this criterion assesses the generation of unique and relevant ideas, including both useful and fanciful designs.

Generalizations and applications

This criterion evaluates the construct of making generalizations from data or information and/or then using those generalizations to apply to new situations. This criterion connects to the use of thinking skills to apply to various contexts in innovative ways.

Problem solving

This criterion connects to ideas about problem-solving and about students' use of given materials and guidelines to develop unique solutions. Although art projects are not typically conceptualized as problem solving tasks, many ask students to design resolutions to parameters given by the teacher or assignment.

Visual analysis

Visual analysis refers to the process of using visual processing to dissect and scrutinize images. This skill is becoming increasingly important in society, as literacy must also include the processing of graphics. In integrated learning experiences, students must process visual images and integrate them across content areas to develop unique products.

Persistence

In addition to creating unique solutions and generating ideas, successful projects must encourage students to persist. This includes overcoming challenges and developing solutions when problems are encountered.

Collaboration

Finally, the rubric assesses collaboration, a criterion that was identified in Phase I of the project. When integrating ideas across content areas, learning experiences that have opportunities for students to collaborate were rated highest.

Implications

This implications for this study are two-fold. Primarily, this research came from a need within a line of study investigating the effects of an arts integrated approach on the thinking skills of students. But through this research, the development of these tools could be useful to practitioners in the field and other researchers.

Future research

The development and reliability and validity evidence of these instruments provides avenues for future research. Specifically, future research will use the rubrics to investigate if there are correlations between lessons and student products that have high levels of arts integration and depth of content knowledge and those that demonstrate and elicit deep creative and critical thinking skills from students. In addition, future research should look for further validation that lessons that score highly on the rubrics for providing opportunities for demonstration of skills also result in student products that score highly on the other sets of rubrics.

Practical applications

Perhaps a larger implication for this current study is the application to classroom practice. The rubrics for assessing lesson plans for arts integration can be used for professional development for teachers to help inform classroom practice around these ideas. Similarly, the rubrics assessing lessons capacity for eliciting thinking skills can be used by teachers as a self-reflective tool to improve classroom practice.

The rubrics to assess the student products could also be used by teachers. Practitioners in the field can use these as assessment tools for evaluation of student work and to gauge the effectiveness of their lessons and classroom practice. Teachers can also use them as formative assessment in lessons to help students become more reflective about their own work, including evidence of thinking and integration of the arts. With the input from teachers, practitioners, as well as content experts, these rubrics were designed to be used by teachers in classroom contexts.

Future directions for the Innovation Collaborative in particular are to implement and develop product guides and materials to support the rubrics for teachers and practitioners, along with accessible professional development materials. Future research opportunities also include the effectiveness of these professional learning experiences in the use of rubrics and the classroom experiences of students in the development of critical and creative thinking.

Limitations

While these rubrics have been through a rigorous development process including content validation and preliminary inter-rater reliability, the rubrics will benefit from greater validation in more diverse contexts. Primarily, with a more robust inter-rater reliability analysis including a larger sample of teacher lesson plans and student products, correlations between high-quality lesson plans and high-quality student products could be drawn. Additionally, with more diverse samples and products, analyses could include testing the hypothesis that products and lessons that have greater levels of arts integration elicit greater levels of thinking skills and creativity. Further research should also be developed around how different populations of practitioners and researchers use and interpret the criteria on the rubrics.

Final thoughts

In order to more fully study and reflect on the creative behaviors of students through their projects and the lessons that are taught by teachers, a set of rubrics were developed. These rubrics were shown to have inter-rater reliability when used to assess K-12 student products by expert art teachers. By considering both the lesson as a context and the student product, this fits with the framework set forth by Renzulli (2016) in that creative behaviors can be facilitated by teachers and these rubrics have the potential to provide insights into creativity. Given the practical applications of these assessment tools, they can be used by researchers and teachers alike.

Disclosure statement

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Notes on contributors

Hope E. Wilson is an associate professor of education at the University of North Florida where she teaches graduate and undergraduate courses in assessment, educational psychology, and statistics. She graduated with a PhD in Gifted Education from the University of Connecticut. Her research focusing on early childhood giftedness has been published in Gifted Child Quarterly, Journal of Advanced Academics, Journal for the Education of the Gifted, and Roeper Review, and she is the co-author along with Jill Adelson of the book Letting Go of Perfect: Overcoming Perfectionism in Kids (Prufrock Press, 2009). She was the 2017 Early Leader Award recipient for the National Association for Gifted Children. She is an associate editor for the Journal of Advanced Academics, and chair of the Research and Evaluation Network for the National Association for Gifted Children. She is a founding board member of the Innovation Collaborative, a non-profit organization working at the intersections of the Arts, Sciences, and Humanities.

Lucinda Presley has worked at the STEAM intersections for over 25 years. She is Chair and Executive Director of the Washington, DC-based Innovation Collaborative, a coalition of national arts, STEM, humanities and higher education institutions that is researching STEAM effective practices. As Executive Director of ICEE Success Foundation, she also works with partners in Texas, nationally and internationally, developing K-12 programming, writing curriculum, and training teachers. She also has led STEAM education initiatives and teacher/artist training for a science museum, an art museum, and a national art provider. She holds a Master of Arts degree in Interdisciplinary Studies.

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Appendix A. Rubrics

Content Rubric: Lesson Evaluation

	Beginning	Developing	Refining	Expert
Degree of Integration	**Single Disciplinary**: Lesson provides opportunities for students to work on individual disciplines which are combined at the end on a superficial level.	**Multidisciplinary**: Lesson provides opportunities for students to plan toward a common goal but work on different disciplines separately, combining them at the end to enhance each discipline. Each discipline could have been addressed separately without impacting the other discipline	**Interdisciplinary**: Lesson provides opportunities for integration throughout, but is structured so that students work within separate disciplines. Students plan on the integration throughout, but work within separate disciplines. They could be successful in one discipline and not the other. However, when combined, the disciplines enhance each other, but are not dependent on each other for success.	**Transdisciplinary**: Lesson requires students to work on disciplines interdependently, seeing that one discipline can*not* complete the task without the other. The lesson helps the students understand that the disciplines rely on each other to contribute to a meaningful understanding of the other in order to address their problem.
STEM Content	STEM content addressed is nominal and/or not connected to standards.	STEM content addressed is connected to the standards, but offers few opportunities to demonstrate understanding.	STEM content addressed is meaningfully connected to the standards, with opportunities to demonstrate understanding.	STEM content addressed provides rich opportunities for deep, meaningful, and innovative understanding of the content. That understanding can exceed grade level.
Arts or Humanities Content (Assessing the predominant discipline)	Arts or humanities content addressed is nominal and/or not connected to standards.	Arts or humanities content addressed is connected to the standards, but offers few opportunities to demonstrate understanding.	Arts or humanities content addressed is meaningfully connected to the standards, with opportunities to demonstrate understanding.	Arts or humanities content addressed provides rich opportunities for deep, meaningful, and innovative understanding of the content. That understanding can exceed grade level.

Content Rubric: Student Evaluation

	Beginning	Developing	Refining	Expert
Degree of Integration	**Single Disciplinary**: Students work on individual disciplines separately. The disciplines they could be combined at the end on a superficial level. *(Decorating a car that they created in science class.)*	**Multidisciplinary**: Students work on different disciplines separately and combine them at the end to enhance each discipline. The integration is not done throughout the process. Each discipline could have been addressed separately without impacting the other discipline. *(Students create and decorate a car in separate science and art classes and combine their products at the end.)*	**Interdisciplinary**: Students plan on the integration throughout, but work within separate disciplines. They could be successful in one discipline and not the other. However, when combined, the disciplines enhance each other, but are not dependent on each other for success. *(Students plan in both art and science how to create an art/science car at the end. However, they work separately in each discipline toward the art/science goal.)*	**Transdisciplinary**: Students work on disciplines interdependently, seeing that one discipline can*not* complete the task without the other. The students demonstrate comprehension that the disciplines rely on each other to contribute to a meaningful understanding of the other in order to address their problem. *(Students create an art/science car where art thinking and concepts inform the scientific/engineering aspects of the car and the scientific/engineering aspects of the car inform the esthetic choices. Neither could succeed without the input of the other. This is all framed around solving a given problem.)*
STEM Content	Student demonstrates limited understanding of STEM content knowledge.	Student demonstrates some understanding of STEM content knowledge.	Student demonstrates comprehensive grade level understanding of STEM content knowledge.	Student demonstrates deep, meaningful, and innovative understanding of STEM content knowledge that can exceed the grade level.
Arts or Humanities Content (Assessing the predominant discipline)	Student demonstrates limited understanding of Arts or Humanities content knowledge.	Student demonstrates some understanding of Arts and Humanities content knowledge.	Student demonstrates comprehensive grade level understanding of Arts or Humanities content knowledge.	Student demonstrates deep understanding of Art and Humanities content knowledge, which can exceed the grade level.

Thinking Skills Rubric: Lesson Evaluation

	Not Addressed	Developing	Refining	Expert
Synthesis and Transformation Fluency Originality Relevancy Imaginative/ Fanciful/Unique Transforming Synthesis Bisociation	Lesson does not provide opportunities for students to generate unique or relevant ideas.	Lesson provides minimal opportunities for students to develop original, unique, relevant, and/or imaginative ideas.	Lesson provides opportunities for students to develop original, unique, relevant, and/or imaginative ideas.	Lesson provides many opportunities for students to develop many original, unique, relevant, and/or imaginative ideas that can include ideas that have been transformed and/or synthesized. The combination of these ideas innovatively solved the problem
Generalizations and Applications Ability to take information and make generalizations and take these generalizations and apply them to situations.	Lesson does not provide opportunities for students to make generalizations. Nor does it allow for applications of generalizations to situations such as problem-solving and innovation.	Lesson provides minimal opportunities for students to make generalizations. It provides minimal opportunities for applications of generalizations to situations such as problem-solving and innovation.	Lesson provides opportunities for students to make generalizations. It provides opportunities for applications of generalizations to situations such as problem-solving and innovation.	Lesson provides valuable opportunities for students to make generalizations. It provides valuable opportunities for applications of generalizations to situations such as problem-solving and innovation.
Problem Solving Asks Questions Defines Problem Acquires, Analyzes and Selects Information Generates and Manages Ideas Develops and Evaluates Solution Generates Multiple Solutions Synthesizes in a Manner that Addresses and/or Solves the Problem	Lesson does not provide opportunities for students to engage in problem solving (e.g., the solution is presented to students).	Lesson provides minimal opportunities for students to develop solutions to problems presented.	Lesson provides opportunities for students to develop solutions to problems presented.	Lesson provides deep opportunities for students to ask thoughtful questions, to use appropriate information in an innovative way, to clarify problems, and to develop unique and innovative solutions that can involve synthesis.
Visual Analysis	Lesson does not provide opportunities for students to use visual analysis.	Lesson provides minimal opportunities for students to use visual analysis.	Lesson provides opportunities for students to use visual analysis.	Lesson provides deep opportunities for students to use meaningful visual analysis to innovatively address the problem.
Persistence	Lesson does not provide opportunities for students to demonstrate persistence.	Lesson provides minimal opportunities for students to demonstrate persistence.	Lesson provides opportunities for students to demonstrate persistence.	Lesson provides deep opportunities for students to demonstrate ongoing persistence.
Collaboration	Lesson does not provide opportunities for students to collaborate.	Lesson provides minimal opportunities for students to collaborate.	Lesson provides opportunities for students to collaborate.	Lesson provides deep opportunities for students to collaborate in a meaningful and innovative manner.

Thinking Skills Rubric: Student Evaluation

	Not Addressed	Developing	Refining	Expert
Synthesis and Transformation Fluency Originality Relevancy Imaginative/Fanciful/ Unique Transforming Synthesis Bisociation	Student did not generate unique or relevant ideas.	Ideas developed by student were minimally original.	Student developed ideas that were original, unique, relevant, and/or imaginative.	Student developed many ideas that were original, unique, relevant, and/or imaginative that could have included transformation and synthesis. The combination of these ideas innovatively solved the problem
Generalizations and Applications Ability to take information and make generalizations and take these generalizations and apply them to situations.	Student does not make generalizations. Nor does the student make applications of generalizations to situations such as problem-solving and innovation.	Student makes minimal generalizations to situations such as problem-solving and innovation.	Student makes applications of generalizations to situations such as problem-solving and innovation.	Student makes deep and meaningful generalizations to applications, such as problem-solving and innovation.
Problem Solving Asks Questions Defines Problem Acquires, Analyzes and Selects Information Generates and Manages Ideas Develops and Evaluates Solution Generates Multiple Solutions Synthesizes in a Manner that Addresses and/or Solves the Problem	Student did not propose a solution to the problem.	Student developed a minimal solution to the problem.	Student developed a solution that was original, unique, and/or imaginative.	Student developed a solution that was original, unique, relevant, and/or imaginative that could have included transformation and synthesis. The combination of these ideas and approaches were what led to the problem's solution.
Visual Analysis	Student did not engage in visual analysis.	Student engaged in minimal visual analysis.	Student engaged in visual analysis.	Student engaged in meaningful visual analysis to innovatively address the problem.
Persistence	Student did not persist throughout the project.	Student persisted minimally.	Student persisted.	Student demonstrated ongoing, task-oriented persistence.
Collaboration	Student did not collaborate.	Students worked independently, but put their work together at the end.	Students collaborated most of the time.	Students collaborated in meaningful and innovative ways throughout the project. Their collaboration their problem.