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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 Treffinger 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 pertaining to the problem; 3) framing problems or problem-finding—listing all possible ways of defining the problem; 4) generating ideas or idea-finding—generating ideas for solving the problem, including those that are wild or unusual; 5) developing solutions or solution-finding—choose and apply criteria for evaluating ideas to find the best solution; and 6) building acceptance or acceptance-finding—plan implementation by identifying responsible persons, a timeline of actions, and available resources.

The I's of Inspiration

Jane Piirto (2004) identified seven "I's" of the creative process: 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: inspiration of love or visitation of the muse in which one is inspired by a loved one; inspiration of nature in which one sees the commonplace 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. Improvisation 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 stage, 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 comprehensive 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 interpreted 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 solution 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 restrictions to better define the problem. An ill-defined problem is one in which the methods and solutions are not provided, allowing 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 problem.

Method

Participants

Eleven adults (7 female, 4 male; 1 African American, 2 Middle 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 discussed 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. Participants were asked to begin thinking about an invention or product 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 concerns 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 ways to structure the problem beyond "make a product using one or more juice bottle bottom pieces." Participants were required to define ten different ways to further restrict the problem.

The third part of the activity asked participants to consider different ways of arranging or altering the plastic juice bottle bottom disks to generate additional product ideas. The given

Table 1.
Comparison of models of the creative process of problem solving.

Wallas's Four Stages (1926)	Creative Problem Solving Model of Osborn (1963), Parnes (1981), and Treffinger & Isaksen (2005)	I's of Inspiration Piirto (2004) and Davis, Rimm, & Siegle (2011)	Four Stage, Eight Step Process Basadur & Basadur (2011), Basadur, Graen, & Green (1982)	Three-Pillared Bridge of Adair (2010)	Current Study Activities
Preparation	Part 1: Understanding the Challenge	Inspiration	Stage 1: Generation	Pillar 1: Defining the Problem	Enrollment in a class on problem solving
	Constructing Opportunities (Mess-Finding)		Problem-Finding		Being presented with the ill-defined problem of making a product of the plastic pieces
	Exploring Data (Fact-Finding)		Fact-finding		Thinking about the problem and generating initial ideas
	Framing Problems (Problem-Finding)	Imagery Imagination	Stage 2: Conceptualization Problem Definition		Imagining products for rooms in a house
					Adding constraints to define the problem
Incubation	Part 2 Generating Ideas Generating ideas (Idea-Finding)	Incubation	Idea-Finding	Pillar 2: Generating Feasible Options	Generating ideas by manipulating the pieces
		Intuition Improvisation			Allowing one's subconscious to work on the problem
Illumination		Illumination			Feeling that one has some good ideas
Verification	Part 3 Preparing for Action Developing Solutions (Solution-Finding)	Implementation	Stage 3: Optimization	Pillar 3: Choosing the Optimum Course/ Solution	Identifying more and less creative ideas
			Evaluate		Choosing an idea for the product
			Select and Plan		
			Stage 4: Implementation		Making the first product
	Building Acceptance (Acceptance-Finding)		Acceptance		Viewing products of others to gain ideas Additional creative idea generation activities
			Action		Making the second product

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 to tell why. They were also required to identify their most creative ideas and least creative ideas, explaining 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 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-Palmon, 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

Figure 1.
A plastic juice bottle and two circular bottom pieces.

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.

Table 3.
Ideas generated by thinking of how the juice bottle bottoms might be made into a product used in each part of a house.

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, stove 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 make-up 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; manipulatives for counting; musical instrument; paint pallet; rattle; scoop 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 tiller; 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.

item. The addition of color and glitter or sequins inspired participants to envision decorative items as shown in the second category of **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 produce effective ideas.

Emotional reactions to the project. Table 7 demonstrates 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 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 Facilitating a Higher Purpose	The final product must be aimed at helping those of lower socio-economic status. This item should be 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 cost of manufacture should 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 bank; covers; decorative flower; drawer organizer; drill many holes and attach a stick for a mini sand sifter; fancy door knob with gems inside; go-cart wheels; glue together with beads inside for rattle; hanger saver; hanger; hanging pot holder; jewelry stand (2); key holder; lamp shade; lemon holder; make a hole in middle for a nail and hold the plastic—not the nail—when hammering in a nail; make hole in middle for napkin holder (2); multi-layer fountain; paperweight; pepper shaker lid; pieces for a decoration; plastic snowflake decorations; protect seedlings; serving bowl, stove rest; sun catcher; thread roll; tissue holder; tote bag; wall sticker; wheels for toy; wind chime (4)
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; doorknob 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); candle holder (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; taps 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)

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.
Manipulative activity	4	The choices of how to arrange the juice bottle bottom disks helped me generate product ideas. 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

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, & Safter, 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.

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
Unusual, unexpected, different, unconventional idea that I have not seen before	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
	Clothing divider in closet	Examining 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
Visually appealing	Wall sticker	Focusing on rooms helped me get this idea
	Chandelier	Thinking of the rooms and what you 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
Complexity of manufacture	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

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 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
		Drink coaster
	These ideas seemed obvious	Earrings
		Medallion
	The idea is not new; there are ornaments that look like these bottle bottoms that are sold in stores for Christmas decorations	Holiday ornament
	All of the saucer and little dish ideas because they are basically the same idea	Saucer
		Coin tray
	Anything could be used for decoration	Decorative pieces
Lack of Complexity	You wouldn't have to transform it or do anything to it You don't have to change its look or composition	Soap dish
		Tray for nuts and bolts
		Wheels for toy vehicle
		Miniature Frisbee
		Coin holder
Lack of Functionality	It would not really fulfill the function well	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

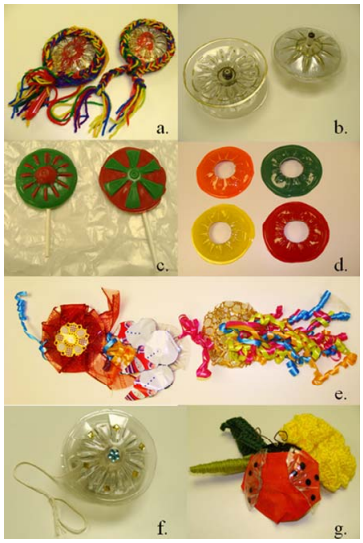

Figure 2.
First products (Part 1).

Figure 3.
First products (Part 2).

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-

tral 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 Polythemus 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/usable 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.
	1	Practical/usable items are effective.
	1	More decoration/elaboration is a plus.

Figure 4.
Second products (Part 1).

Figure 5.
Second products (Part 2).

Figure 6.
First products changed to produce better-crafted second products.

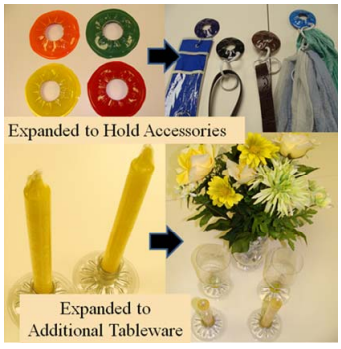

Figure 7.
First products expanded to make related second products.

Figure 8.
Second products related by category to the first products.

Figure 9.
Second products inspired by the first products of others.

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-

Table 12.
Most creative aspects of product determined by maker.

Product	Frequency	Specific Creative Aspect	General Creative Category
First	6	Solving a technical problem with the product in an effective way	Well-craftedness
	4	Appealing physical appearance of the product	Pleasingness or aesthetic appeal
	3	Product was constructed from given and available items; no new components had to be purchased	Relevance
	1	Taking a common idea and making it unique	Originality
	1	Being able to make something that stood up to my standards	Well-craftedness
Second	5	Product was constructed from given and available items; no new components had to be purchased	Relevance
	4	Solving a technical problem with the product in an effective way	Well-craftedness
	4	Appealing physical appearance of the product	Pleasingness or aesthetic appeal
	1	Functionality of the product	Usefulness

Table 13.
Skills reported that influenced their product choice and creation.

Frequency	Skills That Influenced Product	Origin
7	Drawing, cutting, craft and painting experience allowed conceptualization of the product	Domain content knowledge and experience
5	Active imagination and ability to visualize	Personality trait
5	Access to and expertise with a drill and duct tape	Domain content knowledge and experience
3	Sewing/crocheting/knitting skills	Domain content knowledge and experience
3	Experience with theater and set design	Domain content knowledge and experience
2	Science knowledge	Domain content knowledge and experience
2	Playful attitude	Personality trait
2	Experience in chocolate candy making, cooking, baking	Domain content knowledge and experience
2	Art and décor design	Domain content knowledge and experience
1	Patience	Personality trait
1	Modeling/sculpting skills	Domain content knowledge and experience
1	Ability to adapt items (flexibility) and restructure problems	Personality trait

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
First	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
	1	The pieces played with light so I wanted to make a product using this aspect	Imposed criteria
Second	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
	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
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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