Contemporary Educational Psychology 60 (2020) 101840

Contents lists available at ScienceDirect

Contemporary Educational Psychology

journal homepage: www.elsevier.com/locate/cedpsych

How problem identification strategies influence creativity outcomes

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ARTICLE INFO

Keywords:
Creative problem solving
Self-regulated learning
Problem identification
Microanalysis
Creativity
Problem finding
Strategic planning

ABSTRACT

The purpose of this study was to explore the effects of students' strategic approaches to problem identification on their ability to identify problems, solve problems, and develop divergent ideas. Eighth and ninth grade students (N = 90) completed the Torrance Tests of Creative Thinking-Figural (TTCT-F), as a measure of divergent thinking. Then, students responded to semi-structured interview prompts while completing a creative problem-solving task (i.e., Creative Problem Solving-Microanalysis Interview Protocol; CPS-MIP). Problem identification strategies were significantly, positively related to (a) problem identification fluency, (b) problem-solving fluency, (c) TTCT-F Elaboration subscale performance, and (d) TTCT-F average standard score; however, the most adaptive strategic approach differed based on outcome measure. Collectively, this study demonstrates the importance of specific problem identification strategies in generating ideas to solve problems.

1. Introduction

Creative problem solving (CPS) promotes both personal and societal success in an increasingly complex world. Seminal studies have demonstrated individuals' most fulfilling moments occur during creative pursuits (Csikszentmihalyi, 1990); further, creativity has been shown to enhance knowledge retention, achievement, development of innovative solutions, and self-efficacy (Beghetto & Plucker, 2006; Gajda, Karwowski, & Beghetto, 2017; Rasulzada & Dackert, 2009; Sebastian & Huang, 2016). Beyond personal benefits, industry and academic institutions value employees who design novel solutions and approaches to nuanced issues (Osmani, Weerakkody, & Hindi, 2017; US Department of Education, 2017; World Economic Forum, 2016). Given the importance of creativity, both education and industry leaders have called for schools to prioritize developing creative thinking skills (Hall, 2010; IBM, 2010; Wyse & Ferrari, 2015).

2. Examining the creative process

To facilitate this development, creativity itself must be clearly defined, dissected into teachable strategies, and assessed. Historically, the study of creativity has been criticized for the lack of a unified definition (Plucker, Beghetto, & Dow, 2004). However, as the field matured, significant agreement exists over several key components (Batey, 2012). Broadly, creativity occurs when an individual (or group) engages in the creative process to generate a product that is both useful and novel within an environmental context (Plucker et al., 2004). In other words, creativity includes the person, process, product, and environment (Rhodes, 1961). The current work is guided by this seminal definition, as we assess individuals' processes leading to creative outcomes within a social context.

The creative process is not a singular construct, but rather it is composed of multiple stages/processes, working in concert (Sawyer, 2012). The creative process has also been described as creative problem solving (CPS; Sawyer, 2012). Specifically, CPS is a subset of general problem solving, and it emphasizes the ill-defined nature of problems requiring novel and useful solutions (Isaksen, Dorval, & Treffinger, 2000). The conceptual development of CPS models demonstrates an iterative process, beginning with Wallas (1926) and then Osborn (1953). While multiple, contemporary authors have proposed different terminology and structures to describe these processes, significant consensus has emerged, as different models have been mapped onto each other (e.g., Abdulla & Cramond, 2018; Sawyer, 2012).

Generally, most CPS models include two stages: problem identification and problem solving. Problem identification is the process of recognizing and conceptualizing an issue from multiple angles, considering opportunities that may arise from these different conceptualizations, and analyzing the root of the issue before engaging in problem solving (Abdulla, Paek, Cramond, & Runco, 2018). Multiple terms have been used to describe problem identification, including

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https://doi.org/10.1016/j.cedpsych.2020.101840

Available online 20 January 2020

"*problem finding*" and "*problem construction*" (Abdulla et al., 2018). Further, different subprocesses have been proposed, including posing questions (Burnard, Craft, & Grainger, 2006), redefining problems (Sternberg, 2006), and framing problems/exploring data/constructing opportunities (Isaksen et al., 2000). Following problem identification, individuals engage in the development of solutions, which may include idea generation (Sawyer, 2012), conceptual combination (Mumford, Reiter-Palmon, & Redmond, 1994), idea evaluation (Mumford et al., 1994), and prototyping/testing (d.School, 2010).

Throughout CPS, individuals engage in two types of thinking: divergent and convergent thinking (i.e., dual process approach: Finke, Ward, & Smith, 1992; Fürst, Ghisletta, & Lubart, 2017). Divergent thinking is a cognitive process that leads to multiple, different responses to an open-ended problem (Guilford, 1968). Whereas, convergent thinking is the cognitive process that includes the evaluation and selection of ideas, often resulting in an idea or product (Guilford, 1968). Both divergent and convergent thinking are used throughout CPS (Sawyer, 2012). For example, within problem identification, many problems could be considered (divergent thinking) and then narrowed to isolate the primary problem to address (convergent thinking).

3. Exploring problem identification

Problem identification is an important process to study for multiple reasons. As the first step in the CPS process, problem finding is essential because if the problem is not appropriately identified, the solution may be irrelevant (Abdulla et al., 2018). Beyond theoretical importance, empirical evidence demonstrates significant relationships between problem identification and creative outcomes. Csikszentmihalyi and Getzels (1988) seminal work found art students who spent more time exploring materials before developing their final product, not only produced more innovative works but also experienced greater future success as artists. This initial research provided a foundation for more than 40 future empirical studies examining these relationships. Arreola and Reiter-Palmon (2016) recently demonstrated the quality and originality of problem restatements (problem identification) directly related to the creativity of the proposed solution. Further, a meta-analysis found a significant mean correlation between problem finding and creative outcomes (r = 0.22; Abdulla et al., 2018). Yet, this correlation may not illustrate the full complexity of this relationship, as these studies employed a variety of measurement techniques, spanned multiple domains, and examined different populations.

Within the last 20 years, to our knowledge, seven studies examined problem finding and creativity in students in first through twelfth grade. These studies examined problem finding in different domains, including art (Rostan, 2005, 2010), reading (Kousoulas & Mega, 2009), science (Lee & Cho, 2007), picture analogies (Jaarsveld, Lachmann, & van Leeuwen, 2012), music (Barbot & Lubart, 2012), and math (Limin, Van Dooren, & Vershaffel, 2013). They used various measures for problem finding, such as participants' (a) time/involvement in exploring objects before task engagement (Rostan, 2010), (b) ability to list problems associated with a topic or environment (Lee & Cho, 2007), and (c) ability to develop questions or hypotheses (Kousoulas & Mega, 2009). The diversity of approaches makes it challenging to synthesize; however the work demonstrated students' problem finding was related to a variety of outcomes, including problem solving test performance (r = 0.53; Limin et al., 2013), standardized mathematics achievement test performance (r = 0.49; Limin et al., 2013), and divergent thinking (r = 0.15; Jaarsveld et al., 2012).

Beyond being significantly correlated with creativity and various problem solving outcomes, problem finding provides a unique opportunity for intervention. Studies implementing problem-finding interventions demonstrated larger effect sizes than interventions emphasizing other creative thinking techniques (see Scott, Leritz, & Mumford, 2004 for one of the most recent meta-analyses). Specifically, interventions targeting problem identification skills positively related to divergent thinking (r = 0.12), problem solving (r = 0.55), and performance (r = 0.43; Scott et al., 2004). Several recent studies piloted interventions, demonstrating students can improve their ability to identify problems (Jia et al., 2017), and further, interventions emphasizing problem finding lead to improved creative outcomes (Batič, 2014; Love & Barrett, 2016).

Collectively, these studies provide support for the importance of problem finding; however, little is known about strategic approaches supporting problem identification. Other educational disciplines have emphasized the importance of understanding individuals' strategic processes behind specific outcomes. For example, to assess students' mathematics ability, teachers often request students to show their work. Then, teachers evaluate not only the outcome (problem answer/solution), but also the students' process in developing the solution and specific strategies employed (e.g., drawing a table, using estimation techniques, or testing different numbers). While the solution is important, assessing students' mathematical processes offer significant insight to guide subsequent instruction. Further, deliberately teaching math problem-solving strategies leads to improved academic outcomes (Montague, Krawec, Enders, & Dietz, 2014). Similarly, the field of creativity could benefit from assessing strategic approaches to CPS, as this represents a teachable opportunity.

To facilitate and assess students' strategic approach, these strategies need to be identified. Recently, the authors proposed an initial model, Facilitating Problem Finding Model, to organize problem identification strategies (Rubenstein, Callan, Speirs Neumeister, & Ridgley, 2020). This model was developed using a deductive and inductive analysis of students' strategic approaches to problem identification. For the deductive analysis, the Problem Construction Model (Mumford et al., 1994) was used to build the coding scheme. From that analysis, several gaps emerged. First, the Problem Construction Model codes did not sufficiently represent the social aspect of problem identification. Second, the model's complexity made it challenging for all ten specified processes to be reliably distinguished from one another. Therefore, some constructs were combined and eliminated. Finally, the model's terminology may be challenging to use as a practitioner model for supporting teachers' efforts to facilitate student growth. Therefore, an inductive analysis was also completed, and then mapped onto the primary concepts represented in the Problem Construction Model. Specifically, four categories of strategic approaches were proposed, including Resource Management, Elaboration, Analysis, and Manipulation. Each discussed below with their theoretical underpinnings.

3.1. Resource management

Resource management includes strategies students employ to maintain attention and regulate their cognitive resources, such as personal reminders to pay attention or recording information to reduce cognitive load. These strategies support the attention, perception, and memory components within the Problem Construction Model (Mumford et al., 1994). Further, they are represented in more general educational psychology literature within information processing models (Wolters, 1998).

3.2. Elaboration

Elaboration includes strategies that promote the connection of information to existing experiences, research, and external circumstances. Further, it includes any additional effort to elaborate upon the issue, like interviewing those involved and seeking external guidance. In other words, elaboration strategies link the current situation to previous experiences, gathering additional information from stakeholders, or asking for help from experts. Within the Problem Construction Model (Mumford et al., 1994), elaboration strategies are most closely represented by activating problem representations, described as "a representation is activated it if has been associated with these cues in the past" (p. 13). This, however, doesn't fully capture the active gathering of information and help-seeking. Social learning theories may also anchor this set of strategies, as it embodies the importance of social interaction and learning (Bandura, 1986).

3.3. Analysis

Analysis strategies promote the dissection of key components of the issue. For example, they include determining: (a) how a specific situation varies from the ideal, (b) primary causes leading to a current situation, and (c) key components/factors of the situation. The Problem Construction Model represents analysis strategies as representational screening (e.g., considering constraints) or element selection (i.e., which elements to emphasize). Self-regulated learning also represents this construct as individuals plan to employ certain strategies based on a task analysis (Pintrich, 2000; Zimmerman, 2000).

3.4. Manipulation

Finally, the most complex series of strategies are manipulation strategies. When individuals employ these strategies, they actively alter, combine, and refine information to create new representations or perspectives. For example, individuals may envision the situation in a new location or change the vocabulary used to describe the situation. Manipulation connects to with the Problem Construction Model's reorganization of elements. From a broader perspective, manipulation strategies embody generative learning or constructivist approaches in which individuals engage and alter the information to make sense of the situation. Similar strategies have been described in mathematics when students create analogous problems with simplified parameters (Callan & Cleary, 2018).

These four strategies represent the culmination of deductive and inductive explorations. Further, they can be analyzed using a levels-of-processing framework (for reviews and different models, see Dinsmore & Alexander, 2012; Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013; Fiorella & Mayer, 2016). To broadly generalize, lower level/surface processing strategies include initial apprehension or deciphering; whereas, higher level/deeper processing strategies include personalization or transformation. Therefore, Resource Management would represent a lower level of processing, and Elaboration, Analysis, and Manipulation would represent higher levels of processing. To further explore these strategic approaches to problem identification, we must first carefully consider how to accurately measure these constructs.

4. Assessing creative problem solving

Within the current work, we examined how these problem identification strategic approaches (i.e., Resource Management, Elaboration, Analysis, and Manipulation) may relate to specific creativity outcomes. To accomplish this objective, we considered how to measure both creative outcomes and strategic approaches.

4.1. Assessing creative outcomes

To determine the efficacy of specific problem identification strategies, specific creative outcomes must be assessed, which has proven to be a complex issue with many possibilities. A full exploration of these assessment options is beyond the scope of this paper (see Kaufman, Plucker, & Baer, 2008; Batey, 2012 for more extensive reviews). Within this paper, we measure multiple types of outcomes to provide a rich picture of how problem identification strategies may influence proximal (i.e., problem identification outcomes) and distal (i.e., problem solving) outcomes in CPS. Both proximal and distal outcomes are connected within a contextualized outcome. Contextualized outcomes are those that occur within a social context, aligning with Plucker et al. (2004) definition of creativity that specifies: "within a social context". Several research teams have used contextualized tasks to study CPS, including tasks in which participants assumed various roles: (a) a principal who wanted to increase academic achievement or (b) a director of marketing who wanted to increase sales of a new beverage (Medeiros, Partlow, & Mumford, 2014; Watts, Steele, & Song, 2017). Solutions were assessed based on quality, originality, and elegance; most of these studies were completed with college students.

Conversely, a more popular measure of creative outcomes provides decontextualized tasks (Thys, Sabbe, & De Hert, 2014). These types of assessments ask participants to generate as many possible solutions to a prompt, like list all the alternate uses for a brick, without describing the details surrounding the context in which the bricks exist (Alternative Uses Tasks; Guilford, 1968). One other common example of this type of assessment is the Torrance Tests of Creative Thinking-Figural (TTCT-F; Torrance, 1966, 2008), which asks students to modify shapes into pictures and stories. Responses on these types of assessments are often evaluated based on (a) fluency: the number of ideas generated; (b) flexibility: the number of different types or categories of ideas; (c) originality: the uniqueness of the responses; (d) elaboration: the extension of ideas through additional details.

4.2. Assessment of strategies

Regarding the assessment of problem identification strategies, there are currently few measurement options designed to measure individuals' strategic approaches within CPS. Often, current measurement tools examine individuals' global approaches to CPS. For example, an existing teacher rating scale (e.g., Scales for Identifying Gifted Students; SIGS; Ryser & McConnell, 2004) includes one item asking teachers to reflect upon students' ability to find problems in comparison to their peers. Further, most self-report measures do not include any items specific to problem identification, but rather, they emphasize general processes supporting CPS, which students may or may not employ within problem identification (e.g., brainstorming, anagogical thinking: Cognitive Processes Associated with Creativity scale; CPAC; Miller, 2014). Additionally, other methods have been used to explore CPS in general, but again, these have not been used to explore problem identification. Specifically, other researchers have used observations (Getzels & Csikszentmihalyi, 1975; Jang & Ko, 2017), strategy checklists (Osburn & Mumford, 2006) or think-aloud protocols (Gilhooly, Fioratou, Anthony, & Wynn, 2007).

Each of these approaches makes unique contributions. Scales and instruments provide a broad overview, demonstrate adequate psychometric properties, and are easily administered; however, they are not connected to identifiable tasks and may not accurately capture what individuals' cognitions and behaviors as they work through the task. Self-report and strategy checklists may be greatly biased as they represent retrospective reflections. For example, Young and Worrell (2018) found that a more global self-report scale, the Metacognitive Awareness Inventory (MAI), was not aligned with students' actual metacognitive behavior. In contrast, observations and think-aloud protocols allow participants to engage with a specific task. However, they rely upon participants' spontaneous actions or vocalization of internal processes, and participants may not explicitly verbalize their strategies or level of self-efficacy while solving a problem. Therefore, the current study applied a semi-structured interview protocol, called self-regulated learning (SRL) microanalysis, to examine how students engage in problem identification within CPS tasks. This approach targets specific processes (e.g., planning) at certain time points while students engage in tasks (Cleary, Callan, & Zimmerman, 2012; Rubenstein, Callan, & Ridgley, 2018).

SRL microanalysis interviews have been used to study a variety of tasks, including mathematical problem solving (Callan & Cleary, 2018, 2019), athletic skills (Cleary & Zimmerman, 2001; Kitsantas & Zimmerman, 2002), medical procedures (Cleary & Sandars, 2011), and creative problem solving (Callan, Rubenstein, Ridgley, & McCall, 2019, Rubenstein, Callan, Ridgley, & Henderson, 2019). Within creative problem-solving contexts, studies found the general importance of strategic planning (Callan et al., 2019) and the importance of specific strategies (e.g., perspective taking) in supporting creative problem solving outcomes (Rubenstein et al., 2019).

5. Study purpose

The goal of the current study is to explore relationships between strategic approaches to problem identification and creative outcomes. We used an SRL microanalysis protocol to study eighth and ninth graders strategic approaches to problem identification, and examined how those approaches facilitated creative outcomes. Specifically, we included two types of outcomes including a contextualized task and a more commonly used, decontextualized measure of divergent thinking (Torrance Tests of Creative Thinking-Figural; TTCT-F). Within the contextualized task, we assessed a proximal outcome associated with problem identification (i.e., exploring potential problems) and four distal outcomes associated with problem solving (i.e., developing potential solutions). Within the decontextualized measure, we assessed outcomes associated with divergent thinking (e.g., fluency, originality, and elaboration). This study seeks to answer three primary research questions:

RQ1: To what extent are students' specific problem-identification strategies related to or predictive of contextualized, *problem-identification* fluency?
RQ2: To what extent are students' specific problem-identification strategies related to or predictive of contextualized, *problem-solving* fluency, flexibility, originality, and usefulness?
RQ3: To what extent do students' specific problem identification strategies support their performance on decontextualized divergent thinking tasks, specifically the Torrance Tests of Creative Thinking-Figural (TTCT-F; including the average scaled scores and specific subscale scores of fluency, originality, elaboration, abstractness of titles, and resistance to closure)?

6. Method

6.1. Participants

An a priori power analysis indicated that a sample size of 85 participants would be adequate to detect moderate effects [power specified to 0.80, $\alpha = 0.05$, and 4 predictors (i.e., four specific strategic approaches) included; Faul, Erdfelder, Lang, & Buchner, 2007]. Previous work exploring the effectiveness of problem identification on various creative outcomes showed overall moderate effects (Scott et al., 2004). Thus, the current study aimed to recruit at least 85 students to participate. With 90 participants, we proceeded with the study.

The 90 eighth and ninth graders ($M_{age} = 13.81$ years; SD = 0.80) were from two schools located in the Midwestern, United States. Both schools had similar demographic characteristics (socioeconomic status and ethnicity) and were high performing on state assessments. No school differences existed on any variables, including (a) problem identification and solving outcomes, as measured by the Creative Problem Solving Microanalysis Interview Protocol (CPS-MIP), $F(3, 86) = 0.94, p = 0.426$, (b) CPS-MIP problem identification strategies, $F(4, 85) = 1.13, p = 0.349$, or (c) Torrance Test of Creative Thinking-Figural (TTCT-F) outcomes, $F(2, 93) = 0.95, p = 0.389$. Although both schools received professional development throughout the year as a participation incentive, data for this manuscript was collected prior to professional development.

All eighth and ninth grade students were invited to participate, and approximately 78% did so. The students were not compensated and could discontinue participation at any point. Within the sample, 42 students identified as female (46.67%), 79 identified as Caucasian (87.78%), and 15 were eligible for the National School Lunch Program (16.67%).

6.2. Procedure

The current manuscript is a part of a larger project examining how creativity is perceived, assessed, and developed within elementary, middle, and high school students. The primary objective of this manuscript is to examine relationships among problem identification strategies and creativity outcomes, so only data related to that objective was used. Given the resource intensive nature of individual interviews, interviews were only conducted with eighth and ninth grade participants.

The Institutional Review Board approved all study procedures. In the beginning of the school year (August), all parents were notified of the study using a variety of methods: a booth at school registration day (School 1), information in an emailed school newsletter (School 2), and physical correspondence sent home with students (Schools 1 and 2). Researchers were available to answer questions at the school registration day (School 1) and designed an online video outlining the study (School 2). If parents consented, they signed: (a) a consent form to grant permission for students to participate and (b) a media release to allow the interviews to be tape-recorded but not disseminated beyond the research team.

After parents provided consent, data collection began. Data collection occurred during two sessions (Session 1 and Session 2) in September and October (beginning of the school year), and all data collection occurred at students' schools, during the school day, in quiet classrooms specifically reserved for data collection. Session 1 was completed in a group format. During this time, students were provided an opportunity to assent to participation. Three students opted out at that time. Then, research assistants administered the Torrance Tests of Creative Thinking-Figural (TTCT-F) using an administration protocol, lasting approximately 40 min.

Within two weeks of Session 1, students participated in Session 2, which included an individualized interview using the Creative Problem Solving-Microanalysis Interview Protocol (CPS-MIP). Interviewers received training in administering the CPS-MIP during two sessions, and each interviewer was required to reach 100% accuracy in procedures. Participants met individually with an interviewer for approximately 30 min. Students could choose to postpone the interview if it interfered with a preferred or essential class activity. All interviews were completed in empty classrooms. Interviews were audio-recorded and transcribed.

6.3. Measures

6.3.1. Creative problem solving-microanalysis interview protocol (CPS-MIP)

The CPS-MIP is a structured interview protocol examining how students approach CPS tasks. This protocol is an adaptation from previous research targeting specific self-regulated learning (SRL) processes in real-time around specific tasks, like math problem solving (Callan & Cleary, 2018) and creative problem solving (Callan et al., 2019). The protocols' general format includes an introductory task to orient students. Then, students are asked to imagine a similar, yet unique task. They respond to questions about their motivation and strategic plans regarding the prospective task. Then, they are provided the details of the next task, provide their responses, and then discuss their processes. Finally, participants evaluate their own performance. The initial pilot study using the full protocol has been described in depth in previous publications (Rubenstein et al., 2018, 2019a).

This current study examined an introductory task that required students to engage in both problem identification and solving. Specifically, students were asked to help a park ranger who wanted to

Table 1
Analyzed* questions from the creative problem solving-microanalysis interview protocol.

Interview component	Analyzed questions	Strategic approaches and creativity outcomes coded* from responses
Problem Finding	"A park ranger wants to help people see their park's most beautiful view, but it requires a LONG hike through the woods. Many people turn around at the half-way point and walk back to the start, without seeing the beautiful view. The trail will be closed unless more people get to the view. Why do you think people give up?"	**Problem Identification Fluency:** Number of problems identified
Problem Solving: Generation	"The park ranger explains that most people bring a backpack with food and water, and the backpack gets too heavy to carry any farther. That is why people turn around. What could the park ranger do to help more people get to the view at the end of the trail?"	**Problem Solving Fluency:** Number of solutions identified **Problem Solving Flexibility:** Number of different types of solutions identified
Problem Solving: Selection	"The park ranger wants to use one of your ideas. Which one idea would the park ranger like best?"	**Problem Solving Originality**: Uniqueness of selected solution compared to full sample. **Problem Solving Usefulness:** How useful the selected solution is for the stakeholder
Strategic Planning for Problem Identification	"Now, I am going to ask you to think about another story. It will not be the same story. It will NOT have anything to do with the people walking on a trail…before I tell you the story, what can you do to help you identify the problem?"	**Problem Identification Strategy Coding**: Quantity and types of strategies used

* Two coders coded 20% of the data to determine inter-rater reliability, which is reported in Table 5.

increase the number of park visitors to experience an amazing view in the park. Students generated potential reasons why park visitors were not reaching the view (problem identification). Next the researchers narrowed all participants' focus to a standardized problem (i.e., park visitors' backpacks are too heavy) and asked participants to provide specific solutions to increase the number of visitors who reach the view (problem solving). Following the task, students considered what they would do to help them identify problems in the future.

Although other research using the CPS-MIP protocol has included other measures, these measures are administered following the procedures described and were not analyzed in the current study. See Table 1 for specific questions and coded outcomes analyzed in the current study.

6.3.1.1. Coding CPS-MIP. Coding methods replicated previous work (Authors, 2019). Six variables were coded from the individual interviews, including (a) one problem identification outcome (i.e., fluency), (b) four problem-solving outcomes (i.e., fluency, flexibility, originality, and usefulness), and (c) four problem identification strategic approaches (i.e., Resource Management, Elaboration, Analysis, and Manipulation). For a general overview of the coding scheme, see Table 2, and for specific applications, see the following descriptions.

6.3.1.1.1. Problem identification fluency. Problem identification fluency is the number of unique, relevant, identified problems. Ideas were not required to be practical, but they had to be relevant to the task. Problem identification fluency was coded using students' responses to the park ranger task, which asked participants to think of all the reasons why the event may be occurring. For an example of the coding scheme application, the following response scored a 3: "They [the park visitors] get tired [Idea 1 – problem is general fatigue], or most people are with a family, so the younger ones are less able and not as strong and don't have to the stamina so they probably had to go back for not only themselves but their kids [Idea 2 – problem is kid fatigue] so just being tired and worn out at the halfway point [Repeat of Idea 1], or dehydration [Idea 3 – problem is lack of water]."

6.3.1.1.2. Problem-solving fluency. Problem-solving fluency is the number of unique, relevant, proposed solutions. Students were told park visitors did not finish the trail because their backpacks were too heavy because of how much food and water they packed. Then, students were asked to describe possible solutions to address that specific problem. Responses were counted. For example, the following response scored a 4. "Instead of people bringing their own food and water, he [the ranger] could have little stops where you could buy something along the trail, have a guy with a cooler or something sell you a bottle of water for fifty cents [Idea 1 – solution is to provide water] or something and same thing with the food. If you were to get tired sometimes a power snack like a granola bar can power you up and get you going to want to get to the scene [Idea 2 – solution is to provide food]. This might be unrealistic but … a zip line [Idea 3 – solution is to provide transportation using a zip line] or a golf cart [Idea 4 - solution is to provide transportation using a golf cart]."

6.3.1.1.3. Problem-solving flexibility. Problem-solving flexibility is the number of different types/categories represented in students' proposed solutions. The categories were based on different approaches indicated in the data set. For example, the following response scored a two in flexibility, even though it scored a four in fluency: "Instead of people bringing their own food and water, he [the ranger] could have little stops where you could buy something along the trail, have a guy with a cooler or something sell you a bottle of water for fifty cents [Idea Type 1: providing supplies] or something and same thing with the food [Repeat of Idea Type 1: providing supplies]. 'Cause I feel like sometimes if you were to get tired sometimes a power snack like a granola bar can power you up and get you going to want to get to the scene. (P) This might be unrealistic but … a zip line [Idea Type 2 –transportation] or a golf cart [Repeat of Idea Type 2: transportation]."

6.3.1.1.4. Problem-solving originality. Problem-solving originality is the uniqueness of participant's self-selected best idea in comparison to all other participants' generated responses. This was coded from students' self-selected responses to which of their ideas the park ranger would like best. The self-selected idea was coded because that demonstrates the idea the student would choose to pursue. First, responses were grouped by overarching type of idea (e.g., all responses that provided water along the trail). Then, the number in each category served as the general originality score. Then, within categories, specific approaches were identified (e.g., provide a vending machine or drill a well), which served as the specific originality score.

Then, total originality scores were calculated by subtracting both the general and specific scores from the total sample size ($n = 90$), such that higher scores were more original as fewer people discussed them. For example, 36 students offered methods to transport trail visitors' bags directly to the view to lighten the hikers' loads. However, only three people suggested using a horse to transport the bags, so those 3 participants received a score of 41 [i.e., $90 - (36 + 3) = 41$].

6.3.1.1.5. Problem-solving usefulness. Problem-solving usefulness is the likelihood that the students' self-selected best idea would support the specific stakeholder's initiative. This score was placed on a binary scale, in which zero indicated the response did not address stakeholders' goals and one indicated response addressed stakeholders' goals. Stakeholders' goals were determined by consulting professional councils and associations. In this case, the

Table 2
Overview* of MIP-CPS Coding.

Variable	Operationalization	Scoring guidelines	Scaling
Problem Identification Fluency	Quantity of potential problems related to the scenario generated by participant.	Count number of identified problems. Do not count repeats of previous idea(s) using similar/exact words nor ideas that do not address the question.	Continuous scale (e.g., 0 = no problems identified, 1 = one problem identified…)
Problem Solving Fluency	Quantity of potential solutions for a specified problem generated by the participant.	Count number of solutions. Do not count repeats of previous idea(s) using similar/exact words nor ideas that do not address the question.	Continuous scale (e.g., 0 = no solutions, 1 = one solution…)
Problem Solving Flexibility	Quantity of *types* of solutions generated for a specified problem.	Count number of types/categories of ideas. Ideas do not count if they repeat a previous type of idea.	Scaled out of 5 idea types (e.g., 0 = no solutions, 1 = one type of solution…)
Problem Solving Originality	Degree to which the response is unique within the data set.	Group responses by overarching type of idea (e.g., all responses that provided water along the trail). Count number of responses in each category. This serves as the general originality score. Then, within categories, group based on specific approaches (e.g., provide a vending machine or drill a well). This served as the specific originality score. The total originality score was calculated by subtracting both the general and specific scores from total responses (90).	Scaled out of 90 responses. Higher scores were more original, as fewer students took that approach.
Problem Solving Usefulness	Whether the response would meet the stakeholders' goals.	Evaluate responses against stakeholders' primary goals. For example, "park rangers promote the conservation and use of state or national park resources."	Binary scale: 0: Response did not promote stakeholder's goals. 1: Response did promote the stakeholder's goals.
Problem Identification Strategies	Type and quantities of problem identification strategies participants discussed.	For full coding scheme, see Table 3.	Continuous scale (e.g., 0 = no strategies, 1 = one example of that type of strategy, 2 = two examples of that type of strategy.)

* Specific responses and applications of coding scheme are provided in text.

park ranger's goals were established by the Association of National Park Rangers, including "working for comprehensive protective stewardship of the national parks and providing the American public and the National Park Service the most enlightened level of care and service." Responses receiving a zero included ideas that would harm the environment (e.g., removing all trees to build a road) or were not currently possible (e.g., teleportation). All analyses took the dichotomous nature of this variable into consideration.

6.3.1.1.6. Problem-identification strategies. Four problem identification strategic approaches were coded: Resource Management, Elaboration, Analysis, and Manipulation, as theoretically supported and defined in the literature review. Participants' responses were initially coded using the Problem Construction Model (Mumford et al., 1994) and deductively coded into 14 categories. The two schemes were merged in a hybrid approach (Fereday & Muir-Cochrane, 2006). Table 3 displays the categories, descriptions, categories, and sample responses. Responses could provide multiple examples within a category, and all employed a continuous scale. In addition to coding the four individual strategic approach scores, composite strategy scores were created by adding the number of strategies together across categories.

As a sample application of the coding scheme, one student said, "Look at all aspects of the problem [Code: Dissect; Category: Analysis] and how they correlate [Code: Connect1; Category: Elaboration] and how they have direct and indirect effects on things around them [Code: Connect2; Category: Elaboration] and why people may be acting certain ways [Code: Code: Perspective Taking; Category: Elaboration] and how efficient things are [Code: Dissect; Category: Analysis]." Therefore, this student had zero examples of Resource Management, three examples of Elaboration Efforts (i.e., connect, perspective taking), two examples of Analysis (i.e., dissect), and zero examples of Manipulation. The strategic composite score was five (i.e., 0 Resource Management + 3 Elaboration + 2 Analysis + 0 Manipulation = 5 Composite Score).

6.3.1.2. Coding reliability. Multiple methods were used to determine the interrater reliability of the coding schemes for strategic approaches and creative outcomes, including generalizability theory, kappa, and percent agreement. Each method has unique benefits and drawbacks. Therefore, multiple methods are presented to better approximate the level of agreement between two raters across multiple types of outcome variables (see Tables 4 and 5). Generalizability theory accounts for patterns of agreement and multiple sources of variance, including students, tasks, and raters (see Briesch, Swaminathan, Welsh, & Chafouleas, 2014 for further discussion of this approach). Within this study, both the G-coefficients and phi-coefficients ranged from 0.87 to 0.99, indicating acceptable reliability (Webb, Shavelson, & Haertel, 2006). Kappa, however, is interpreted differently than other reliability estimates. Specifically, Kappa describes the extent to which coding accuracy surpasses chance agreements, thus, Kappa values of 0.41–0.60 indicate moderate agreement, 0.61–0.80 is substantial agreement, and 0.81–0.99 is almost perfect (Viera & Garrett, 2005). Generally, Kappa represents an underestimate, and acceptable ranges tend to be lower than other approaches (Viera & Garrett, 2005). Conversely, percent agreement is likely an overestimate of reliability (McHugh, 2012). Therefore, considering these methods collectively provides a more robust picture of coding reliability.

6.3.2. Torrance tests of creative thinking-figural (TTCT-F)

In addition to the CPS-MIP, students completed the TTCT-F. The TTCT-F is a popular method to measure the efficacy of interventions and identify creative potential (Thys et al., 2014). Therefore, we studied the relationships among students' problem identification strategies and their performance on TTCT-F average standard score and subscale scores. Re-normed in 2008, the TTCT-F has demonstrated high reliability of composite measures (*KR21* ranging from 0.83 to 0.93) and high inter-rater reliability (0.96–0.99; Torrance, 2008). The TTCT-F demonstrated higher predictive validity for creative achievement ($r = 0.33, p < .001$) than other divergent thinking tests (Kim, 2008).

Specifically, the TTCT-F assesses students' ability to transform shapes or lines into pictures. The TTCT-F contains three activities, and students are given 10 min to complete each activity. For example, on one activity, students are provided a series of circles and instructed to add details to the circles to make pictures out of them. The specific

Table 3
Description of problem identification strategies.

Strategic approach category	Description	Collapsed Inductive Codes	Sample Responses
S1: Resource Management	Students suggested they would revisit the initial prompt, underline key words, regulate their attention, or take notes.	• Revisit Prompt • Physical Representation • Attention	• "I can listen for clues." • "Listen to the words. Pick out things that would help." • "Really pay attention to what you are saying and taking time to process what you are saying and not just listening but actually understanding what you are saying." • "Focus. Don't space out."
S2: Elaborative Efforts	Students described connecting information to others' or their own life experiences. They suggested asking for help, taking the perspective of the stakeholders, or conducting additional research.	• Help-Seeking • Perspective-Taking • Connection • Research • Brainstorming • Inspiration-Seeking	• "…look it up online or ask a friend who knows the book." • "…think of past situations you were in or stories you have read." • "I could ask people what if they need help or if I see someone who does need help, ask them if they need help."
S3: Analysis	Students indicated that they would dissect the issue into key components or causes, look for discrepancies between what is happening and the ideal, or consider methods of evaluating the situation.	• Dissect • Discrepancy • Convergence	• "Look at what is causing the problem." • "Look for who, what, when, why, or how." • "Just dissect it; break it up." • "…see what is not going right and what should be going right and what is different from that and see what is causing it." • "…pull out each fact about the problem and determine why each thing went wrong."
S4: Manipulation	Students provided an active strategy to alter the current issue to think about the situation in a new way.	• Manipulate • Experiment	• "…see where the problem is happening and move it to a different place." • "I could think about new ways the problem could be worded." • "Think of the problem in a different situation." • "Reread…and switch the parts around of the problem."

instructions were as follows:

> In ten minutes, see how many objects or pictures you can make from the circles below… The circles should be the main part of whatever you make…Try to think of things no one else will think of. Make as many different pictures or objects as you can and put as many ideas as you can in each one…

For the current study, the Torrance Center at the University of Georgia provided onsite training to all research assistants. This training consisted of two days of instruction and scoring practice. Following the training, all scorers took and passed a certification test to ensure mastery of the scoring system. The scoring system consisted of five main subscales: (a) fluency: number of relevant responses (i.e., the stimulus must be used, and exact duplicates are not counted), (b) originality: number of unusual ideas based on the statistical infrequency of responses in the normed sample, (c) elaboration: number of added details and ideas to the basic response, (c) abstractness of titles: scored from 0 (response provided an obvious description of picture, like "cloud") to 3 (response provided an appropriate title but not connected to a concrete component of picture, like "hope"), and finally (e) resistance to closure: avoidance of drawing lines that close an incomplete figure, scored from 0 (figure was closed and all details are inside closed figure) to 2 (figure is never closed or only part of the figure is closed). These five, norm-referenced, standardized subscales are aggregated to produce the "Average Standard Score." All descriptive data are presented in Table 6.

Table 5
Reliability and descriptive statistics for strategic approaches.

Strategy approach with specific strategies	Mean	SD	Range	Kappa	% Agreement
S1: Resource Management	0.78	0.76	0–3	0.78	90.67%
S2: Elaboration	0.62	0.82	0–4	0.69	97.71%
S3: Analysis	0.43	0.65	0–2	0.62	92.00%
S4: Manipulation	0.06	0.23	0–1	–	96.00%
Strategy composite	1.89	1.29	0–7	0.69	93.80%

Notes. Manipulate was so rare within these responses, therefore a Kappa coefficient was inestimable. Generalizability theory analyses were also conducted for the strategy composite and yielded G and Phi coefficients of 0.90.

Table 6
Subscale and scale descriptives for the TTCT-F.

TTCT score	Mean	SD	Range
Fluency	110.19	18.09	53–138
Originality	111.58	20.70	42–148
Elaboration	111.91	23.66	62–160
Abstractness of Titles	96.82	26.99	0–147
Resistance to Premature Closure	106.71	20.82	40–147
Average Standard Score	107.48	15.92	61–141

Table 4
Reliability and descriptive statistics for response coding.

Outcome	Mean	SD	Range	G-coefficient	Phi-coefficient	Kappa	% Agreement
Problem ID Fluency	4.37	3.06	1–24	0.99	0.99	0.77	89.86%
Problem SV Fluency	4.13	1.83	1–10	0.97	0.97	0.69	90.50%
Problem SV Flexibility	2.57	1.01	1–5	0.97	0.97	0.89	95.77%
Problem SV Usefulness	0.33	0.47	0–1	0.87	0.87	0.75	88.00%

6.4. Data analysis plan

The purpose of this study was to examine the extent to which students' problem identification strategies are related to different creative outcomes. Our overarching hypothesis was that more strategic approaches to problem identification would lead to improved problem identification, problem solving, and divergent thinking. This hypothesis is supported by previous research demonstrating that strategies applied during the CPS process led to improved creative outcomes (e.g., Mumford, Supinski, Baughman, Costanza, & Threlfall, 1997; Harms, Reiter-Palmon, & Derrick, 2018). Further, we hypothesize specific strategic approaches would be more adaptive than others; specifically, deeper-thinking strategies will be more predictive of creative outcomes given previous work on strategic thinking in general (Dunlosky et al., 2013; Fiorella & Mayer, 2016). Specifically, Manipulation will be the most predictive strategic approach, followed by Elaboration and/or Analysis, and then Resource Management. To test these hypotheses, we proposed a series of three primary research questions to examine multiple creative outcomes.

RQ1: To what extent are students' specific problem identification strategies related to or predictive of contextualized, *problem identification* fluency? To address this question, we planned to examine how students' strategic approaches to problem identification influenced their ability to identify specific problems within the task. We hypothesized all strategies would be positively correlated to problem identification fluency, and deeper-thinking strategies would be most important. To test these hypotheses, we planned to run an initial correlation analysis among four problem identification strategies and problem identification fluency. Then, the significant strategies would be entered into a count regression model to predict problem identification fluency.

RQ2: To what extent are students' specific problem identification strategies related to or predictive of contextualized, *problem solving* outcomes (i.e., fluency, flexibility, originality, and usefulness)? We planned to examine how students' strategic approaches to problem identification influenced students' ability to develop creative solutions. To determine the creativity of students' solutions, we examined four different outcomes: fluency, flexibility, originality, and usefulness. We hypothesized all strategies would be positively correlated to all problem solving outcomes, and deeper-thinking strategies would be most important. To test these hypotheses, again, we planned to run an initial correlation analysis among all problem identification strategies and all problem-solving outcomes. Then, we planned to build four separate count regression models using all significant problem-identification strategies to predict the four different problem-solving outcomes.

RQ3: To what extent do students' specific problem identification strategies support their performance on decontextualized divergent thinking tasks, specifically the Torrance Tests of Creative Thinking-Figural (TTCT-F; including the average standard score and specific subscale scores of fluency, originality, elaboration, abstractness of titles, and resistance to closure)? This research question considers how problem identification strategies may influence decontextualized, popular creativity measurements. Our hypothesis was that students who were more strategic in identifying problems would develop more creative responses on the TTCT-F. We hypothesized that these relationships would be present, but not as strong as they would be within the contextualized creative problem-solving task because the problem identification strategies were directly connected with the contextualized task. To determine the extent to which problem identification strategies were related to or predictive of TTCT-F performance, we planned to first to determine which strategies significantly correlated with TTCT-F outcomes. Then, to examine the relationships among the significant strategies, we would run separate linear regression models for each outcome that had two or more significant correlations.

6.5. Preliminary analyses

6.5.1. Outlier detection

Outlier detection was conducted using Cook's distance (with outliers indicated by values greater than 1) and Mahalanobis distance (Stevens, 1984). To detect outliers using Mahalanobis distance, the value [1-CDF.CHISQ (Mahalanobis Distance, number of predictors] was calculated for each outcome and compared to 0.001, with values less than 0.001 indicating potential outliers. Overall, only one student was a consistent outlier across outcomes and detection methods. This student scored very high on several outcomes (e.g., problem identification fluency of 24, which is over 6 SDs (SD = 3.06) higher than the mean problem ID fluency (4.37). Therefore, while this student may be an outlier, this student may also represent a particularly capable/adept/gifted creative problem solver and was retained in the sample for the current study.

6.5.2. Count regression models

Due to the nature of the problem identification and problem solving outcomes, these data were analyzed using regression models for count data. The Poisson regression is appropriate for the count nature of the number of ideas (fluency) and number of categories (flexibility). However, the Poisson regression also assumes that the variance and mean are equal for the count data. Therefore, our analytical plan included fitting Poisson regression models and negative binomial models for each of the count outcomes. After fitting the models, we then conducted an overdispersion test using the "pscl" package in R (Jackman, 2017; R Core Team, 2018). The results of the overdispersion test were non-significant, retaining the null of no overdispersion and meeting the restrictions of the Poisson models. Further, the AIC values suggested that the Poisson models consistently fit better than the negative binomial models. Table 7 shows the overdispersion test results and AIC values for each of these models. While possible for participants to fail to identify any problems or provide any problem solutions, all participants had at least one; therefore, we used zero-truncated Poisson regression models and the results of these models were interpreted for each of the count outcomes.

6.5.3. Linear regression assumptions

The assumptions of linear regression were assessed for the TTCT-F outcomes. Lack of multicollinearity was assessed using tolerance and VIF values. For TTCT Elaboration, the tolerance and VIF values were 0.947 and 1.056, respectively. For the total TTCT score, the tolerance and VIF values were 0.971 and 1.029, respectively. For each TTCT

Table 7
Model fit and overdispersion tests for poisson and negative binomial models.

Models	AIC	Overdispersion Test X^2 (*p*)
Problem ID Fluency		0.4601 (0.2488)
Poisson	385.74	
Negative Binomial	387.28	
Zero-truncated Poisson	381.18	
Zero-truncated Negative Binomial	381.90	
Problem SV Fluency		−0.0013 (0.5)
Poisson	354.27	
Negative Binomial	356.27	
Zero-truncated Poisson	350.55	
Zero-truncated Negative Binomial	354.52	
Problem SV Flexibility		−0.0011 (0.5)
Poisson	286	
Negative Binomial	288	
Zero-truncated Poisson	268.34	
Zero-truncated Negative Binomial	271.53	

outcome, values showed no indication of multicollinearity (O'brien, 2007). Normality was assessed for the TTCT outcomes using skewness and kurtosis values and visual examination of the PP-plots. Skewness (0.33 elaboration, −0.20 total score) and kurtosis (−0.46 elaboration, −0.27 total score) suggested normality, as did the PP plots. Residuals plots for each TTCT outcome were created and used to assess the assumptions of homoscedasticity, linearity, and independence. The residuals plots suggested that each of these assumptions were met.

6.5.4. Bonferroni correction

Based on initial correlation results, it was established that 5 regression models would be run to explore the research questions. Therefore, the Bonferroni correction (Gissane, 2017; McLaughlin & Sainani, 2014) was used to control for the probability of Type I error inflation. To control for Type I error, the α was corrected to 0.01 (0.05 divided by five regression models), and all regression model results and coefficients were interpreted accordingly. Further, all *p*-values were reported to three decimal places for more accurate interpretation.

6.5.5. Strategy frequencies

Most students provided at least one strategy. Only 8 students did not discuss any strategy. In general, students more frequently employed less cognitively complex strategies. Specifically, Resource Management strategies were the most frequently discussed. Approximately 60% of the sample discussed Resource Management strategies to help them maintain their attention and focus on specific details of the problem, Within our sample of 90 students, 37 students discussed one Research Management strategy, 15 provided two strategies, and 1 student provided three strategies. Elaboration strategies were the second most popular, as 47% of the sample discussed these types of strategies (32 students provided one Elaboration strategy, 7 gave two examples, and 3 gave three or more). Finally, 34% of the sample discussed Analysis strategies, and 6% of the sample discussed Manipulation strategies.

7. Results

Students' problem identification strategies were coded and used to explore how those strategies influence creativity outcomes within RQ1-3. Correlations among problem identification strategies and all creativity outcomes are presented in Table 8. Using these results, subsequent regression models were run, and outcomes are presented in Tables 9 and 10.

Table 9
Zero-truncated poisson regression models.

Outcome	B (SE)	*p*	McFadden's Pseudo R^2
Prob ID Fluency			0.13
S2: Elaboration	0.30 (0.05)	< 0.001**	
S3: Analysis	0.18 (0.08)	0.0197	
S4: Manipulation	0.38 (0.18)	0.0333	
Prob SV Fluency			0.04
S2: Elaboration	0.06 (0.06)	0.3486	
S3: Analysis	0.19 (0.08)	0.0166	
S4: Manipulation	0.37 (0.20)	0.0610	
Prob SV Flexibility			0.02
S3: Analysis	0.18 (0.11)	0.0900	
S4: Manipulation	0.44 (0.26)	0.0903	

Notes. McFadden's Pseudo R^2 was calculated using the following formula for each outcome model: Pseudo $R^2 = 1 - (-2LL_{full}/-2LL_{null})$ It should be noted that McFadden's Pseudo Pseudo R^2 should not be interpreted as R^2 derived from OLS regression. *p*-values should be interpreted after controlling for the use of five regression models; for statistical significance, $p < .01$. Further, at least three numbers after the decimal are reported for all p-values for more nuanced interpretation.

Table 10
Regression models using strategic approaches to predict TTCT outcomes.

TTCT Outcome	R^2 (*p*)	β	*p*	sr^2
TTCT Elaboration	0.17 (< 0.001)			
Elaboration		0.33	0.002	0.10
Manipulation		0.18	0.081	0.03
Total Scaled Score	0.13 (0.003)			
Resource Manage.		0.28	0.008	0.08
Elaboration		0.27	0.009	0.07

Notes. Regressions were run for each creative outcome that had more than one significant correlation with students' problem identification strategies. Only significantly correlated strategies were included in the models.
sr^2 = Semipartial Correlation Squared represents the proportion of unique variance in outcome variable after controlling for all other variables.
p-values should be interpreted after controlling for the use of five regression models; for statistical significance, $p < .01$. Further, three numbers after the decimal are reported for all p-values for more nuanced interpretation.

Table 8
Correlations among problem identification strategies and creative thinking outcomes.

	S1: Resource management	S2: Elaboration	S3: Analysis	S4: Manipulation	Strategy composite****
Microanalysis interview protocol-creative problem solving-trail problem					
Problem ID Fluency	0.03	0.52**	0.26*	0.34**	0.54**
Solution Fluency	0.11	0.21*	0.33**	0.30**	0.42**
Solution Flexibility	0.15	0.07	0.29**	0.30**	0.33**
Solution Originality	0.10	0.10	−0.02	0.15	0.14
Solution Usefulness***	−0.26*	−0.05	−0.11	−0.07	−0.25*
Torrance test of creative thinking-figural					
Fluency	0.28**	0.04	0.08	0.10	0.24*
Originality	0.23*	0.11	0.12	0.06	0.28**
Elaboration	0.05	0.37**	0.08	0.26*	0.35**
Abstractness of Titles	0.13	0.12	0.05	0.06	0.18
Resistance to Closure	0.11	0.17	0.03	0.13	0.21*
Total Scaled Score	0.23*	0.23*	0.10	0.17	0.36**

* *r* significant at the 0.05 level (2-tailed).
** *r* significant at the 0.01 level (2-tailed).
*** Point Biserial Correlations (r_{pb}) were used as Usefulness was a binary variable.
**** The composite score was created by adding all problem identification strategies together. This creation of the composite score has been used in previous literature to provide a general strategic score (Cleary et al., 2015; DiBenedetto & Zimmerman, 2010; Follmer & Sperling, 2018).

7.1. RQ1: To what extent are students' specific problem identification strategies related to and/or predictive of contextualized, problem identification fluency?

The most proximal outcome of problem identification strategies is students' problem identification ability. The more problem identification strategies students indicated, independent of type, the more problems they identified ($r = 0.54$). Moreover, some problem identification strategies were more adaptive than others. For example, Elaboration ($r = 0.52$), Analysis ($r = 0.26$), and Manipulation ($r = 0.34$) correlated significantly with problem identification, but Resource Management did not.

The zero-truncated, or positive, Poisson regression model demonstrated that only Elaboration strategies significantly predicted the number of problems identified (B = 0.304, $p < .001$). Manipulation and Analysis strategies were not significant predictors (B = 0.377, $p = 0.0333$ and B = 0.175, $p = 0.0197$, respectively). In other terms, students who planned to use more Elaboration strategies tended to identify more potential problems; Analysis and Manipulation strategies appeared to be less helpful.

7.2. RQ2: To what extent are students' specific problem identification strategies related to and/or predictive of contextualized, problem-solving fluency, flexibility, originality, and usefulness?

This research question examined the relationship between students' ability to strategically approach problem identification and actual problem-solving outcomes, including the fluency, flexibility, originality, and usefulness of the solutions developed. Holistically, the number of problem identification strategies significantly correlated with some problem-solving outcomes, including problem-solving fluency ($r = 0.42$) and problem-solving flexibility ($r = 0.33$). However, no significant relationships were found between the total number of problem identification strategies and originality. Unexpectedly, the total number of problem identification strategies related negatively to the usefulness of the solution ($r_{pb} = -0.25$). Each problem-solving outcome and specific strategies will be explored in greater depth in subsequent sections.

7.2.1. Problem-solving fluency

Three types of strategies, Elaboration ($r = 0.52$), Analysis ($r = 0.26$), and Manipulation ($r = 0.34$), significantly correlated with problem-solving fluency. To explore these relationships further, these three strategies were entered into a zero-truncated Poisson regression model. There were no significant predictors in this model using our Bonferroni corrected α. However, these results suggest that Analysis may be a more important predictor of problem solving fluency (B = 0.186, $p = 0.0166$) than either Elaboration (B = 0.059, $p = 0.3486$) or Manipulation (B = 0.367, $p = 0.061$).

7.2.2. Problem-solving flexibility

Two strategies, Analysis ($r = 0.29$), and Manipulation ($r = 0.30$), significantly correlated with the problem-solving flexibility. To explore these relationships further, these strategies were entered into a zero-truncated Poisson regression model. However, neither Analysis (0.184, $p = .0900$) nor Manipulation (0.437, $p = 0.0903$) significantly predicted problem-solving flexibility.

7.2.3. Problem-solving originality and usefulness

Only one correlation was significant with either of these outcomes. Specifically, Resource Management, was negatively correlated with solution usefulness ($r_{pb} = -0.26$), suggesting when students' strategic approach involved lower level strategies, like paying attention and re-reading the prompt, they were less likely to develop a useful solution. Given the lack of additional significant variables, no further analyses were run.

7.3. RQ3: To what extent do students' specific problem identification strategies support their performance on decontextualized, divergent thinking tasks, specifically the Torrance Test of Creative Thinking-Figural (TTCT-F)?

This research question examines decontextualized, creative outcomes (i.e., TTCT-F). This provides the opportunity to explore the effects of strategic problem identification using a more traditional measure of divergent thinking. All correlations are presented in Table 6, and all regression models are presented in Table 7. Each will be explored in greater depth in the specific sections to follow. In general, the problem identification strategy composite was significantly correlated with all TTCT subscales (except Abstractness of Titles) and with the Average Scaled Score ($r = 0.36$). This suggests students who identified more problem identification strategies also demonstrated higher creativity outcomes across TTCT-F measures, yet distinct strategies exhibited different relationships with the subscales and full-scale scores.

7.3.1. Fluency and originality

Resource Management was the only significant correlate of Fluency ($r = 0.28$) and Originality ($r = 0.23$), suggesting students who purposefully plan to regulate their attention/emotions, revisit questions, and take notes developed a greater number and more original ideas on the TTCT-F. Because only one strategy type was significantly correlated to these outcomes, no further analyses were run.

7.3.2. Elaboration

Two strategies, Elaboration ($r = 0.37$) and Manipulation ($r = 0.26$), significantly correlated with the Elaboration subscale on the TTCT-F. To explore these relationships further, both strategies were entered into a regression model. The full model was significant, $F(2,85) = 8.63$, $p < .000$, $R^2 = 0.17$. However, only Elaboration was a significant predictor in the model ($\beta = 0.33$, $p = .002$), uniquely accounting for about 10% of the variance. In contrast, Manipulation was not a significant predictor in the model ($\beta = 0.18$, $p = .081$).

7.3.3. Abstractness of titles and resistance to closure

Neither outcome was significantly correlated to any of the strategies, so they were not explored further using a regression analysis.

7.3.4. Average scaled score

Two strategies, Resource Management ($r = 0.23$) and Elaboration ($r = 0.23$), significantly correlated with the Average Scaled Score on the TTCT-F. To explore these relationships further, both strategies were entered into a regression model. The full model was significant, $F(2,85) = 6.25$, $p = .003$, $R^2 = 0.13$, and both Resource Management ($\beta = 0.28$, $p = .008$) and Elaboration ($\beta = 0.27$, $p = .009$) were significant predictors in the model. Each uniquely accounted for about 7–8% of the variance.

8. Discussion

This manuscript entails an extension of SRL microanalysis procedures (i.e., the CPS- MIP) to examine students' approaches to problem identification, which is a unique application of these procedures to a complex task and processes. The application of this instrument yielded information regarding how students approach problem identification and which types of problem identification strategies are most related to specific creative outcomes, including both contextualized and decontextualized outcomes on divergent thinking assessments. In part, this study represents a proof of concept, for which there are many applications. Specifically, other researchers and teachers may find the use of the CPS-MIP helpful in exploring how students' problem finding approaches change throughout an intervention or within a classroom setting. CPS-MIP could also be used as a manipulation check to determine if strategies taught as a part of an intervention are being transferred to new tasks. Future research is needed to verify the versatility of this assessment in both providing a research method to explore problem identification and a practical assessment for gauging to student growth. For more details on this protocol design, see Rubenstein et al., 2018, and for more information regarding general SRL microanalysis procedures, see Cleary et al., 2012. Within this study, the instrument was used to consider the adaptiveness of problem identification strategies across creativity outcomes.

8.1. Finding 1: Problem identification strategies influence multiple creative outcomes, but they most significantly influence proximal, task-specific outcomes

Our initial hypothesis was that problem identification strategies would be more closely related to problem identification outcomes than problem solving outcomes or more general divergent thinking. This hypothesis was generally supported. Students' problem identification strategies were most closely related to their problem identification fluency, in comparison to their problem solving outcomes. Within problem identification fluency, elaboration strategies were the only significant predictor after the Bonferroni correction. When creative outcomes were more distal to problem identification (i.e., problem solving and divergent thinking), the strategic approaches were less significant. These findings offer support for the trend in educational psychology research to measure cognitive processes in relation to specific tasks, rather than using more global approaches, as students may regulate cognitive processes based on task type (Callan & Cleary, 2018; Cleary & Callan, 2018; Cleary, Callan, Malatesta, & Adams, 2015; Follmer & Sperling, 2018; Young & Worrell, 2018).

However, while not as strong of a relationship, problem identification strategies still significantly correlated with more distal outcomes. The more problem identification strategies students possessed, the better they tended to perform across all outcome types. This finding may suggest that a more complex model needs to be tested to represent how problem identification strategic approaches influence problem identification outcomes, which in turn influences problem-solving strategic approaches and problem-solving outcomes.

8.2. Finding 2: Higher-level strategies were most adaptive in contextualized CPS divergent thinking outcomes (i.e., generation of ideas)

Our initial hypothesis was higher-level strategies (Elaboration, Analysis, and Manipulation) would facilitate improved creative outcomes across outcomes. We hypothesized that Manipulation would be the most adaptive, given it required more involvement with the prompts. Some prior work has found ambiguous results regarding the relationships between level of processing and academic outcomes. However, Dinsmore and Alexander (2012) suggested the equivocal results could be explained by the diverse methodological and conceptual approaches. Further, within studies examining task-specific outcomes and strategic approaches, they found a strong relationship between level of strategies and performance on the task (Dinsmore & Alexander, 2012).

Within the current study, our hypotheses were partially supported. Higher-level strategies (Elaboration and Analysis) were more adaptive in outcomes that required generation of ideas (problem identification fluency, problem-solving fluency and flexibility); however, manipulation was not consistently the most adaptive strategy. Resource management was not significantly correlated with these outcomes. Collectively, these results may indicate Elaboration, Analysis, and Manipulation are all serving as advanced strategic approaches for students at this developmental level as they engage with a CPS task. More work is needed to examine the tasks and outcomes best supported by different strategic approaches.

8.3. Finding 3: Problem identification strategies did not improve contextualized CPS convergent thinking outcomes (i.e., selection of ideas)

Unlike the generation of ideas (i.e., fluency and flexibility), problem identification strategic approaches did not seem to support the selection of more original or useful ideas. In fact, Resource Management negatively correlated with usefulness. This finding was contrary to our hypothesis. One notable difference between (a) fluency/flexibility outcomes and (b) originality/usefulness outcomes is that originality/usefulness were coded on students' self-selected best response, whereas, fluency/flexibility was coded on all students' responses provided during the generation phase. Responses were coded in this manner because fluency and flexibility are processes that enhance generation of ideas; whereas, the successful implementation of an idea depends on the novelty and usefulness of the primary idea selected to pursue.

Idea evaluation/selection represents a key component during both the problem identification and problem solving phases in many problem-solving models (Sawyer, 2012). Recently, Abdulla and Cramond (2018) highlighted the importance of evaluation, yet, most students in our work did not describe evaluation/selection as part of a problem identification process. Therefore, they may not engage in deliberate evaluation throughout the CPS process, which may explain why none of their strategies influenced contextualized outcomes associated with the selection of novel or useful ideas.

These unexpected findings could be due to several potential factors. First, eighth and ninth grade students may not have developed strategic approaches for selecting an original and useful idea to pursue. This requires a deliberate analysis of the stakeholders' needs and what is already typically presented. While we hypothesized that Elaboration, Analysis, and Manipulation would all help accomplish this goal, perhaps, the students were not ready developmentally to apply these strategies to convergent thinking processes.

Another potential explanation could be that selection of an original and useful idea is universally complex. In our previous work, we were unable to find problem-solving strategies that helped students select original or useful ideas within a CPS task (Rubenstein et al., 2019). Further, variables, like idea quality and originality, were not improved by commonly promoted creative thinking strategies like the Six Thinking Hats (Hocking & Vernon, 2017). Conversely, McIntosh, Mulhearn, and Mumford (2019) prompted students to consider positive outcomes, negative outcomes, both types of outcomes, or neither for their ideas. When prompted, students developed more elegant plans to solve the problem. Future work should explore which strategies should be taught and if students can independently apply those strategies across tasks.

8.4. Finding 4: Lower-level strategies (i.e., Resource Management) may be most helpful in timed, decontextualized, divergent thinking assessments

The TTCT and other measures of divergent thinking represent the most widely used assessments of creativity (Thys et al., 2014). They are often used to determine the efficacy of interventions that target the development of creative thinking, including interventions promoting problem identification. In fact, interventions emphasizing problem identification yielded some of the most significant results (Scott et al., 2004). Therefore, while these divergent thinking assessments are distal to the CPS task and processes, we hypothesized problem identification strategies would still be positively related the TTCT-F outcomes. Our hypothesis was only partially supported. Resource Management was significantly correlated with the TTCT-F Fluency subscale, Originality subscale, and Average Scaled Score; whereas, the TTCT-F Elaboration subscale was significantly correlated with Elaboration and Manipulation strategies. Sans the Elaboration subscale, Resource Management was the primary strategic approach supporting creative outcomes on the TTCT-F.

Resource Management may have been particularly important on the

TTCT-F because it is a timed test that rewards fluency of ideas. The timed nature of this assessment may benefit students who are able to remain focused throughout the entire time. Further, the TTCT-F booklet resembles a standardized assessment booklet (e.g., similar bubbles to fill in for the student's name). Students have strategies to stay focused during a timed, standardized test may transfer those strategies to stay focused during a timed creativity assessment.

This finding has several practical implications. First, studies examining problem identification interventions should use measures that assess students' problem identification ability and strategic approaches. By measuring participants' approaches, researchers could better understand what strategies and components within the intervention were responsible for the changes. Second, within the current zeitgeist, students frequently learn to monitor their attention within standardized assessments, and they are able to transfer that approach to other tasks that appear similar. This strategic approach is helpful in some circumstances (TTCT-F), and perhaps, less helpful in others (CPS-MIP). This should prompt deliberate teaching a variety of strategic approaches to support a variety of outcomes.

9. Limitations and future directions

Several limitations of the current study should be addressed within future work, including the nature of the problem solving context and the requirements/restrictions of the interview format.

9.1. Problem solving contexts

Placing problem identification in a specific context, such as identifying why people are not continuing on a trail, may inadvertently limit the types of strategies that students propose to help identify and solve problems. Limited details were provided regarding the park ranger. If students asked about specific details (e.g., "how long has the park ranger worked for this park?"), they were instructed that they could "use their imagination to answer their question." In this way, each student may have conceptualized the problem-solving context in a slightly different way, which may influence students' responses to an extent. Further, the park context may not be common knowledge for different samples and students, which may influence students' abilities to select the most useful response. Within the current sample, the park scenario would represent a common experience; however future work should explicitly measure students' exposure. Previous research used a similar approach, as participants were only expected a cursory understanding of problem-solving simulation contexts. For example, undergraduate students were expected to an educational leadership scenario, despite not having any training as educational administrators (Watts et al., 2017).

In future studies, additional contexts should be piloted. This park problem has several key characteristics that could be applied to different tasks. In general, the task has a primary stakeholder with a goal, and the goal is to help a secondary audience persist in a challenging condition. We have designed similar tasks for future studies, such as an owner of a zoo needs to ensure zoo visitors stay in line to enter a crowded park. This presents an interesting avenue for future research to examine the stability of responses and effect of specific contexts.

Further, the interview setting may have also influenced the strategies that students proposed or actually used to identify a problem. During the SRL microanalysis interviews, students were not provided with specific resources. Therefore, some students may not have viewed certain strategies as feasible. For example, during the interview, students could not consult with others, do Internet research, or conduct polls of park goers even though some students suggested that is what they would do.

In future research, this may be addressed in several ways: (a) make the actual interview context more authentic, by providing students with access to resources that may be available to the stakeholder, (b) adjust the interview instructions to specify the stakeholder can access any resource, or (c) add a specific question to the protocol that asked students to justify their responses. For example, just as students were asked in the current interview to select their best idea, another question may ask students to select and explain their best strategy. This may give important information about the constraints that the student imposed on the problem-solving context. Despite this limitation, one of the benefits of the current work remains that students' problem identification and CPS approaches were captured in real-time and in a specific context through the use of SRL microanalysis.

9.2. Interview format

While the SRL microanalysis interview format undeniably offered several benefits to answering these research questions and has the potential to answer several more, its requirements for time, trained interviewers, and one-on-one format may restrict its application. For example, in the current study, these requirements limited the sample size that was feasible for data collection and analysis. This format may also restrict its application in more authentic learning environments. Using microanalysis in classroom environments may allow for teachers to identify where students experience difficulties during the creative problem solving process and which strategies they use naturally; this information could be used to facilitate more adaptive approaches and reassess to measure growth (e.g., Peters-Burton & Botov, 2017).

Therefore, to make SRL microanalysis a more feasible assessment and intervention approach, researchers may explore conducting microanalysis in alternative formats, like group-based administration, online delivery formats, or more self-directed approaches in which the student progresses through the questions and tasks on their own with timed, specific prompts without a one-on-one interviewer. These formats may allow researchers to compare responses across a greater number of contexts, participants, and tasks, which would answer important questions about students' approaches.

10. Conclusion

Collectively, these findings demonstrate the importance of students' strategic approaches to problem identification and different problem-identification strategies are adaptive in different contexts. Further, this work suggests future intervention studies should carefully select assessment methods that match the interventions' emphasized CPS strategies. For example, if an intervention includes teaching students how to analyze a problem, the TTCT-F may not be the outcome that will demonstrate the efficacy of the intervention. Additional empirical work needs to be done in this area to further clarify these relationships. This work provides an initial exploration on eighth and ninth graders' problem-identification approaches and the relationships among the strategies and creativity outcomes, yet more work needs to explore how these approaches develop throughout an individual's life, how those approaches can be enhanced, and which of these strategies best support specific outcomes. As the field of creativity continues to demonstrate how creativity is ubiquitous, important, and can be facilitated (Sawyer, 2012), it becomes essential to take a deliberate approach to understanding the cognitive processes leading to creative outcomes.

Funding source

This research was supported by an Academic Excellence Grant from Ball State University, Muncie, IN.

Acknowledgements

The research team would like to thank the teachers and administrators from Burris Laboratory School for their support.

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