BIOMEDICAL ENGINEERING | RESEARCH ARTICLE

A triz-directed approach in proposing device-oriented ideas that cultivate water-drinking habits among children

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Abstract: This study aims to investigate problems concerning water-drinking habits among children, ongoing efforts to resolve these problems, limitations in these ongoing efforts and recommended ideas to overcome these limitations. The TRIZ approach was used primarily to identify the root causes of the main problem and establish technical contradictions in order to steer the researchers to specific solution models. The solution models generated from the 40 inventive principles of TRIZ were used to recommend ideas that could potentially resolve the technical contradictions. The recommended ideas were then substantiated with existing research, concepts or analogies in order to authenticate their practicalities with regard to the study’s aim. The inventive principles extracted include the universality, preliminary action and segmentation principles. The principles used allowed the proposal of inventive design recommendations at the end of the study. For instance, based on the segmentation principle, the idea to improve water-drinking habits among children can be in the form of a water bottle that is compartmentalised into two parts; the top part being the containment unit for the water and the bottom

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PUBLIC INTEREST STATEMENT

Every parent should be concerned about their child’s daily water intake. Children who do not drink enough water experience headaches, constipation, fatigue, obesity and reduced cognitive performance. In today’s busy society, parents who work full-time often find themselves stressed and short on quality time with their children. These parents might resort to nagging or scolding when it comes to getting their children to drink water. Without proper tools, effectively training a child to develop water-drinking habits can be difficult. Hence, a device is necessary to facilitate the process of cultivating a child’s water-drinking habit. This study uses a systematic innovation technique known as TRIZ to help researchers propose ideas for such a device. Using TRIZ principles, ideas such as the dual compartment water bottle, and measurement, accumulation and display device were proposed and discussed. Further research on these ideas can be explored, especially on the design, development and testing stages.
part being the storage section for a reward beverage (perhaps a sweet drink such as orange juice or syrup). The compartmentalised water bottle idea would entice children to completely consume the water in the bottle before accessing the reward beverage. Although further research and verifications are still required, the proposed ideas can serve as precursory recommendations for researchers and designers in their pursuits to improve the water-drinking habits among children in future.

**Subjects:** Ergonomics; Cognitive Ergonomics; Ergonomics & Human Factors; Work Design - Ergonomics; Technology; Industrial Design

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1. **Introduction**

   In the era of modernisation, people tend to overlook the effects of globalisation on the environment. One of the most significant effects is the increasing temperature of the Earth’s surface (Chan, 2018). Although it takes years for the full scale of the problem to seriously take effect, the initial repercussions are still experienced through the intense temperature from the drought season in countries such as China, Pakistan, and Iran. The degradation of the environment will slowly affect the ecosystem and living environment, and bring detrimental impacts upon the earth, one of which includes global warming (Jariya & Maitree, 2013). Besides the drought, effects can also be observed through the massive heat wave in countries such as Saudi Arabia, Sudan, and even Russia. Even though far apart, the sudden rise of temperatures in these countries during different periods of the year is gradually becoming an eye opener for everyone especially to those living in these countries.

   As a result from the increase of Earth’s surface temperature, dehydration becomes one of the negative effects that humans often have to face (Bortholy & Pongracz, 2018). Even though individuals have been taught to drink sufficient fluids every day, they can still encounter involuntary dehydration without realising it due to their hectic schedules and daily activities (Greenleaf, 1992). However, the most commonly observed form of dehydration is voluntary dehydration, which often occurs when an individual refuses to drink sufficient fluids, especially non-sugary beverages such as water (Masento et al., 2014). Water plays an important role in maintaining the hydration levels of an individual (Jequier & Constant, 2010). In fact, water plays multiple important roles in a functioning body. For example, it acts as a carrier of nutrients and waste products, solvent, reaction medium and even reactant. Water also acts as a lubricant and shock absorber for the body (Jequier & Constant, 2010). Water is vital for the continual sustainability of life.

   The average sedentary adult man needs to consume at least 2,900 mL of fluids daily while an average sedentary adult woman needs at least 2,200 mL per day in order to stay hydrated. This amount can come from non-caffeinated beverages, non-alcoholic beverages, soups and food (Kaushik et al., 2007). Infants aged 6–12 months need a total water intake of 800–1000 mL/day. Once a child reaches 2 years of age, a total water intake of 1100–1200 mL/day is adequate. Boys and girls between 2–3 years of age would require 1300 mL of water per day while children aged 4–8 would need 1600 mL/day. As children reach the age of 9, the daily water intake requirement differs depending on their gender. A boy aged 9–13 years would need 2100 mL of water per day while a girl within that same age group would require 1900 mL/day (Kavouras & Armstrong, 2010). However, there has not been one unified standard on the healthy amount of drinking water required for children due to various conditions such as climate and lifestyle. For example, the total daily mean intakes of water for American children between ages 2–5 and 6–11 years are 1.4 L and 1.6 L respectively (Kant & Graubard, 2010).
It may not be appropriate to generalise the practice of consuming large amounts of water every day or even setting a minimal intake of water consumption due to interfering factors such as climate, diet and physical activity (Jequier & Constant, 2010). Although there have been many guidelines concerning the minimum required amount of drinking water to be consumed per day in order to remain hydrated, the emphasis should in fact be made to encourage individuals to monitor their hydration level (Masento et al., 2014). This ideology should also be applied in the case of a child’s hydration habit as much as it should in the case of an adult. It is not the amount of water intake, rather the child’s hydration level that should matter. Parents need to comprehend this idea and educate their children instead of just forcing them to drink a lot of water every day.

In association to the aforementioned rationalisations, it is important to ensure that enough fluids are consumed daily to maintain a healthy body. Although it might sound easy for adults to establish a habit of drinking water, there are some who still do not drink enough fluids daily. Using a simple analogy, if an adult is already not drinking enough water each day, then much less could be expected of a child when it comes to independently consuming enough water on a day-to-day basis. The lack of water consumed by children is something that every parent should be concerned about. Leading a healthy lifestyle would not be possible if the body is not hydrated well enough daily.

Future efforts are needed to ensure that children are not neglected as far as their awareness on staying hydrated is concerned. Early prevention has to be taken into consideration. Many efforts have been carried out to cultivate the water-drinking habits of children. One of these efforts includes providing free drinking water at schools (Bogart et al., 2016). Besides that, some of these efforts include using an eye catching water bottle design, adding fruit-infused flavours into water, setting multiple reminders throughout the day and rewarding children with a treat after they consume water (Jebb, 2014).

However, there appear to be few device-oriented ideas proposed to improve the water-drinking habit among children. Apart from educating children to drink more water, it is critically important to identify appropriate solutions that can help cultivate their habit of drinking water daily. The aim of this study is to propose ideas that improve the water-drinking habit among children with the use of the TRIZ approach. A review of literature is carried out in the next section to uncover the importance of drinking water and the implications entailed when one does not drink enough of it daily.

2. Literature review
Physical health, cognitive abilities and excess weight gain are some of the few effects that a normal healthy individual could encounter due to the lack of water (Popkin et al., 2010). Hence, the act of ensuring that enough fluid is consumed daily would help prevent the likelihood of such effects. An individual will have a higher chance of being diagnosed with hypertension and even stroke if they experience prolonged dehydration (Thornton, 2010).

The human body also requires water to fully function. All functions of the body, especially thermoregulation, need water to operate properly. Through the thermoregulation process, the human body will be able to maintain its core temperature constantly throughout the day. The flow of blood in the human circulatory system plays an important role in the thermoregulation process (Silva et al., 2018). This process returns the body to its equilibrium temperature, by lowering the body’s temperature when the body heats up and increasing the temperature when the body becomes cold. Hence, it is crucial for body tissues to be hydrated adequately through water intake so as to balance the water losses from the body.

A person can experience involuntary dehydration when their body fluids are not restored completely through drinking. Involuntary dehydration can happen more frequently when people are under pressure from exercise, dehydration, altitude change or surrounding temperature change (Greenleaf, 1992). A person becomes more involuntarily dehydrated with the increase in
his/her mental stress. The consequence of dehydration include orthostatic hypotension, tachycardia, hypotonia of ocular globes, speech ability limitations, extremity weakness and concentration problems (Jequier & Constant, 2010).

On the other hand, voluntary dehydration is more direct because it happens when a person refuses to drink a sufficient amount of water. The lack of awareness on the required amount of fluid to achieve a state of balance in hydration is likely to be the main reason this dehydration occurs. Some examples of voluntary dehydration include school children living in hot climates and runners who consumed insufficient water due to poor estimations of hydration level (Masento et al., 2014). Poor taste mechanism, dissatisfaction with the taste of water, over consumption of caffeine and alcohol, participation in exercise and also environmental conditions are several factors that could contribute to chronic or mild dehydration (Kaushik et al., 2007).

A person’s water intake is encouraged by his/her thirst sensation. After water is consumed, it is conserved through the renal system by the change in urine production. Children and older adults are categorised as vulnerable groups because these bodily mechanisms may not function as reliably as compared to regular adults. Even if reliable for some older adults, these mechanisms might still be inadequate in maintaining their hydration state due to the dependency of older adults on others. Young inexperienced children may have problems interpreting their thirst response which is prompted by homeostatic mechanisms (Masento et al., 2014). Studies have shown that adults with severe dehydration experience issues in their cognitive abilities (Shirreffs et al., 2004).

Children have a larger surface-to-mass ratio. Hence, they are at a greater risk of being voluntarily dehydrated compared to adults (D’Anci et al., 2006). Even during the hot hours of the day, children are less likely to reduce their physical activities, which can cause them to lose even more fluids from their body. As a consequence, when it comes to school lessons or studies, they may not be able to learn in their best condition due to the dehydration effects on their cognitive abilities (Bar-David et al., 2005). Results have uncovered that even at the beginning of the day, around 84% of children are in a state of mild voluntary dehydration (Fadda et al., 2012). In summary, dehydration in children affects their cognitive performance (Bar-David et al., 2005; Shirreffs et al., 2004) and hinders them from learning in their best possible state throughout the day.

There have been studies that address this issue to a certain extent. A study conducted by replacing caloric beverages with non-caloric ones (including water) resulted in a weight loss of 2.5% among obese men and women. At the same time, an improved level of hydration was also observed (Tate et al., 2012). In another study on children, Fadda et al. (2012) highlighted how consuming supplementary water (an additional storage of water) during school hours had a positive effect on transitory subjective states such as fatigue and cognitive performance. Urine tests were conducted on children, followed by a cognitive test which included tests on memory, concentration, attention and executive functions. It was found that dehydration significantly impairs a child’s auditory digit span. A similar study was conducted on 58 children within the range of 7–9 years old by randomly assigning them into two groups, where one group received additional water and another did not. The children with access to additional water rated themselves less thirsty than the children from the other group. They also had better visual attention and performed better in various tasks (Edmonds & Burford, 2009).

In order to overcome this predicament, there have been developments in devices that improve the habit of drinking water among individuals, especially children. These devices are as such:

- Communication Water Bottle (Wernow & Wernow, 2017),
- Dieter’s Water Intake Quantity Tracking Vessel (Pollio, 2007),
- Liquid Consumption Counters (Bischoff & Bischoff, 2012),
• Monitoring Water Drinking Device (Yugang et al., 2013), and
• Drinking Water Reminding System (Taiwan Gomet Tech, 2012).

These devices were developed in order to remind children to drink water and stay hydrated daily. However, such inventions appear to focus on reminders that require independent monitoring at the child’s end. There has yet to be a device that not only reminds the child to consume water, but also includes the educative experience on the importance of drinking water delivered by other underlying parties (such as parents, siblings, peers, etc.). Hence, this study aims to propose device-oriented ideas that improve the water-drinking habit among children, with an emphasis on including the aforementioned educative experience. The next section contains justifications on the use of TRIZ as a problem-solving tool in this study apart from other tools such as lateral thinking and design thinking. The TRIZ methodology is then applied to the main problem at hand, which includes children not consuming enough water on a daily basis.

3. Methodology
The use of TRIZ techniques is employed in this study. The word TRIZ comes from the Russian phrase which means the “Theory of Inventive Problem Solving” (Domb & Rantanen, 2008). TRIZ is a problem-solving toolkit that will direct the user in identifying multiple ways to solve a problem. It has been conceptually developed to address mainly technical problems (Pokhrel et al., 2015). One of the examples on the successfulness of TRIZ includes the design of the Smart Product-Service Systems, or better known as Smart PSSs (Lee et al., 2019). TRIZ was able to contribute in the development and demonstration of the Smart PSS for drug and cosmetics retail chains. Besides that, TRIZ has also been used in developing a special rig that was used to accommodate a creep test (Asyraf et al., 2019). The special rig was to be used in order to design an improved cross arm that was required for the lifting of electric cables in transmission towers. TRIZ is a tool which follows a systematic approach that is highly reliable, predictable and repeatable (Illevbare et al., 2013). Moreover, the flexibility of TRIZ to be used in various fields of study makes it adaptable to solve problems related to technology, business, social science, arts, culture and even philosophy (Souchknov et al., 2007). The preceding studies that highlight the effectiveness of TRIZ in solving various problems are testaments on the capability of TRIZ in potentially resolving the problem of this study.

Besides TRIZ, there is also a variety commonly-used problem solving methods. Tools such as design thinking and lateral thinking are usually used to solve design problems. However, each of them solves problems from a different point of view and has different emphasis in certain areas. Hence, each tool has its advantages in solving problems in different angles. Table 1 shows the comparison between these three problem solving tools. Lateral thinking focuses on creative approaches while design thinking has the advantage of meeting customer’s needs. However, design thinking can be more time consuming.

From Table 1, TRIZ methodology has the ability to solve difficult and complex problems that demands users to think outside of the box. Besides that, TRIZ has an advantage of systematically generating possible solutions from identified problems. Moreover, the flexibility of using TRIZ in various fields of study makes it adaptable and versatile in areas such as technology, business, social science, arts, culture and even philosophy (Souchknov et al., 2007). Therefore, it is suitable to adopt TRIZ for this study. The TRIZ process flow that is used in this research is shown in Figure 1.

The first step of the TRIZ process flow involves defining the main problem which in this research focuses on the poor water-drinking habit among children. From the main problem that is defined, a Cause and Effect Chain (CEC) analysis diagram is constructed to find the root cause of the main problem. Upon obtaining the root causes from the analysis, the TRIZ engineering contradictions are formulated. The contradictions obtained are then matched with 40 inventive principles to generate new ideas of devices that could cultivate a good water-drinking habit among children.
| Problem Solving Tool | TRIZ | Lateral Thinking | Design Thinking |
|----------------------|------|-----------------|----------------|
| General definition   | A systematic problem-solving method based on logic and data, not intuition or spontaneous creativity of individuals or groups. (Altshuller, 2002) | Attentive towards the generation of new ideas. Liberation from old ideas and the stimulation of new ones. (Lawrence, 2013) | An analytic and creative process that engages a person in opportunities to experiment, create and prototype models, gather feedback, and redesign. (Razzouk & Shute, 2012) |
| Advantages           | • Identifies problems and propose direct solutions. • Higher confidence that most possible solutions have been considered. • Systematic approach. (Gadd & Goddard, 2011) | • Intentionally seeks irrelevant inspirations and seeks to find as many solutions possible (De Bono & Zimbalist, 1970). | • Considers the emotional experiences on top of physical details. (Elsbach & Stigliani, 2018) |
| Limitations          | • Large number of methods and possible approaches. (Ilevbare et al., 2013) | • Time consuming • Difficult to identify best solution. (Altshul et al., 2016). | • Lack of formality in the method to the context • Require more brainstorming sessions. • Lower performance and reduce effectiveness. • Require more time. (Seidel & Fixson, 2013) |
| Key Principles       | • Problems and solutions were repeated across industries and science. • Patterns of technical evolution were repeated across industries and sciences. • Innovations used scientific effects outside the field from where the original problem was found. (Salomatoy, 2005) | • Restructures thought patterns for new combinations to arise. • Generates alternatives, challenges previously held assumptions, and develops innovative thinking. (Burgh, 2014) | • Preparation. • Assimilation. • Strategic control. (Razzouk & Shute, 2012) |
| Important Techniques | • 40 Inventive Principles for solving problems. • Technology Trends to evolve a technical system to the next generation. • Scientific Effects used to solve problems in unique ways. • Separation Techniques (Altshuller, 2002) | • Plus, Minus, Interesting • Considering All Factors • Consequences and Sequel • Aims, Goals, Objectives • First Important Priorities • Alternatives, Possibilities, Choices • Other Point of View • Six Thinking Hats (Burgh, 2014) | Cognitive Operations: • Generation. • Exploration. • Comparison. • Selection. (Razzouk & Shute, 2012) |
The first step of the TRIZ process flow involves defining the main problem. It is important to have a clear and well-defined main problem definition as it sets the direction of the problem-solving process. The project aims to solve this issue through external and more tangible measures, which involves the proposal of a potential device to solve the main issue. For this study, the main problem is defined as such:

### 3.1. Children are not drinking enough water

The second step involves the construction of the Cause-and-Effect-Chain (CEC) analysis, where the root cause of the problem is uncovered. Based on the root cause, an engineering contradiction is formulated in the third step and cross-referenced with the TRIZ contradiction matrix. Using the parameters from the matrix, some inventive principles are extracted and used for idea generation in the fifth step.

In order to express the hypothesis about the cause of a problem, a CEC analysis diagram is used. It is a structured way that helps researchers focus on the process where a problem is occurring and target the actual causes of the problem. As the CEC analysis diagram is being constructed, it is possible that the chain would lead to a direction that is oriented towards human behaviour or psychological causes. Although these could be the potential root causes of the problem, they are excluded from this analysis because they involve areas that are beyond the scope of this study. Figure 2 shows the CEC analysis diagram constructed for this study. The main problem is stated at the top most of the diagram. The question of “why” is asked with regard to the occurrence of the main problem until a potential root cause is deduced at the end of the chain.

The green, orange and red outlined boxes are the root causes. In order to narrow down and focus on a root cause that is within the delimitations of this study, more information is needed to justify and eliminate the other causes. Many academic papers tend to uncover the potential causes as to why children are not drinking enough water. However, a common theme among these journals is to study the reasons or methods to encourage healthy living which includes staying hydrated by drinking enough water.

One of the reasons why children do not drink enough water is because they are not nurtured with a habit of drinking water. Besides that, when children are busy with daily activities, the consistency of their water-drinking habits could somehow be affected. It is found that when being engaged in a habitual behaviour, people’s thoughts tend to stray away from the actual activity. They are more likely to think about issues unrelated to that habitual activity, which means that they do not have to consciously guide their actions (Wood et al., 2002). Assuming that drinking water is not important could also unfavourably influence a child’s habit of drinking.
water. The question of “why drinking water is deemed not important” is then asked again, which leads to a likely cause that children are not taught the importance of drinking water. Apart from that, the notion that children are not trained to drink enough water could also be the reason why drinking water is deemed unimportant to them. Parents or teachers often neglect training children due to the lack of tools and devices that aid the training process.

Water-drinking habits can be effectively cultivated with the involvement of parents. A study suggested that parents can act as the gatekeepers of children’s water consumption (Larsson et al., 1999). However, in order to drink enough water, the habit of it must first be developed. An information-based approach will do little as compared to habitual-based interventions because such interventions disrupt the environmental factors that will automatically cue habit performance (Verplanken & Wood, 2006). The responsibility in imparting knowledge on the importance of drinking water to children falls on the shoulders of parents and teachers. However, parents and teachers are faced with a challenging task because habitual formation takes time and effort. Without the proper tools and methods, even the seemingly simple task of training a child to develop water-drinking habits can be difficult. Busy parents often find themselves nagging, instructing or even forcing their children to drink water. These actions may not be the most appropriate techniques because they do not nurture children towards independently forming the habit of drinking water. A device is necessary to ease the process of aiding a child to drink more water which will eventually lead to habitual formation.

Moreover, another cause to the main problem includes the assumption from children who think that they are sufficiently hydrated when they are not, which can happen because they easily forget the amount of water consumed each time they are busy with their activities in school or at home. The lack of devices to help monitor the hydration levels (by the amount of water consumed) also causes children to forget the amount of water consumed. Devices such as smart water bottles are conventional water bottles with high-tech functions primarily designed to encourage consumers to drink more water using technology. However, children do not normally use these devices because they are fragile and sold at an expensive price. With reference to the preceding discussions on the CEC analyses, the three possible root causes as to why children are not drinking enough water are:
The lack of devices that aid in training children to cultivate a water-drinking habit. 

2. The lack of devices that aid in teaching/educating children to cultivate a water-drinking habit. 

3. Smart water bottles are expensive and not suitable for children. 

From the root causes obtained in the CEC diagram, a technical contradiction is structured. In general, a contradiction is an improvement in one characteristic of a system which results in the degradation of another characteristic. A technical contradiction on the other hand is a situation in which an attempt to improve one parameter of a system leads to the worsening of another parameter. A technical contradiction has the following structure:

If … (manipulative variable changes) 

Then … (responding variable #1 improves) 

But … (responding variable #2 worsens) 

The TRIZ contradiction focuses on the positive outcome which is the “then” statement, and the “then” statement is normally a reversal of the original/main problem into a positive statement. After establishing the “then” statement, the “if” statement is addressed with a possible obvious solution, followed by the “but” statement which aims to contradict the solution, since a possible obvious solution would definitely contain some flaws. This method of formulating contradictions is more straight-forward because it focuses on the original/main problem. Using the TRIZ method of formulating contradictions with reference to the three root causes deduced from the CEC diagram, three technical contradictions were constructed.

The first root cause (sub-problem 1) includes the “lack of devices that aid people in training children to cultivate a water-drinking habit”. Hence, the first technical contradiction can be formulated as such:

Technical contradiction 1: 

IF teachers/parents possess tools to train children in drinking more water, 

THEN children will have more opportunities to practise and eventually cultivate a water-drinking habit 

BUT it will take a longer time to effectively train children. 

The second root cause (sub-problem 2) includes the “lack of devices that aid people in teaching/educating children to cultivate a water-drinking habit”. Therefore, the second technical contradiction can be proposed as such:

Technical contradiction 2: 

IF teachers/parent possess tools to educate children in drinking more water, 

THEN children can better learn the importance of drinking water. 

BUT it will take a longer time to effectively train the children. 

The third root cause (sub-problem 3) includes the fact that “smart water bottles are expensive and not suitable for children”. Thus, the third technical contradiction can be suggested as such:
Technical contradiction 3:

**IF** affordable devices are available to replace expensive smart water bottles,

**THEN** children will be able to track the amount of daily water intake,

**BUT** these devices might fall short in terms of functionalities.

With reference to these formulated technical contradictions, inventive principles can be extracted. The inventive principles are simple ways in resolving technical contradictions. A contradiction matrix is used to help researchers obtain a set of recommended inventive principles to solve technical contradictions. The contradiction matrix was designed to formalise and facilitate the usage of inventive principles.

In order to extract the inventive principles, the technical contradictions need to be matched with system parameters. A system parameter is a “property or attribute” given to describe a function of a system. It takes the point of view of the function rather than the components. According to TRIZ, there are 39 system parameters that can be matched with the technical contradictions established. Table 2 shows the list of TRIZ 39 system parameters. With these system parameters matched, the contradiction matrix can be used to select the appropriate inventive principles. There is a total of 40 inventive principles within the contradiction matrix. Table 3 shows the 40 inventive principles of TRIZ.

In TRIZ, a problem that contains a contradiction is known as an inventive problem. In the establishment of TRIZ, it was discovered that patents filed worldwide followed a certain pattern across different industries (Pokhrel et al., 2015). At one point, various industries underwent the same technological cycle and there were remarkable similarities in the patents filed (Domb, 2018). These findings were documented and used to create the TRIZ matrix of contradiction which is applied in this research.

Referring back to the technical contradictions, the “then” statement is actually known as the improving variable, while the “but” statement is known as the worsening variable. In order to proceed further with the TRIZ problem-solving process, these variables are linked with the TRIZ 39 system parameters. Taking the second technical contradiction as an example, the improving variable is “children can better learn the importance of drinking water”, while the worsening variable is “it will take a longer time to effectively train the children”.

After obtaining the improving and worsening variable from the contradiction, the variables are matched with one or more system parameters. Referring back to the second technical contradiction, the improving variable can be matched with a system parameter known as ease of operation. It is also the 33rd system parameter in the list of 39 TRIZ system parameters. The term “ease of operation” is defined as convenience of use whereby an easy operation process has better controllability and high yield. Since the improving variable can be carried out without a large number of people, the ease of operation term is chosen as the system parameter of the improving variable.

The worsening variable of the second technical contradiction can be matched with the system parameter loss of time. The loss of time, which is also the 25th system parameter in the list, is defined as the waste of time taken to provide or perform a needed activity. Since it will take a longer time to effectively train the child, the loss of time is said to occur. From the systems parameter obtained, the contradiction matrix can be utilised by finding the intersection between the improving parameter (or feature) which is arranged in rows and the worsening parameter which is arranged in columns. The inventive principles extracted are asymmetry, mechanics substitution, preliminary/prior action, and discarding and recovering.
Table 2. TRIZ 39 System Parameters

|  |  |  |
|---|---|---|
| 1. | **Weight of moving object** | 21. |
| 2. | Weight of non-moving object | 22. | Waste of energy |
| 3. | Length of moving object | 23. | Waste of substance |
| 4. | Length of non-moving object | 24. | Loss of information |
| 5. | Area of moving object | 25. | Waste of time |
| 6. | Area of non-moving object | 26. | Amount of substance |
| 7. | Volume of moving object | 27. | Reliability |
| 8. | Volume of non-moving object | 28. | Accuracy of measurement |
| 9. | Speed | 29. | Accuracy of manufacturing |
| 10. | Force | 30. | Harmful factors acting on object |
| 11. | Tension, pressure, stress | 31. | Harmful side effects |
| 12. | Shape | 32. | Manufacturability |
| 13. | Stability of object | 33. | Convenience of use |
| 14. | Strength | 34. | Reparability |
| 15. | Durability of moving object | 35. | Adaptability |
| 16. | Durability of non-moving object | 36. | Complexity of device |
| 17. | Temperature | 37. | Complexity of control |
| 18. | Brightness | 38. | Level of automation |
| 19. | Energy spent by moving object | 39. | Productivity |
| 20. | Energy spent by non-moving object |  |  |

Figure 3 shows an example of how to obtain the inventive principles from the contradiction matrix. The improving parameters (or features) are arranged in rows while the worsening parameters are arranged in columns. In the example shown, the improving feature of the contradiction is speed while the worsening feature of the contradiction is device complexity. The intersecting boxes would contain the inventive principles for the particular contradiction. The extracted numbers (10, 28, 4 and 34) represent a few of the 40 inventive principles TRIZ which include preliminary action, mechanics substitution, asymmetry, and discarding and recovering. The extracted principles are then used to propose solutions that are aimed at resolving the technical contradiction.

Tables 2 and Tables 3 present the system parameters and inventive principles for the first technical contradiction. The potential device-oriented idea aims to not only be a training tool for children but also to help them cultivate a water-drinking habit. Hence, the inventive principle of **Universality** was selected since this principle aims to make an object perform multiple functions.

Tables 4 and Tables 5 are the system parameters and inventive principles for the second technical contradiction. The potential device-oriented idea aims to be a tool that provides teaching opportunities for parents and teachers in order for them to educate children on the importance of drinking sufficient water. This aim may involve significant efforts to reinforce a child’s memory with regard to drinking water, as children are known to easily forget casual instructions that they are
not accustomed to remembering and often require frequent reminders. For example, eating can be considered as a habitual activity because many people eat at the same time and at the same place. Hence, eating or drinking should come naturally without much intention (Conner et al., 2002). The inventive principle of Preliminary/Prior action was selected because the preceding

| Table 3. TRIZ 40 inventive principles (Domb, 2018) |
|---------------------------------------------------|
| 1. Segmentation | 21. Skipping |
| 2. Taking out | 22. Blessing in disguise |
| 3. Local quality | 23. Feedback |
| 4. Asymmetry | 24. Intermediary |
| 5. Merging | 25. Self-service |
| 6. Universality | 26. Copying |
| 7. Nested doll | 27. Cheap short-living objects |
| 8. Anti-weight | 28. Mechanics substitution |
| 9. Preliminary anti-action | 29. Pneumatics and hydraulics |
| 10. Preliminary action | 30. Flexible shells and thin films |
| 11. Beforehand cushioning | 31. Porous materials |
| 12. Equipotentiality | 32. Colour change |
| 13. The other way around | 33. Homogeneity |
| 14. Curvature | 34. Discarding and recovering |
| 15. Dynamization | 35. Parameter changes |
| 16. Partial or excessive actions | 36. Phase transition |
| 17. Another dimension | 37. Thermal expansion |
| 18. Mechanical vibration | 38. Strong oxidants |
| 19. Periodic action | 39. Inert atmosphere |
| 20. Continuity of useful action | 40. Composite materials |

Figure 3. Inventive principle selection using the contradiction matrix.

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actions (such as frequent reminders or instructions) need to be taken before the primary action (drinking water) takes place.

Tables 6 and Tables 7 are the system parameters and inventive principles for the third technical contradiction. The potential device-oriented idea aims to be an affordable and suitable tool for children with functionalities similar to that of a smart water bottle. The designs and functionalities of smart water bottles are geared towards accommodating the current busy lifestyle of a working adult. Hence, it is to no surprise that such a device would be more expensive than a regular water bottle due to its smart features that are created using complex and advanced electronic components. A child might easily drop or destroy the expensive water bottle. Hence, rather than using several different types of external components to perform the task of monitoring the daily water

| Table 4. System parameters for technical contradiction 1 |
|--------------------------------------------------------|
| **Technical Contradiction Variables** | **System Parameters** |
| Improving Variable | #38 Extent of Automation |
| Worsening Variable | #15 Duration of Action of Moving Object #25 Loss of time |

| Table 5. Inventive principles from system parameters 1 |
|-------------------------------------------------------|
| **Pairs of System Parameters** | **Inventive Principle** |
| #38 & #15 | #6 Universality #9 Preliminary anti action/Prior counter action |
| #38 & #25 | #24 Intermediary #28 Mechanics substitution/Another sense #35 Parameter changes #30 Flexible shells and thin films/Thin & flexible |

| Table 6. System parameters for technical contradiction 2 |
|--------------------------------------------------------|
| **Technical Contradiction Variables** | **System Parameters** |
| Improving Variable | #33 Ease of operation |
| Worsening Variable | #15 Duration of action of moving object #25 Loss of time |

| Table 7. Inventive principles from system parameters 2 |
|-------------------------------------------------------|
| **Pairs of System Parameters** | **Inventive Principle** |
| #33 & #15 | #29 Pneumatics and hydraulics/Fluidity #3 Local Quality #8 Ant-weight or Counter weight #25 Self-service |
| #33 & #25 | #4 Asymmetry #28 Mechanics substitution/Another sense #10 Preliminary/Prior action #34 Discarding and recovering |

| Table 8. System parameters for technical contradiction 3 |
|--------------------------------------------------------|
| **Technical contradiction Variables** | **System Parameters** |
| Improving Variable | #37 Difficulty of Detecting and Measuring |
| Worsening Variable | #23 Loss of Substance |
intake, it would be more sensible and cost-efficient to utilise a single structure and internalise the components within it to perform this task. Thus, the inventive principle of Segmentation was selected since this principle emphasises on dividing an object into independent parts Tables 8Tables 9.

From the TRIZ approach of technical contradictions, possible solutions produced are further discussed in the next section. The inventive principles obtained are then selected to form new ideas. The preliminary ideas proposed can be used as a potential solution for the main problem involves children not drinking enough water on a daily basis.

4. Results and discussions
Based on the process of resolving TRIZ technical contradictions, two preliminary ideas can be suggested. This section presents the preliminary device-oriented ideas based on the 40 inventive principles of TRIZ. The preliminary ideas can potentially serve as a solution to the main problem of children not drinking enough water on a daily basis. The figures and references used for each preliminary idea serve as elements to justify the idea's conceptual outlook and function.

4.1. Dual compartment water bottle
The idea of a dual compartment water bottle was derived from the Segmentation principle, which states that an object should be divided into independent parts in order to resolve the contradiction. Figure 4 is an example of an existing product in the market that demonstrates how the dual

### Table 9. Inventive principles from system parameters 3

| Pairs of System Parameters | Inventive Principle                          |
|----------------------------|---------------------------------------------|
| #37 & #23                  | #1 Segmentation                             |
|                            | #10 Preliminary action/Prior action          |
|                            | #18 Mechanical vibration                    |
|                            | #24 Intermediary                            |

Figure 4. An example of the dual compartment water bottle known as HydraDuo (Cool Things, 2010).
compartment water bottle idea could look like. The device in Figure 4 known as HydraDuo was actually designed for adult consumers who wish to store two types of beverages for sports or leisure purposes (such as water and alcohol, or water and an isotonic drink). Nonetheless, it would be of interest to explore if this idea could be extendable to children with regard to cultivating their water-drinking habits.

A dual compartment water bottle would have the similar function as a normal water bottle. However, it will have two different segments of fluid. The first compartment will consist of the main fluid which is water whereas the second compartment will consist of a rewarding fluid which can be a sweet beverage. In order for a child to be rewarded the sweet beverage, he/she would have to first finish drinking the water first. The second compartment filled with beverage can only be accessed with the help of an adult. Hence, this feature helps in preventing the child from misusing the water bottle.

A tight-sealed plastic membrane that requires a large amount of twisting force to open and allow the beverage to flow into the first compartment will be used. This feature helps in preventing the child from managing the water bottle by himself/herself, thus preventing them from ingesting any smaller parts or components of the water bottle. At the same time this feature also helps in preventing the child from consuming the beverage before drinking the water.

However, there is a weakness to this design. Some studies have showed that extrinsic rewards have a detrimental effect on a person’s intrinsic motivation. Results have shown that it significantly undermined the self-motivation of a person (Budynas & Nisbett, 2015). It is possible that children might not develop a good water-drinking habit and remain dependent on rewards. Although this preliminary idea may not seem psychologically beneficial due to the side effects of constantly rewarding a child, the device could still be utilised for a short period of time. If monitored carefully it could effectively cultivate good water-drinking habits among children. However, if not monitored, the solution might cause children to experience other health issues such as obesity as the child would consume more sugary drinks compared to water.

The solution for this study’s main problem would require more interaction between the child and his/her parents as it is still important for parents to educate and explain the benefits of drinking water to the child. Apart from this idea, another preliminary idea is also proposed in the next subsection. The second idea is formed from other inventive principles and targets to solve the main problem while considering the educative and interactive importance of parents.

4.2. Measurement, accumulation and display device
This idea was derived from the universality and preliminary action principles. The universality principle aims to ensure that an object can be made to perform multiple functions, while the preliminary action principle aims to ensure that the required change of an object is performed before the main action or function takes effect. This device idea is predicted to possess the capability of computing, storing and displaying the amount of water consumed by an individual. Figure 5 illustrates this idea with an existing device that is often used in our daily lives, which is also known as a regular food scale. Nevertheless, it would not be enough to simply utilise a conventional food scale to measure and record the amount of water consumed in order to facilitate the habit formation that a parent/teacher is reinforcing on a child. The device idea would need to be equipped with smarter and more convenient features to aid parents/teachers in encouraging children to drink more water. One suggestion would be to use data storage devices to accompany the idea in order to accumulate the amount of water consumption data. Another suggestion would be to incorporate artificial intelligence within the system which allows the device to recognise the individual that is consuming the water. Through this way, the monitoring of a child’s hydration level can be better facilitated.

Figure 6 on the other hand illustrates the similarities of the aforementioned idea with an existing product that is available in the industrial market trade. This product is known as a checkweigher, and its
The objective is to check the target weight of packaged products in the fresh and dry sector (Bizerba, 2015). It contains up to 100,000 memory spaces to facilitate the accumulation of data across different products, and a robust software which not only displays the weights, but also monitors the physical
condition of the packaged products. Such features from a system could potentially be adopted into a system that intends to cultivate the water-drinking habits among children.

The aforementioned mechanisms and illustrations should not only be aimed towards measuring, accumulating and displaying the amount of water consumed by a child, but also consider the interactions among several individuals, namely the parents and child. With this notion in mind, it is important for such a device to be developed in a way that it requires the use of both the parent and child in order for it to be effective in cultivating water-drinking habits. For instance, instead of frequently instructing or reminding the child to drink more water, the monitoring of water consumption through this device should be done together with the child to encourage him/her to consume more water. The above-mentioned concept could also be gamified with the use of AI to create an environment where the parent encourages his/her child to consume water regularly through a friendly competition.

5. Conclusion
Dehydration is a serious matter that could affect every individual in their daily life. Hence, prior and immediate action should be taken in order to overcome this matter as it affects not only adults but also children. In this context, parents and teachers play a pivotal role in cultivating their water-drinking habits because children have a higher risk of experiencing voluntarily dehydration due to their larger surface-to-mass ratio compared to adults.

One of the root causes of why children are not drinking enough water includes the lack of devices that aid people in training children to cultivate a water-drinking habit. One of the potential solutions that could be used to solve this particular root cause was from the inventive principle known as universality, which suggests that in order to solve the problem an object could perform multiple functions. From this principle, the conceptual idea of a dual compartment water bottle was proposed. Besides that, the lack of devices that aid people in teaching/educating children to cultivate a water-drinking habit was also another root cause to the problem. In order to solve this particular root cause, the preliminary/prior action principle was selected because actions such as frequent reminders or instructions need to be taken before the main action (drinking water) takes place. The third root cause to the problem suggested that smart water bottles are expensive and not suitable for children. For this root cause, the segmentation principle was selected since this principle emphasises on dividing objects into independent parts. By combining the inventive principles of preliminary action and segmentation, the conceptual idea of a measurement, accumulation and display device was proposed.

In a nutshell where future research will be carried out, a proper concept selection and product development should be carried out in order to materialise the idea of cultivating water-drinking habits among children. The finalised design should be prototyped and tested for its effectiveness among children aged between 4 to 6 years. This new idea that cultivates water-drinking habits among children could possibly be extended to accommodate the nurturing of other habits, such as to encourage children to consume more vegetables, fruits and vitamins. From this study, preliminary formations of ideas that cultivate water-drinking habits among children now exist. Further research that extends from this study would benefit future generations in preventing hypertension, urinary tract infections and weight gain, thus improving the public health of our society at large.

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