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Analyzing the Creative Problem-Solving Process: Inventing a Product from a Given Recyclable Item

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Detailed documentations of creative invention are scarce in the professional literature, but could be useful to those engaging in or studying the problem solving process. This investigation describes the creative process of graduate students (7 female, 4 male) in a problem-solving theory and practice course grappling with the task of creating products from four identical recyclable items that were circular, star-impressed bottoms of plastic juice bottles. Several popular models of the problem-solving process are compared to the participants’ steps in this invention problem. Participants first provided emotional reactions to the given ill-defined problem of making a product from the specified items. They used several techniques to generate ideas and to restrict or define the problem, choosing an optimal product that fits their requirements. An analysis of participants’ reflections concerning their creative process showed that although participants first found the problem challenging and could not conceptualize effective products, the idea-generating activities assisted them in making a wide variety of useful products. Participants’ knowledge and skill areas were highlighted by their choices of products. After completing and presenting a first product, participants engaged in additional activities to generate ideas for a second product. The second product was either an improvement of the first product, a new but related product, or a product inspired by the work of others in the class. Products of this loosely defined problem included: maracas, dish, spin top, candy suckers, closet organizers, party decorations, yoyo, ladybug, wall décor, flowers, catch game, party hat, candle holders, moth life cycle, catapult game, toy clock, goblets, castanets, accessory organizer, and spice shaker.

Keywords: Problem Solving; Creativity; Invention; Creative Process; Product Evaluation

Introduction

This study documents the creative process of graduate students in a problem-solving theory and practice course who were presented with the ill-defined problem of creating a product from given items: the circular, clear, star-impressed bottom pieces of plastic juice bottles (often referred to here as “juice bottle bottoms”). The goal of this article was to document and analyze the creative process, while connecting it to existing models, for the purpose of providing an in-depth example of participants’ progression as they solve an ill-defined problem. This investigation will be of use to others teaching about, implementing, or studying the creative process. A multitude of studies have been conducted to unravel the creative process and various factors affecting it; however, few follow the process in-depth from start to finish and provide the reader with details of participant creative ideas, products, and reflections. Additionally, many models of the creative process have been put forward, resulting in confusion to novices in the field. Although this article does not have the scope to examine connections of the participants’ processes to every creative model presented in the professional literature, several familiar models, discussed in the next section, will be addressed.

The Creative Problem Solving Process

Wallas’s Four Stages

Graham Wallas, in The Art of Thought (1926), stated the creative process should include four major steps: preparation, incubation, illumination, and verification. The preparation stage is focused on learning the craft and understanding the task at hand. During this stage, the problem and its requirements are defined and information relevant to the problem is gathered. The next stage, incubation, requires the conscious mind to stop its focus on the problem, allowing the subconscious to take over. This generally occurs when a person is occupied with non-demanding tasks such as sleeping, walking, driving on an interstate highway, or watching television. Illumination occurs as a person suddenly becomes aware of one or more solutions to the problem. The verification stage involves a check of the viability of the solution, sometimes resulting in a revision leading to a more successful solution.

Creative Problem Solving Model

Alex Osborn’s (1963) Creative Problem Solving model also used stages to outline the process. This popular model was
modified over time by Sidney Parnes (1981) and Donald Tref- 
finger with Scott Isaksen (2005), acquiring additional steps. Six 
steps compose the current model: 1) constructing opportunities 
or mess-finding—locating a problem for application of the 
problem solving process; 2) exploring data or fact-finding— 
collecting, assessing, and reviewing all the available data per-
taining to the problem; 3) framing problems or problem-finding 
—listing all possible ways of defining the problem; 4) generat-
ing ideas or idea-finding—generating ideas for solving the 
problem, including those that are wild or unusual; 5) develop-
ing solutions or solution-finding—choose and apply criteria for 
evaluating ideas to find the best solution; and 6) building ac-
ceptance or acceptance-finding—plan implementation by iden-
tifying responsible persons, a timeline of actions, and available 
resources.

The I’s of Inspiration

Jane Piirto (2004) identified seven “I’s” of the creative pro-
cess: Inspiration, Imagery, Imagination, Improvisation, Intuition, 
Incubation, and Insight to which “Implementation” was later 
added (Davis, Rimm, & Siegle, 2011). Piirto identified several 
areas of Inspiration that prompt attention to a problem: inspira-
tion of love or visitation of the muse in which one is inspired by 
a loved one; inspiration of nature in which one sees the com-
monplace as new or beautiful; and inspiration of the intellectual 
in which one delights in the creative accomplishments of others.

Another method of generating creative ideas uses Imagery or 
pictures seen in the mind’s eye, along with Imagination. Im-
provisation or free-play with ideas, including humor, helps 
boost creativity. Piirto recognized Intuition or subconscious 
“knowing” of factors related to a solution that arrive through 
psychic intuition or dreams. Incubation, similar to Wallas’s 
age, occurred during meditation or a release from conscious 
thinking. Piirto’s insight is similar to Wallas’s illumination 
stage as the moment when a person first experiences “Aha!”
The last “I” of “Implementation” was similar to the Creative 
Problem Solving model’s last stage of “acceptance-finding”.

Basadur’s Four Stage, Eight Step Process

Basadur and colleagues (Basadur & Basadur, 2011; Basadur, 
Graen, & Green, 1982) developed an organized and more com-
prehensive model of the creative problem-solving process from 
a business viewpoint: Stage 1 Generation (steps of Problem 
Finding and Fact Finding); Stage 2 Conceptualization (steps of 
Problem Definition and Idea Finding); Stage 3 Optimization 
(steps of Evaluate /Select and Plan); Stage 4 Implementation 
(steps of Acceptance and Action). The first three stages of 
Wallas’s model fit into the first half of Basadur’s model.

Problem finding may be the most crucial stage of the entire 
process (Bassadur & Bassadur, 2011; Kabanoff & Rossiter, 
1994) because the actual problem may be ambiguous or inter-
preted in many different ways (Getzels, 1982). Finding the 
problem in science may be the most creative step of problem 
solving because once the problem has been formulated, its so-
lution may just be a routine process of carrying out experiments 
or calculations (Einstein & Infeld, 1938). Asking new questions 
or regarding issues from new angles may lead to innovations.

Similarly, in art, the initiation of a work may not begin with a 
problem in mind, but merely, an exploration of new media or 
subject matter from which the problem emerges (Getzels, 1979; 
Moore, 1955). Problem definition follows the generation stage 
in which problem finding and fact finding occur. Ill-defined 
problems require the additional creative work of placing re-
strictions to better define the problem. An ill-defined problem is 
one in which the methods and solutions are not provided, al-
lowing problem finding to emerge (Lee & Cho, 2007). The 
problem in the current investigation was ill-defined so that 
participants could engage in the creative act of defining a prob-
lem.

Method

Participants

Eleven adults (7 female, 4 male; 1 African American, 2 Mid-
dle Eastern, 1 European, and 7 Euro-American), who were 
involved in a graduate course in problem-solving, participated 
in this study. The activities occurred over a five-week period 
during a semester-long course) as participants created and re-
created inventions from given recycled items. This research 
project was approved by the Human Subjects Committee of the 
overseeing university; all participants gave written consent for 
their data and photographs of their work to be included in the 
study.

Organization of the Problem-Solving Activities

Table 1 shows general connections between several models 
of the creative problem solving process and the activities of the 
current investigation.

1) The course. The problem solving course in which the 
study took place addressed both theory and practice of problem 
solving. The course was an elective course for masters-level 
educators interested in gifted education and for doctoral-level 
candidates who were planning to be college instructors or 
school leaders. The topic of problem finding had been dis-
cussed in depth in class, along with several different theoretical 
and practical approaches to problem solving.

2) Initial reactions. At the start of this project, four plastic 
juice bottle bottoms were provided to each participant. Par-
cipants were asked to begin thinking about an invention or prod-
uct they could make using one or more juice bottle bottoms. 
Participants were asked to record their initial reactions to the 
task. The ensuing discussion led to challenges, ideas, and con-
cerns to guide future process steps.

3) Idea finding and problem definition. Before actually 
creating a product, participants were asked to complete a set of 
three idea finding or problem definition activities. Participants 
later reflected on the results. Participants were given a drawing 
of the floor plan of a house and asked to think of products used 
within each room that could be made with the given circular 
plastic pieces: kitchen, bathroom, dining room, bedroom, living 
room, and balcony, garage, car or workplace, and garden. Other 
areas for which to generate possibilities included an indoor 
kids’ playroom, clothes closet, jewelry chest, and other places 
of personal choice.

In the second part, participants better defined the problem by 
generating ideas for new or additional products used within each 
room that could be made with the given circular plastic pieces. 
Participants were provided with new ideas and suggested addi-
tional product. The given
ways to manipulate the items were: 1) drill holes, cut slots, and use hot glue, epoxy, and string to attach; 2) use paint, markers, foil, glitter or sequins; 3) arrange in a circle, band, sheet, row, pile, sphere, flat, stack, doubled as a lentil, or single; 4) arrange as a dangling disk, as a container, as support, as a pedestal, as a lid, as a wall, or as a scoop.

Using the results from the idea finding activity, participants reflected upon their discoveries. The survey reflection included several items. Participants were asked to circle a number on a scale from 1 to 10 with “1” representing the “not creative” end of the continuum and “10” the “extremely creative” endpoint to indicate the level of creativity for their generated set of ideas from the three exercises. On a similar scale, participants were next asked to circle a number to indicate overall, daily creative ability with 5 or 6 being average. Participants were asked to identify the activity that helped them the most to generate creative ideas and explained their reasoning for both. Finally, participants described emotional thoughts they had during the process of generating ideas.

4) First products and reflections. Participants were given one week to design and produce their most creative idea. Each product was placed on display and photographed while participants described their process details to the class. Following the group share, participants completed a reflection survey in which they rated the creativity of their product and their overall, daily creativity. They also explained how they obtained their creative ideas and determined the most creative aspect of their product. They told why they chose to make this product rather than other alternative ideas, discussed skills that influenced the way they made their products, and told insights, inspirations, or ideas do they had after seeing the creative products that other people in the class made.

After sharing and reflecting, the participants were introduced to Eberle’s (2008) SCAMPER process using Michalko’s Thinkpak (2006). SCAMPER is an acronym listing actions to guide this process: substitute, combine, adapt, magnify, minify, modify, put to another use, eliminate, reverse and rearrange. Each person drew a Thinkpak card and explained how the SCAMPER operation described on the card could be applied to Eberle’s (2008) SCAMPER process using Michalko’s Thinkpak (2006). SCAMPER is an acronym listing actions to guide this process: substitute, combine, adapt, magnify, minify, modify, put to another use, eliminate, reverse and rearrange. Each person drew a Thinkpak card and explained how the SCAMPER operation described on the card could be applied to their product. The activity was repeated, leading to an open discussion about improving the first product or inventing a new, yet related, product.

5) Second products and reflections. Participants were given two weeks to complete an improved or new product. During class, participants showed their second products, pointed out improved or innovative features, discussed the inspiration for the product, and explained the relationship of the second product to the first product. The creative process was finalized with another survey in which participants were asked to rate the creativity of their second product; to rate their overall, daily creative ability; to clarify the connection between the first and second product; to explain the inspiration for the second product, along with skills that influenced the way participants made their products; to identify the most creative aspects of the second product; and, finally, to tell insights, inspirations, or ideas they obtained from seeing the creative second products of classmates.
Data Analysis

The quantitative analysis involved calculation of means with standard deviations; employed t-tests to determine significant differences.

The qualitative analysis utilized the constant comparison method to group ideas with similar ideas into categories. These categories underwent continuous refinement as additional participant responses were analyzed and often category labels shifted and defined new relationships (Dye, Schatz, Rosenberg, & Coleman, 2000; Goetz & LeCompte, 1981).

Results

Initial Reactions to the Problem

The juice bottle and two cut-out bottom pieces are shown in Figure 1. Table 2 shows people’s initial reactions to being asked to create a product from the recycled circular plastic bottom pieces cut from a juice bottle. Many people immediately sought to define the problem better by asking about other materials, expressing a desire for a useful product, and seeking guidelines to better define the problem. Everyone tried to define the problem more clearly. Some people expressed insecurities about their creativity and had a desire to make the product visually appealing while acknowledging their interest in the challenge.

Generating Ideas for the Product

Imagining products for rooms in a house. Table 3 shows the ideas participants generated as they visualized how a juice bottle bottom might be made into a product for each room of a house. Each room resulted in numerous ideas with little repetition. Participants exhibited little functional fixedness (Duncker, 1945) by using these items as shallow dishes or containers similar to their original use as the bottom of a juice container. Instead, a large variety of configurations and uses were generated.

Defining the problem more narrowly. Table 4 provides categories of participant responses to restricting or defining the problem. The problem initially presented to the participants was not well-defined. A well-defined problem gives little room for problem finding because the problem is a standard one with a known method of solving that will result in a correct answer (Dillon, 1982; Getzels, 1987; Lee & Cho, 2007). The problem in the current study was ill-structured because minimal information and restrictions were given (i.e., “Make an invention using one or more juice bottle bottoms”); participants needed to define their own sub-problems to produce creative products (Lee & Cho, 2007; Reiter-Palom, Mumford, Boes, & Runco, 1997).

The data in Table 4 demonstrate the strong desire of many participants to make a useful product rather than a merely decorative one. Many of the restrictions were goals for the use of the product rather than restrictions for how it would be created or other non-goal constraints.

Ideas generated by manipulating the plastic pieces. Table 5 shows the ideas generated from considering different ways the recycled plastic disks might be manipulated (e.g., attached with hot glue, arranged in a circle, dangling) or treated (e.g., drilled). The first category of Table 5 presents ideas generated by considering how holes might be used in the creation of an

Table 2

Initial concerns and reactions when project was introduced.

| Frequency | Issue          | Example Statements                                                                 |
|-----------|----------------|------------------------------------------------------------------------------------|
| 9         | Other materials| How will I include a maximum number of juice bottle bottoms with a minimum of other materials? What other materials can I use? |
| 9         | Technical and tool issues | Cutting them will be hard as the plastic is rather thick. If making a mold, need to make a hole for filling that won’t ruin the shape. |
| 7         | Useful         | How will I nail down a useful product? I’d like to make a product that would actually be used. |
| 5         | Concern about creativity | How in the world can I turn this into something else? Do I need to be crafty? |
| 5         | Guidelines     | What are the guidelines for a product? What concept am I applying? |
| 5         | Originality    | Does it have to be something new? I want my product to be one of a kind. |
| 4         | Adhesives and attachment | How will I get these materials to hold together? What is the best adhesive for this? |
| 4         | Visually Appealing | I want to make sure my work is beautiful to look at. People like color, so the product should be colorful. |
| 3         | Early ideas    | Looks like a shield. Reminds me of headlights. |
| 2         | Obtaining enough juice bottle bottoms for the product | Might have to spend money to buy more juice bottles to get enough bottoms for my product. |
| 2         | Interesting problem | This will be challenging but interesting. |
| 2         | Safety         | Safety of my product is important. |
| 1         | Diversity      | Can we combine construction and writing and tie it all to a diversity issue? |
| 1         | Environment    | Am I polluting the environment by making something or should I just recycle? |
| 1         | Inexpensive    | I want my product to be inexpensive. |

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The largest number of participants favored the strategy of thinking about different ways of manipulating the juice bottle bottoms in the last category in Table 5. Arrangement of multiple juice bottle bottoms into different configurations prompted a multitude of invention designs ranging from alphabet letters to an outlet cover to a Tiki torch. The given ways of manipulating the recycled bottle parts in the last category in Table 5 resulted in many items used as containers and supports.

This strategy of thinking about different ways of manipulating the juice bottle bottoms allowed participants to generate over 150 different ideas. Participants considered this technique helpful as many were wondering what they might be able to do with these recycled items besides the obvious ideas of using them as wheels on a toy or a type of dish. The way of manipulation can be easily correlated with the generated ideas as they were often directly connected to the wording of the suggested manipulation.

### Favored strategies for idea-generation.

Table 6 gives participants’ reflections regarding why they favored one idea-generation strategy over others when generating creative ideas. The largest number of participants favored the strategy of imagining the juice bottle bottom as an item in different rooms, stating their main reason as the visual support afforded by the house floor plan diagram. Michalko (2001), in his book of strategies for generating creative ideas, noted that the explosion of creativity during the Renaissance was strongly connected to the use of graphics (e.g., drawings, diagrams, sketches) in recording and presenting knowledge. His strategy of making thoughts visible was favored by participants who mentioned that the visual floor plan allowed them to better define the problem. There were 10 strongly positive reactions and 14 negative ones. The participants’ reflections focused on emotions. Participants were asked to describe the emotional reactions they experienced during the process of using the recently discussed strategies (considering items for different rooms of a house; manipulating the juice bottle bottoms in different ways; imposing a variety of restrictions to better define the problem). There were 10 strongly positive reactions and 14 negative ones. The last item in the positive column of Table 7 contains both negative and positive aspects although the final reaction was more positive (relief). Many of the negative reactions reflected a lack of self-confidence rather than dislike of the task. The relatively low number of emotional reactions that involved enjoyment and play may be reflective of the participant pool of graduate students who often feel pressured to perform well on everything.

### Table 5.

| Room                  | Items to Be Made of Juice Bottle Bottom or Bottoms                                                                 |
|-----------------------|-------------------------------------------------------------------------------------------------------------------|
| Kitchen               | Candy dish; chopped vegetable container; decoration on curtain; detergent measuring cup; jewelry holder on windowsill; mold for chocolate, Jell-O, or ice; Popsicle melting protection; pot scrubber rest; saucer; sink stopper; slotted spoon, spoon rest, stovetop utensil rest; tea bag holder; window prism |
| Bathroom              | Back scrubber; bath toy; curtain ring; curtain weight; curtain (link together to form continuous surface); decoration on tub; drawer organizer; jewelry holder; liquid makeup holder; single-dose medicine container; soap dish; toothbrush holder; tub drain stopper; window curtain. |
| Dining Room           | Appetizer plate; base for bowls, glasses created from recycled plastic bottles; bread plate; chair back decoration; chandelier; coasters; individual condiment holder; individual hors d’oeuvres plates; lamp shade; lemon slice holder; nameplate; nametag; napkin holder; painted and mounted in front of light for ambiance; pot holder; serving dish; underneath table leg; vase bottom. |
| Bedroom               | Baby mobile for crib; bed frame post; candle holder; coin tray; door stop; earring holder; hanging wind chimes; jewelry holder; jewelry such as pin, medallion, bangle; lamp cover; mobile; outlet cover; base of potpourri holder; reminder under pillow; sleep mask (paint two black); wall decoration; wall hanger. |
| Living Room           | Artwork or wall hanging; bookends; candle holder; candy dish; checkers game pieces; coasters; decoration on lamp; decoration on TV; furniture coaster or slide under leg; light pull; outlet cover; prop for remote control; retro room divider; small cover for plate; spinner for game. |
| Balcony               | Alarm system cover; ashtray; bird feeder; bird nest support; coaster for drinks; cover for bottles or drinks to keep out bugs; hanging mechanism for mobile; nut dish; outdoor lighting; plant stand; rain catcher; Tiki torch; wind bell or wind chime. |
| Kids’ Play Area       | Bean bag targets; dog dish; doll’s bath tub; draw faces on them and use as game; flying saucer toy; Frisbee; game pieces; kids’ craft stamper; manipulations for counting; musical instrument; paint pallet; rattle; scroop for sandbox; spinning top; tires for toy cars; window in doll house. |
| Garage                | Bike hanger; container for loose nuts, bolts, screws; curtain for window giving frosted effect; decoration on ceiling or wall; hanger to indicate when to stop car when pulling into garage; headlight cover/ replacement; mini shelves for small items; number hanger; oil drip catcher; paint container for touch-ups; reminder on car door; spoon or scoop; temporary paint can cover. |
| Car or Workplace      | Car traction under tire; cell phone holder; coin bank or holder; container for paper clips; cover on cups in car; hanging air freshener; hanging rear-view mirror decoration; mix paints for touch-up and lay wet brush on tray; portable plate; reminder on windshield; scraper for ice on windows; tea bag rest. |
| Garden                | Bird feeder; border around plantings; create a network of juice bottle bottoms for a vented greenhouse effect; cut it and attach to stick as rake; decoration or sign on tree or fence; digger; drill holes for drip irrigation; edger; golf hole cover; holder for seeds to be planted; landmark for plantings; pet pooper scooper; pet toy; protect seedlings with small hand tilter; row marker; shovel; sun catcher; turn into plastic flower decoration; use with twinkle lights for decoration. |
| Clothes Closet or Jewelry Chest | Attach adhesive for lint remover; clothes tag; clothing divider; cut outside in shape of plus sign and screw to wall as clothes hanger; divider in closet; hanger for jewelry; jewelry stand made from several combined; label for dirty clothes; make into decorative vest; make on a base and cut another into X shape and store rings on it; necklace hanger/ organizer; paint to match clothing; ring holder; sachet; scarf hanger; separator for neckties or scarves; show stretcher or support. |
Table 4.
Possible restrictions and ways of defining the product to be made of recycled juice bottle bottoms.

| Frequency | Category                                      | Example Problem Definition Statements                                                                 |
|-----------|----------------------------------------------|--------------------------------------------------------------------------------------------------------|
| 25        | Purposeful and Useful Product                | Product needs to be used at home. Use the product for seaside purposes. The product needs to be more   |
|           |                                              | useful than decorative.                                                                                |
| 15        | Configuration or Method of Construction      | Must use hot glue, string or other types of fasteners to make the product. One juice bottle bottom piece|
|           |                                              | must remain intact. The product must stay transparent.                                                 |
| 7         | Educational or Effective in                  | The final product must be aimed at helping those of lower socio-economic status. This item should be   |
|           | Facilitating a Higher Purpose                | used by all across race or ethnicity. The product must be designed to better the world.               |
| 7         | Attractive                                    | Product must be pleasing to the eye. Product must be attractive to children.                           |
| 6         | Decorative                                    | The product can be encrusted with glitter, sequins, buttons, etc. for decoration. The product needs to  |
|           |                                              | be decorated with paints or markers.                                                                  |
| 5         | Shape                                         | The product must stay round. The product should resemble an animal in shape.                           |
| 5         | Safety                                        | The product needs to have no sharp edges. The product must be large enough not to be swallowed by pets. |
| 5         | Manufacture and Marketing                    | Needs to take less than 30 minutes to manufacture by hand. The product should be put together as a     |
|           |                                              | do-it-yourself kit.                                                                                    |
| 4         | Environmentally Friendly                      | The product must send a positive message about recycling. The product should promote environmental     |
|           |                                              | education and enjoyment.                                                                              |
| 3         | Toy                                           | The product should be a toy or something to play with.                                                |
| 3         | Melting of Plastic                            | The product should not be melted during its manufacture. One can heat and melt the plastic juice bottle |
|           |                                              | bottoms while creating the product.                                                                  |
| 2         | Teamwork                                      | The class should determine the central theme. The product has to be made by a team—each person adds   |
|           |                                              | something and then passes it on to the next person.                                                   |
| 2         | Portable                                      | The product must be portable.                                                                          |
| 2         | New and Original                              | The product must be completely new. The product can be a modification of an existing item.            |
| 2         | Durable                                       | The product must be durable.                                                                          |
| 2         | Cost                                          | The product must be usable.                                                                           |
| 1         | Time                                          | The product must be no more than $5.00.                                                                |
| 1         | Time                                          | The time for the product’s creation must be limited.                                                   |

Table 5.
Ideas generated by thinking of how the juice bottle bottoms might be manipulated in different ways.

| Way of Manipulating | Items to be made of Juice Bottle Bottom or Bottoms |
|---------------------|----------------------------------------------------|
| Drill holes, cut slot, use hot glue, epoxy, string, to attach | Add holes for slotted spoon; bird feeder (4); castanets; cat toy (2); catapult; chandelier; clothing divider; coat rack; connect six in cube shape, fill holes with duct tape, and create slot for ball; covers; decorative flower; drawer organizer; drill many holes and attach a band, sheet, row, pile, container, as support, use hot glue, epoxy, drill holes, cut slot, to attach string, to attach with glitter, sequins, buttons, etc. for decoration. The product must be decorated with paints or markers. |
| Use paint, markers, line with foil, encrust with glitter, sequins, to color or decorate | Bangle bracelet, belt buckle; brooch (2); Christmas ornament (3); coaster (2); connect three together, attach handle, and decorate for a fan; decoration; door knob decoration; earrings (5); flowers; flying saucer toy; Frisbee; hair accessory; holiday decoration; lid; line with foil for mini solar cooker; musical instrument; necklace pendant (2); number sign; original artwork; paper holder; parking tag; pattern for painting or pastry; plant decoration; reflector along path; reflector to wear when walking; reward for achievement; sewn into a fabric bag and walk on to massage feet; shell game; stack together, paint green and glitter for Christmas trees; stained glass; sun catcher (2); tag; tea bag holder; wall decoration (3); wreath |
| Arrange in a circle, band, sheet, row, pile, sphere, flat, stack, doubled as a lentil, or single | Alphabet letters; bed frame post; bicycle decoration on spokes; bird feeder; bobbin for ribbon; bookends; carry out cup lid; chocolate mold; classroom spotlight; coin holder; counter; curtain; decorative bowl; drum; earring; Frisbee; frosted window; furniture slides; goggle eye glasses; headlight cover; ice mold; kaleidoscope; knee protector; lightweight ball; mancala game board; mini-plates for dips; necklace (2); noise maker; outlet cover; paint palette; picture frame; plastic vest; playhouse window; reminder; replace token when playing cards; ring for drawing back curtains; snowflake ornament; soap dish; soap or candle mold; target; Tiki torch; toy hat; wall hanging; wreath (3); yoyo |
| As a dangling disk, as container, as support, pedestal, as lid, as wall, as scoop | Attach two on sides of a cap as a translucent sun shield; attach to bottom of shoes as ice grippers; bird feeder (2); candy dish; chandelier; child’s mobile; connect four to make walls of a mini-terrarium; cover for seeds on ground; cup lid; decoration on car hub cap; game—place several on floor and try to toss rocks into them; glass and bowl support base; ice fishing slush scoop; individual salsa container; jewelry stand (2); Kool-Aid stir spoon; ladle; litter box scooper; measuring cup; medallion; mobile (2); nail/screw container; paperweight; pedestal for spices; potpourri holder; privacy screen; roulette; room divider; scarecrow; scoop for Epsom salts for bath; seed starter; signs; soap dish; spoon rest; sugar scoop; sun catcher; support between book and wall of library; support for contact lens case; tassels for shoes; tea bag rest; use to fix hole in cloths by drawing through hole in juice bottle bottom and tying with ribbon; wind chimes (2) |
Identifying more- and less-creative ideas. The reasons given for choosing a product as particularly creative, as shown in Table 8, are originality, visual appeal, complexity, and functionality. Personal implicit theories allowed participants to judge the creativity of their products even when these individuals did not perhaps have a specific definition of creativity in mind. Implicit theories are personal opinions of non-experts in contrast to explicit theories developed by professionals through research (Runco, Nemiro, & Walberg, 1998). Two of the criteria, originality and functionality, used by participants were similar to those identified in a study of implicit theories of creativity of students from the United States, China, and Japan: novelty and appropriateness (Paletz & Peng, 2008). Elaboration and originality, along with fluency and flexibility, are Guilford’s four divergent production abilities that are often used as a foundation for measuring creativity (Guilford, 1967; p. 138). Participants identified complexity as a criterion for identifying a creative product; this may be similar to elaboration. Additionally, complexity has been identified as the most important characteristic of highly creative visual arts products (Brittain & Beittel, 1960). Finally, visual appeal, identified as a criterion for a creative product by participants, has also been used as a criterion in a study of art students’ products (Getzels & Csikszentmihalyi, 1976): artists and art critiques rated drawings on aesthetic value. Additionally, The Torrance Tests of Creative Thinking streamlined scoring guide (Torrance, Ball, & Safer, 2008) lists the creative strength of “richness of imagery” as a score-able creative trait. This creative strength involves images that are lively, intense, vivid, appealing to the viewer, and show variety.

Participants’ reasons given for classing ideas as not creative, provided in Table 9, seemed to be the opposite of why ideas were chosen for being most creative. However, lack of visual appeal was not a reason that appeared to influence a decision of lack of creativity in this participant sample.

The First Products

Figures 2 and 3 show the products generated by participants. Everyone was able to create a viable and satisfactory product from the juice bottle bottom pieces. Two people created two products (one person made the dish and spin top; another

Table 6.
Reasons for favoring one above the other idea generating activities.

| Favored Activity                          | Frequency Chosen | Reasons for Favoring This Method for Idea Generation |
|-----------------------------------------|------------------|-----------------------------------------------------|
| Generating products for different rooms| 5                | By seeing the room, I could focus on that aspect. I am a visual learner and could visualize the products in the rooms. The visual support of the room layouts was important for me. The choices of how to arrange the juice bottle bottom disks helped me generate product ideas. |
| Manipulative activity                   | 4                | This helped me think of a greater variety of ways to use the disks. I wasn’t restricted by where the object could be used. |
| Page of constraints                     | 2                | This was like verbal brainstorming for me. I only had to consider one idea and how to constrain it. |

Table 7.
Emotional reactions early in the project.

| Positive Emotional Reactions | Frequency |
|------------------------------|-----------|
| Excitement at the creative challenge | 4 |
| Playful, childlike, joyful in trying out ideas | 3 |
| Completely engrossed in the problem | 2 |
| Satisfaction in generating good ideas | 1 |
| Stressed to have to generate ideas followed by relief when the task was complete | 5 |

| Negative Emotional Reactions | Frequency |
|------------------------------|-----------|
| Frustrated or exasperated when trying to think of ideas | 5 |
| Lack of confidence in ability to be creative | 4 |
| Confused or perplexed about what to do next | 2 |
| Restricted or limited by the juice bottle bottoms | 2 |
| Fear of not having enough time to think of the best idea | 1 |

Table 8.
Reasons for choosing ideas as particularly creative after the early idea-generating activities.

| Reason for Choosing Idea as Creative | Idea | How the Idea Was Generated |
|-------------------------------------|------|-----------------------------|
| Protect hands when hammering a nail by using a hole drilled in the juice bottle bottom to hold the nail | Mentally visualizing where I can use the item |
| Unusual, unexpected, different, unconventional idea that I have not seen before | Mental |
| Clothing divider in closet | Examination needs in my own closet |
| Line with foil for mini solar cooker | Continually thought of ways to combine and manipulate the bottoms |
| Small hand trowel | I like to work with gardening and so thought of how to use it there |
| Wall sticker | Focusing on rooms helped me get this idea |
| Chandelier | Thinking of the rooms and what I might find in them |
| The light art sculpture with beautiful lighting effects | I combined some of my technical theatre skills as a designer with the juice bottle bottoms |
| Decorative book ends that are drilled, glued, painted, decorated and made of multiple juice bottle bottoms | I put myself in that room and observed my surroundings |
| Making a mold and then using it to paint the wall | The bottom has a star that made me think of a decoration |
| Highly functional Holder | Some way I would really use it |

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Table 9.
Reasons ideas were judged as not creative.

| Category of Reason | Specific Reason | Idea Judged as Not Very Creative |
|--------------------|----------------|----------------------------------|
| Lack of Originality| It was one of my first ideas | Doorstop |
|                     | These ideas seemed obvious | Drink coaster |
|                     | The idea is not new; there are ornaments that look like these bottle bottoms that are sold in stores for Christmas decorations | Earrings |
|                     | All of the saucer and little dish ideas because they are basically the same idea | Medallion |
|                     | Anything could be used for decoration | Holiday ornament |
| Lack of Complexity  | You wouldn’t have to transform it or do anything to it | Saucer |
|                     | You don’t have to change its look or composition | Coin tray |
| Lack of Functionality| It would not really fulfill the function well | Decorative pieces |
|                     | | Soap dish |
|                     | | Tray for nuts and bolts |
|                     | | Wheels for toy vehicle |
|                     | | Miniature Frisbee |
|                     | | Coin holder |
|                     | | Knee protector |
|                     | | Wind chime |

person made the party hat and flowers); one of these was inspired by suggestions from a relative (the flowers). The products represented a wide range of usage areas from entertainment (maracas, party decoration, party hat, spin top, catch game, yoyo) to table and food use (candy suckers, dish, candle holders) to home décor (party decoration, wall decoration, flower arrangement) and household use (closet clothing organizers).

The products were strongly influenced by the skills, interests, and prior experiences of the makers. For example, a person with theatre experience made the maracas and performed briefly with them when showing them to the class. The candlesticks were made by a participant who had been involved in theatrical set design; she explained that she had often been required to create expensive-looking set items from inexpensive materials. The person who made the wall décor told how she had made other decorative elements for her home in these same colors. The participant who made the ladybug on the yarn flower had experience in crochet and knitting. The catch game was influenced by an elementary-age son of a participant who enjoys active games. Similarly, the creator of the party hat often makes paper hats for special occasions.

Techniques for manipulating the given material for the first product. The physical properties of the juice bottle bottom pieces affected the product choices of participants. Several people remarked on the light and shadow pattern of the star-shaped mold impression in the center of the circular plastic piece, expressing a desire to make use of that in the product. Makers of the dish, spin top, yoyo, candlestick holders and catch game enjoyed this effect, highlighting it in their products. Several other participants used the art technique of reverse painting to produce a colorful object with a very glossy plastic surface. The room décor and closet clothing bar organizers employed this technique. The maracas and ladybug combined sparing use of paint with the transparent light and shadow design to produce pleasing patterns in their products. Applying black marker lines and glitter to the back of the plastic piece was combined with reverse painting to make a shimmering, glossy product in the psychic eyes of the party hat and the flowers in a pot. The star-shaped central impression of the given recycled plastic pieces was put to use as a candy mold for the colorful, patterned candy suckers. Finally, the cupped, circular shape of these plastic pieces was covered with wrapping paper and used as a support for bows and additional decorations in the party decoration.

Participants used a variety of methods to attach the plastic pieces to each other or to additional materials. Drilling holes was the method used by several participants. The closet clothing rod organizers were produced by drilling a very large cen-
entral hole so that they could slide onto the closet rod. Screws inserted into drilled holes held together the fancy dish and spin top, while a small wooden dowel was placed in a drilled hole for the yoyo. Wire was used in drilled holes to attach the ladybug wings, chenille sticks were used as flower stems for the flower pot, and thread was sewn through holes in the eyes for the party hat. The makers of the maracas, wall décor, and candle holders used hot glue or cement to hold their inventions together. The participant who made the maracas explained that she used the colorful yarn braid to decorate the maracas while hiding the hot glue seam. Finally, two types of tape were used in these first products. The ball toss and catch game’s creator used duct tape to hold a spoon to each of the catch paddles, while the party decoration maker used clear plastic tape to attach the party decorations.

Criteria for choosing a product idea. Table 10 shows participant reasoning for choosing one idea over others for the first product. Many reasons focused on practical aspects of creating the product. This may be a reflection of the limited time graduate students have for homework. The last two reasons given in Table 10 correlate with two of the factors for considering a work to be creative: usefulness and originality.

Creation of the Second Products

Participants had two weeks to create a second product with one to four juice bottle bottoms. Researchers observed that participants approached the second challenge with enthusiasm fueled by recent success of making a first product. Most welcomed the opportunity to improve the first product or implement new ideas to make a new product.

Products made. Figures 4 and 5 present the second products made by participants. Again, participants created a variety of colorful, useful items. Two materials for teaching elementary students were produced: an attractive diagram of the life cycle of the Polyphemus Moth, and a two-sided hedgehog having a clock with movable hands on one side and information about the diet of the animal on the other. This is a reflection of the study population as being composed of teachers or former teachers.

Participants’ second products formed four categories: products that were very similar to the first products but improved in some way (see Figure 6); second products that resulted from the expansion of first product ideas into additional items (see Figure 7); products that were different than the first products, but related by being similar in theme (see Figure 8); and, finally, products that were inspired by the first product ideas of other class members (see Figure 9), as discussed in the next section.

Inspiration from viewing products of other participants. Table 11 presents participants’ insights, inspirations, and ideas after seeing the creative products of classmates. Responses between the making of the first and second products were very similar: both times participants noted how they might use a technique in the future; remarked about the desirability of decoration; suggested they might make use of other people’s ideas; commented that recycled materials might be put to use for other products; observed that interest and strengths contribute to effective products; and mentioned that usefulness was important. Initial perceptions of the assignment were that the circular juice bottle bottoms would limit the creative ideas for products. The third insight category shows that six people noted

| Table 10. Reasons given for why idea for first product was chosen above other competing ideas. |
|---------------------------------|-------------------------------------------------|
| Frequency | Reason Product Was Chosen                        |
| 3         | Clear vision of how to make it                   |
| 3         | Could use available items without spending extra money |
| 3         | Do-able within time constraints                   |
| 3         | Practical product that will actually be used      |
| 2         | Perceived as a unique idea                        |

| Table 11. Insights after making the first and second products. |
|-----------------|---------------------------------------------------------|
| Product | Frequency | Insight Category                      |
| First          | 9          | A technique I might use in the future. |
| 7              | More decoration/elaboration is a plus.                |
| 6              | Although at first the given items seemed limiting, they were not. |
| 4              | One’s experiences and skills influenced product.      |
| 4              | Many items might be recycled—one could create challenges. |
| 3              | Taking another person’s idea and applying it to your own product. |
| 3              | Practical/useable items are effective.                |
| Second         | 11         | Another person’s ideas of expanding the product might be applied to my own or to a new product. |
| 7              | One could make even more useful things with recycled items. |
| 6              | A technique I might use in the future.                |
| 4              | The nature of creativity as being learned and related to personality and strengths. |
| 3              | Practical/useable items are effective.                |
| 1              | More decoration/elaboration is a plus.                |

Figure 4. Second products (Part 1).
that one could indeed generate many viable, different, creative ideas.

Creative aspects of products. Participants' identification of the most creative aspects of both the first product and the second product are shown in Table 12. In both trials, three of the eight components of a creative product (Cropley, 2000) were recognized by participants in their work: well-craftedness, aesthetic appeal, and relevance. Two other components, originality and usefulness, were mentioned once in the two trials. The remaining three components of creative products listed by Cropley, complexity, understandability, and germinality (introducing a new way of conceptualizing an area by opening up new approaches to the problem (Runco & Pritzker, 2011) were not discussed as most creative traits of products. However, the set of products produced exhibited all eight of these traits; participants just did not recognize the last three traits as being their products' most creative aspects. For example, one of the first products, the candy sucker, showed germinality because it introduced a new way of thinking about products using the bottle bottom pieces. Instead of using the pieces as part of a plastic product, the inventor used the pieces as molds to make a candy product. This was an entirely new way of viewing the problem.

Influences and ideas for products. Table 13 explains the participants’ skills that influenced the creation of their products. Most participants mentioned content knowledge within a do-
main, experience and preparation, and cognitive skills from various domains as influencing their product choice, as these are dimensions (along with social-emotional processes, family aspects, cultural aspects, and historical forces) of creative development leading to successful product creation in a domain (Feldman, 1999). These findings indicate that participants tended to create their products in domains with which they had experience and psychological comfort. Several personality traits were also mentioned: active imagination, playful attitude, patience, flexibility, and ability to restructure problems. These personality traits or abilities were five of 11 listed by Cropley (2000).

Table 14 shows how the students obtained their ideas when creating both the first and second products. During the creation of the first product, many participants imposed criteria on their product choices, more than the second trial in which they tended to use a strategy to modify their first product. Those who created a new product, somehow related to the first product but not a modification or improvement of it, seemed to be the ones who reported imposing new criteria on their work for the second trial. Those whose second products were improvements of their first tended to report using strategies to obtain ideas.

Perceptions of creativity. Table 15 documents the participants’ perceptions of personal creativity and creativity of products during the study, from the initial activity to the final product. T-tests were conducted to determine if statistically significant differences existed between perceived general creativity from the beginning to the end of the study and between perceived creativity of the first and second products. No significant differences were found. This result may be related to the time span of the study being fairly short (5 weeks), the fact that participants had practiced some creative techniques with other assignments previously in the course, and participants rated themselves as quite creative (about “7” on a scale of 1 to 10) at the outset of the study.

Conclusion

The current investigation compared participants’ problem solving process to several popular models. The model with the fewest stages was Adair’s (2010) three-pillared bridge. The first pillar was “defining the problem”; the second pillar was “generating feasible options”; and the last pillar was “choosing the optimum course/solution” (Adair, 2010: p. 53).

The participants in this study took a similar approach in using restrictions to better define the given loosely-defined problem, generating solutions through several activities, and then choosing an optimal product that fit their restrictions. These restrictions often included time, skill, and cost constraints. Refinement of several products took place as participants made their second products, but inspiration sparked expansion of products, new, yet related, products or entirely different products resulting from combinations of ideas. Imposing additional criteria often led to unique, less strongly-connected second products.

Participant reflections revealed personal implicit theories of characteristics of creative products as original, visually appealing, complex, functional, well-crafted, and relevant. The two creative product criteria recognized by Cropley (2000), but not mentioned explicitly by study participants were understandability and germinality. As mentioned previously, one product, the
Table 14.
Method of obtaining idea for product as reported by participants.

| Product | Frequency | Method of Obtaining Idea or Constraint | Category     |
|---------|-----------|----------------------------------------|--------------|
|         | 3         | Challenged myself to make something entertaining—A toy | Imposed criteria |
|         | 3         | I connected to something I saw and made a similar product | Strategy |
|         | 3         | Wanted to make something really different | Imposed criteria |
|         | 2         | I challenged myself to make it all from recycled materials | Imposed criteria |
|         | 2         | I looked around my house for materials and ideas | Strategy |
|         | 2         | Reviewed the ideas I had generated earlier and my list of constraints | Strategy |
|         | 2         | Wanted to incorporate a particular technique | Imposed criteria |
|         | 1         | Challenged myself to make something visually appealing | Imposed criteria |
|         | 1         | Considered problems of others and how my product might solve them | Strategy |
|         | 1         | I decided to make a decorative item | Imposed criteria |
|         | 1         | Manipulated the pieces to gain ideas | Strategy |
| First   | 1         | The pieces played with light so I wanted to make a product using this aspect | Imposed criteria |
|         | 5         | Desire to make a useful product | Imposed criteria |
|         | 3         | Inspired by classmate’s product | Strategy |
|         | 3         | Wanted to use a particular technique | Imposed criteria |
|         | 2         | Modified original product to improve it | Strategy |
|         | 1         | Decided to depict a favorite animal | Imposed criteria |
| Second  | 1         | Learned a technique from other products | Strategy |
|         | 1         | Manipulating the pieces helped me generate an idea | Strategy |
|         | 1         | Saw something at home and adapted it | Strategy |
|         | 1         | Use SCAMPER Technique to gain ideas | Strategy |

Table 15.
Creativity in recent work and in general on a scale of 1 to 10 in which 1 is not creative and 10 is very creative.

|                          | Mean creativity rating of initial ideas for possible products | Mean general creativity reported at the time of rating the initial ideas | Mean creativity rating of the first product | Mean general creativity rating at the time of first product | Mean creativity rating of the second product | Mean general creativity reported at the time of second product |
|-------------------------|-------------------------------------------------------------|-----------------------------------------------------------------------|---------------------------------------------|-------------------------------------------------------------|-------------------------------------------------------------|-------------------------------------------------------------|
| First                   | 6.9 (1.6)                                                   | 6.7 (1.3)                                                            | 6.8 (1.5)                                  | 6.9 (0.8)                                                   | 7.2 (1.8)                                                  | 7.1 (1.2)                                                  |

Note: Standard deviations given in parentheses.

candy suckers made from using the juice bottle bottoms as a mold, introduced the conception of using the given materials to manufacture the product rather than as an actual part of the final product. This candy sucker product can therefore be considered as representing germinality. All products, once named, were understandable. Perhaps participants did not mention this aspect because it was assumed that the product needed to be understandable.

The authors hope that this journey into the problem solving process will be useful for others as an in-depth example of how different people approached the same loosely-defined problem. All were successful in solving the problem in interesting, unique ways. The large variety of products from different categories shows that participants were able to overcome functional fixedness of the circular, dish-shaped given material to generate items with many configurations and uses. Many useful insights were generated as participants approached the problem a second time and considered the inventions of classmates.

Suggestions for Future Research

In-depth problem solving studies such as the current study might be implemented with younger participants such as elementary students to investigate differences and similarities in the process. Two notable early childhood problem-solving studies have been conducted: toddlers working with cylinders and spheres (Geiken, 2011) and first graders working with wooden block ramps and pathways for rolling marbles (Van Meeteren, 2013). Few other early childhood studies have been completed to investigate the invention process of younger children.

An investigation of participants of multiple ages might reveal developmental changes in approaches. This invention problem solving project might be a good activity for residents of a retirement community or a mental health facility. The creative problem solving process might facilitate social connections, usage of prior knowledge and skills, and a sense of satisfaction in the
making of a creative product.

Implications for Classroom Practice

This article can be used as an example of the problem solving process. A teacher wanting to integrate problem solving with a content area might provide similar given recycled items to students and restrict the problem to one related to the content being studied. For example, if a unit on African history is being studied, students might make African musical instruments, architectural models, costumes, jewelry, or masks. If the content area is science, students might make water or rock cycles, atomic models, planetary mobiles, laboratory equipment, models of fossil life, or a diagram of the parts of a flower. This project might also serve as a model for adult groups creating holiday decorations for charity bazaars from recycled materials.

Even though the current project extended over a five-week period, only about one hour per week was spent specifically working in class on this project. The authors suggest that class instructors implementing a similar product-making project allow more class time for reflection and discussion of ideas, particularly if the students are enrolled in K-12 schools rather than being adults in a graduate course.

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