Exploring Idea Generation Techniques in Conceptual Design Stage

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ABSTRACT

Design is a creative activity that aims to present a new product or a new concept for an existing products. Designing of products typically proceeds through a number of stages to be manufactured. Conceptual design is considered the most important stage within design as idea generation process takes place. When it comes to idea generation process, the first thing comes to the mind is sketching which is used by designers to investigate ideas and visualize them. This is because most of designers use it, design schools work hard to improve their students' sketching skills, and companies and design studios produce sketches to persuade their clients. It seems sketching is the only technique to generate ideas, but it is not. There are various techniques were developed by designers or within other domains such as economy and psychology. These techniques can be used individually and in a group such as brainstorming, mind map, written scenario and stepladder technique. This paper aims to explore different idea generation techniques, investigate how they work, and find a framework for these technique to work together to add more dynamic, speed, and creativity to idea generation process. It first review these techniques from different domains. Then, these techniques are analyzed and classified. In the last step, a framework for idea generation techniques is created to enable designers to benefit the best from different techniques. The framework divides the process of conceptual design into 3 steps to reach the final idea and describes which techniques should be used by designers to help him through idea generation. These steps are: (1) defining problems and identifying needs, (2) gathering information, and (3) generating ideas. The systematic approach of this framework enable designers to think systematically about the design problem and solutions with no pushing into find the final idea. The dividing into 3 steps make the process easier, fast and the use of different techniques together can increase creativity in design process.

Keywords: conceptual design, idea generation techniques

1. Introduction

Design is a creative activity that aims to present a new product or a new concept for an existing product. Designing of products typically proceeds through a number of stages to be manufactured. Design process is the term expresses about these sequence stages. Conceptual design stage is the most important phase in the design process. This is because of design alternatives or design concepts produced in this stage that offer the greatest scope for improvement in product design [38]. That may be the reason for considering it as the most demanding phase of design on designers [32].

Idea generation process is the core activity of conceptual design where ideas are generated. Sketching is the most frequent method used by designers as it is easy, cheap, and available all the time [45]. But designers developed many other techniques to support generating ideas such as function analysis and morphological charts. They also used techniques from other domains such as economy and psychology. All these techniques aim to support generating ideas or solution for design and problems.

In this paper, we reviewed 15 idea generation techniques which developed from several domains and used by designers individually or in a group to generate idea through conceptual design stage. These techniques were classified into four categories: (1) problem-based techniques, (2) concept-based techniques, (3) user-based techniques, and (4) product-based techniques. Each approach from these categories can help in generating ideas from a different point of view. That may increase creativity in design process. After that, a conceptual design framework was generated to support designers through generating ideas. It works as a guide for designers to choose suitable techniques and combine between different techniques according to design situation.

2. Problem-based techniques

Problem-based techniques are about analyzing problems to describe it from different points of view. After this step, they reformulate the problem according to participants' different perspectives. They can be used individual or in a group. There are two techniques within this categories: How to's and synectics techniques.

2.1. How to's:

In this technique, a problem statement is provided at the beginning to give a brief description of the problem. Participants ask questions about the problem, each from his point of view. Questions are recorded in a list. In this stage, no judgement should be done, participant should associate on other's ideas and work for quantity rather than quality. After that, they evaluate the questions and select the most important ones which cover the problem from different perspectives. At the end, they formulate a final concrete target to continue with it [50].

2.2. Synectics:

In 1961 Gordon and Prince [19] presented synectics method to support problem analysis and idea generation by using analogies. Analogy means to look for what similar to the current problem or the idea wanted in other domains and get inspired by it [30] [33] [34]. Then the designer attempts to develop this solution or idea to be applied within the original domain.

Synectics begins with defining the problem and then analyze it. After that, designers start to generate ideas and record them in same time of thinking about relevant analogies [3] [44]. Then, they select the suitable analogy and solution and fit it to the problem or the design situation. The last step is to develop the concept and present it. There are many types of analogies that can be used in design such as direct, personal, nature, fantastic, and paradoxical analogy [10] [50].

3. Concept-based techniques:

Designers tend to think about concepts, therefore many tools and methods were developed by designers themselves or borrowed from other domains to support concept creation. Sketching is the most famous technique that designers use as it is easy and initiative. But as sketching, there are various techniques that concern concept creation such as brainstorming, mind map, and 3D modelling. These methods can be classified into two categories: visual, mental techniques.

3.1. Visual techniques

Visual techniques contains techniques that concerning the creation of the concept appearance to be seen, developed, and evaluated. We review here four types of techniques: sketching, collage, brainsketching, and 3D modelling.

3.1.1. Sketching:

Sketching is an important method that designers widely used and still in generating ideas within conceptual design stage [45]. It seems to be the favorite method for designers [14]. Sketching can be defined as a representation of an idea existing in mind of the designer. It is different from drawing process where artist draw something existing in real. It works as a link between the design problem and the concept or the solution [17]. It is useful to visualize ideas and explore its properties such as scale and proportion [11] [51]. Sketches can be calssified into four types according to their purposes: ideation sketches, explorative sketches, explanatory sketches, and persuasive sketches.

1) Ideation sketches: are to transfer ideas from mind into papers. It works as a tool to record idea and an attempt to understand the concept which a designer think about. It doesn't concern the shape or the form of the product but how this product will be constructed.
2) Explorative sketches: are to explore the design space and here concepts begin to be generated. It concerns the shape and the form of the product, so many ideas are generated and evaluated to reach to the best form that can serve the function.
3) Explanatory sketches: should be understood from people who see it. It explain product's form and functions. It also can be used as a communication method between design team members or between designers and clients.

4) Persuasive sketches: are used to influence people to buy the product. People may be a producer, a client, or a consumer. Persuasive sketches should be colorful, realistic, and attractive. Computer graphic software are often used to create it or to add some features to it to be more attractive.

Figure (1) shows different types of sketches.

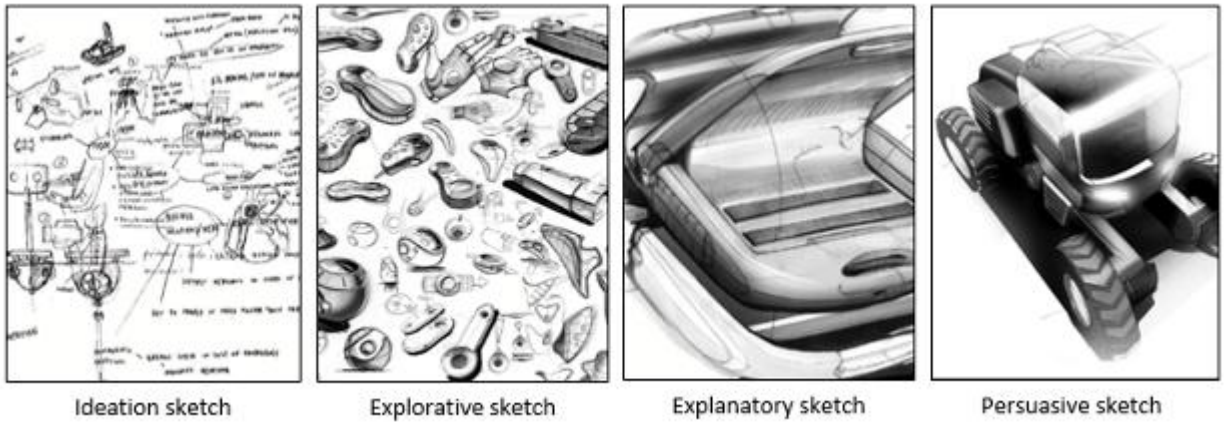

Figure (1) shows different types of sketches.

3.1.2. **Collage**:

Collage is an old art technique that began in China and then moved to Japan and form it to the rest of the world. It backs hundreds of years but it made a dramatic change in art works in the early 20th century when artists used it in many art works. Designers after that use collage to serve deferent domains of design such as graphic design, architecture design, and product design [50].

Collage can be defined as a visual representation that is made by collecting different pieces of different sources together in a new form. These sources includes different materials such as paper, metal, and stones. It comes in different forms such as newspapers, magazines, photos, and colored paper. These pieces are glued together to a surface or can be used in digital form by using any photo editor to put those together [36].

Collage helps designers in idea generation process as following:

1) Exploring the color palette that can be used in product idea and concept.
2) Studying the design context for more understanding about how the product will be used, the using environment, and targeted users.

After using collage in idea generation process, designers should be able to determine design requirements and appearance features of the product according to their aim of using collage.

3.1.3. Brainsketching:

Brainsketching is an idea generation method that was developed based on brainwriting but instead writing thoughts on paper cards, participants use sketching to express their ideas on large sheets of paper [16] [55]. This conversion from using writing to drawing came from the need for visual expression while generating ideas [16] [29] [54].

In brainsketching, participants start sketching while they are silent. They sketch on large sheets of paper. They exchange drawings and silent sketching continue for another period of time. Sketches exchange can be done around 5 times [29] and the period of time can be determined by the session facilitator according to the nature of the problem or the concept needed. In between rounds the facilitator may emphasize the rule of “building on other’s idea”. Although sketching is the main mode of the process, written annotation may be used to serve the idea [54]. Brainsketching allows participants to be in a group but in the same time they still can produce their idea individually [46].

3.1.4. 3D modelling:

A 3D model is a physical representation of a product idea. Designers use 3D models to express, visualize, and materialize ideas and concepts [2] [43]. This offers more realistic than sketching as 3D models can be turned over and looked at from different directions. This support idea development and speed up communication of ideas within the design team. It also enable designers to test and evaluate ideas easily. There are five types of 3D models as following [50]:

1) Sketch model: is a rough model with simple materials such as paper, foam, and wood. It is used to express ideas in the early stage. It is easy to be made as it doesn't consume time in building it which suits the ideation process. It is not an ultimate model as designers do several changes to it through design.
2) Proof of concept model: is used to test if specific technical principle works or not. Form of the product is usually be simplified by the designer as there is no need to waste time in building it with details because concentration here is on technical issues.
3) Dummies: are a 1:1 scale model of a product or an idea. It represents the external appearance of it without any technical features.
4) Detail model: is a more quality version of dummies. It is 1:1 scale model with a good external appearance and limited functions.
5) Final model: is made with high quality look to express the final idea. It is built from wood, metal, or plastic with a very good finishing. It also may include product's functions work.

Previous types of 3D models were used and still but designers is many design cases. But with the development of Computer graphics and CAD systems many designers shorten time consumed in building real models by building digital 3D models to serve same purpose in less time [52] [56].

3.2. Mental Techniques:

These techniques aim to record ideas in a written shape to be developed and evaluated. They were developed in different domains such as economy and psychology but designers used them to support idea generation process of product and service design. These techniques are brainstorming and mind map.

3.2.1. Brainstorming:

People used brainstorming for decades to generate ideas and solve problems. It was firsty developed by Alex Osborn in 1953 in his book "Applied Imagination" [50]. From this time, many improvements had been added by various researchers to the original approach. The aim of brainstorming is to stimulate generating large number of ideas or solutions and during the process ideas shouldn't be evaluated [20]. Brainstorming can be used individually or in a group. Usually individual brainstorming is used to solve simple problems or to prepare a list of ideas. But group brainstorming still more efficient as it takes advantage of the all participants' ideas. It also encourage participants to share their ideas as they feel they are a part of a team. On the other hand, it is considered risky for individuals if others attempt to evaluate their ideas through the session. Therefore there is a need for a good leader for the session to guarantee that all procedures are applied precisely.

Otherwise to solve the shyness problem and to encourage people to participate through brainstorming sessions, some approaches were developed such as the stepladder technique [14] [37] [40], Brainwriting [28] [31], online brainstorming [21] [58], and Crawford's slip writing approach [60]. For product and service design, reverse brainstorming approach [8] was inspired from reverse engineering technique to help designers to think more efficient about the product or the service development. It works by reversing the main question asked in the brainstorming session. Instead of asking "how we can solve a problem?" we ask "how we can cause a problem?" .

3.2.2. Mind Maps:

Mind mapping has come a long way since 1970s when the British researcher Tony Buzan introduced it to the world [2] [9] [35]. It is now on the brink of becoming a mainstream tool that enables many individuals to tackle and take control of the huge amount of information that we are forced to interact with every single day. Buzan [2] aimed to express radiant thinking by using a simple way that use text and graph and need no more than a pencil and a paper. It unlocks the mind and makes it easy to express, organize and visualize thoughts and ideas. It also can be applied in various life domains, the thing that enhance human performance.

A mind map can be described as a tree with many branches that come out from one main stem. This stem is considered as a key word, main idea, or a theme that all sub ideas are arranged around it [2] [4]. Mind mapping procedures can be summarized as following:

1) Start in the middle of a blank paper and write the key word or the main idea that you intend to think about.
2) Develop the related sub-topic around it using lines as branches to connect between them.
3) Repeat the previous step of sub-topics to add more and detailed information to the graph.

Mind mapping is used in different stages of design process but it is often used in idea generation in conceptual design. It plays two main role [9]. Firstly, it helps in defining the problem and clarify all it aspects. The second role is to arrange design ideas that flow from mind in an arranged way. It also can be used to evaluate ideas or problem solution by drawing a map for advantages and disadvantages. Designers can use it also to find out priorities and determine work paths. Figure (2) show an example of a mind map while for a lamp shade.

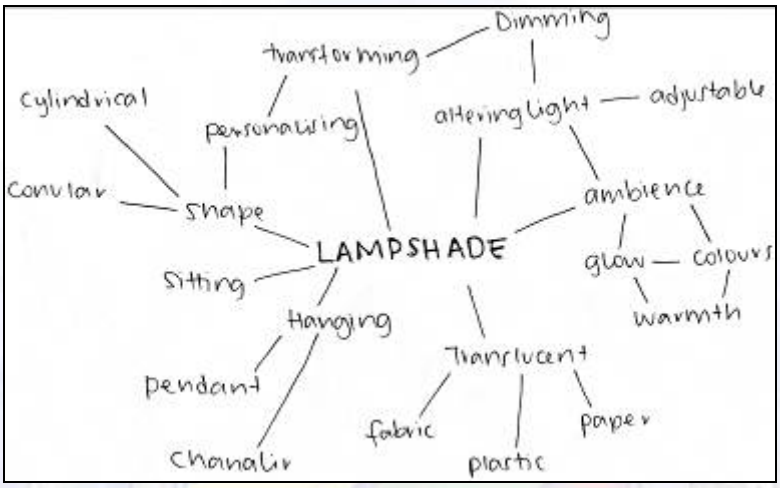

Figure (2) show an example of a mind map while for a lamp shade.

3.2.3. Checklists for Concept Generation:

Checklists are simple tools to help designers in generating idea. It is a series of questions arranged in lists and through answering these questions by the designer he can improve ideas [47]. It aims to encourage creativity, systematic thinking, and divergence in conceptual design phase [13]. Checklists need a focus point for its questions such as product requirement or product functions. There are many checklists were developed by researchers such as SCRMPER technique [27] and Osborn's checklist [50].

Checklists can be used individually or in a group through brainstorming session [50]. Its procedures can be as following:

1) Defining a product idea.
2) Selecting a checklist to work with and more than one can be used in the same time.
3) Answering the questions.
4) Improve the idea.

4. User-based Techniques:

Many users find difficulties or face problems when they come to use products. This is simply because users were ignored by designers while designing the product or the service. And this is the main reason behind appearing of user-centred design approach to include users within design process as a target in addition to form, material, function, and manufacturing. This means designers should understand the user approach when he use the product or the service to find best solutions to him. User-based techniques includes four techniques: role-playing, storyboard, written scenario, and context mapping.

4.1. Role-playing:

In role-playing designers attempts to simulate the using process by perform the same tasks that a user do in real life. Through this process they be aware of difficulties that may face users while using the product of the service and they also acquire the knowledge of the interaction process between the user and the product [15] [48]. As the entire body of the designers is used while he/she plays the user role, the designer gains more experience that he could get by using other techniques such as scenario and storyboard which we will review later here [1]. After finishing the role-playing, a designer has a good conceptual idea about the using process that he can convert it to a visual or written description.

1) Procedures of role-playing can be summarized as following [50]:
2) Define the actor and the goal of acting.
3) Define the using process steps.
4) Record the acting process and repeat acting several time to be sure that actors are completely immersive in the task.
5) Analyze the recordings.

4.2. Storyboard:

Storyboard is a visualization of the use phase of a product or a service. It is a series of drawn photos that its sequence express about the using process [20]. It is used by designers to understand the steps of using a product. It also is used as a tool to communicate between different people concerned about designing a specific product such as design team members whom may be from different background. It enables designers to focus on understanding user groups, context, product use and timing as it is used to analyze design situations' problems and feelings. It can be used in all conceptual design stages from idea generation stage to idea evaluation [23] [24].

When including storyboard technique in idea generation process, designers tend to think first about the idea, simulation, and the user. Secondly, they define what a storyboard should express about. It should give a clear message. Then, a sketchy storyline and timeline are designed and created. Various panel sizes, white spaces, frames, and captions are used to emphasis on specific situations. It is advised not to repeat images and don't make all panels the same [18] [53]. Sketchy style of the storyboard that elicit comments, sleeks, and detailed presentation makes the storyboard more attractive to the design team or consumers who react more to than other styles.

Comics and movies can be a great source in making a storyboard. Also, there are many web applications that can help in creating storyboard in an easy way and in short time such as "Storyboard That" [62] and "ACMI Generator" [61].

4.3. Written scenario:

Designers need to be aware of interaction between the product and the user. When they develop products, they tend to explore this interaction by writing a scenario that show how users may interact with the product and describe the using context [42]. Before writing the scenario, designers determine targeted group of users and gather information about tasks to be performed by the user and the context of usage. After writing the scenario, designers should involve users to review the scenario and get feedback from them. This step give designers more recognition of the user-product interaction [6] [7]. In conclusion, using written scenario in idea generation process leads into a good conceptual idea about the interaction. It also aids in communication and evaluation of ideas. Figure () shows the steps of written scenario method.

4.3. Context mapping:

In product design, context refers to the entire atmosphere where the product is used. It includes social, cultural, and physical environment of the using phase. Contextmapping attempts to collect information about the use process from this context [49] [57]. This happens by involving the user in the design process as an expert. The user is trained by the designer to notice his context through using a product and record what is happening as much

as he/she can [26]. From this knowledge gained from the user, the designer can draw an image about the using phase and can create a concept to develop ideas.

Context mapping has 4 steps to be done:

1) Preparation:
   Designers determine the topic of the study and what they want to get from task. They plan the entire process of context mapping and make interviews with volunteers to find the suitable users to conduct the experience.
2) Sensitising:
   In this stage users start to observe their daily routine in using a product by using a sensitizing package that was designed to help them. They are encouraged to record memories and notices as much as they can. This task takes a week.
3) Meeting:
   This is a meeting between designers and users. It may be a group meeting or an interview with each participant alone. In this step, designers try to get more information from users about the last step.
4) Analysing:
   Designers begin to analysis all data they get from users from their records or from the meeting. They try to find patterns for the use process. After this process, designers start to conceptualize ideas and improve products.

5. Product-based Techniques:

All products contain two main aspects: form and function. These two aspects used as approaches by many designers and companies in the last decades as it is the easiest and fastest approach to create a not-failed product. Product-based techniques includes two methods which are related to form and function analysis: function analysis and morphological chart.

5.1. Function Analysis:

Functions refers to tasks that a product can do. Analysis of a product's functions means creating an abstract model of the product without thinking about shape, dimensions, or materials. It describes basic functions of a product and how they work together [12] [43]. In the abstraction process it is recommended to eliminate sub-functions and build the function structure based on a limited number of basic or general functions [39]. This way of thinking in an abstract way stimulates creativity and prevents individual from jumping to ideas or solutions directly which make them more efficient as first ideas which come to mind may not be the best or the most suitable one.

After function analysis happens, a designer can move to think about product's parts which will do these functions. And then he can determine materials of each parts according to that. He may also think about shape or form. In some cases function analysis leads designers to use morphological charts to find best options for the product.

5.2. Morphological chart:

While using sketching to generate ideas without a system as ideas come to mind randomly. Morphological chart push designers to generate ideas in an analysis-based system [22] [59]. A starting point to this method can be functions or shape. Functions are analyzed to find basic functions but not as function analysis technique there is no need to eliminate sub-functions [43]. Shape also can be analyzed to find out the basic parts of the product. After preparing a list of all functions or parts, designers begin to find out alternatives for each component. All components are organized in a systematic way in a chart to make them easy to be handle [12]. Designers begin to construct various ideas from the chart by building different function structure or by collecting parts together in a different shapes but to serve the function of the product.

1) Possible procedures can be arranged as following:
2) Identifying all product's parameters (function, sub-functions, and parts).
3) Construct a morphological chart to fill it with proposed components.

4) Create solutions or concepts and evaluate them to select the best one.

6. Conceptual Design Framework:

Conceptual design phase aims to develop concepts or rough prototype. It is considered that longest phase in the whole design process. It begins with defining problems or identifying needs of the user. The next step is to gather needed information to understand technical issues, functions, and the user. The problem can be redefined or reformulated. After that designers start to generate ideas and record them either by sketching or in written form such as that produced in brainstorming or mind map session. Ideas produced are evaluated and improved. We can notice an iterative process here between generating ideas and evaluation. In the last step, designers select the most efficient idea to be presented as a concept to the client or the producer.

The framework proposed here integrates the reviewed idea generation techniques into conceptual design phase. It works as a guide for designers through the process. It connects between techniques and the conceptual design stage with showing which techniques can be used within each step. This give the designer the freedom to choose techniques that suit his situation and also encourage him to use more than one which may increase his creativity.

Conceptual design framework can summarized in the following steps:

1) Step 1: defining problem and identifying needs:
   In this step designers tend to define the problem statement and begin to analyze it. He may also identify the user needs of a product or a service. There are three techniques that can help designers to do that: how's to, synectics, and mind map. How's to techniques helps designers to cover all aspects of the problem through questions asked in the session. Synectics offer linking the problem with other analogy which help designers to be more open-minded to the solutions or concepts. For mind map techniques, it can be used when it comes to identifying user needs to make a list.

2) Step 2: gathering information:
   In this step designers collect date about several issues that can be included in two categories: the product and the user. The aim of this step is to understand how the products will work, its parts, and materials. For the user, it important to understand the context that the product will work in and how the user will interact with it. Function analysis can be used to analyze the product functions to its essential functions. It also can help in producing a rough concept for the product based on its functions. User-based techniques such as role-playing, storyboard, written scenario, and context mapping can help designers in understanding user interaction with the product.

3) Step 3: generating ideas:
   Concept-based techniques normally are used in this phase. Most designers use sketching to generate ideas as it is the easiest method to work with. In this conceptual design framework, we suggest that using mental techniques before moving into visualization will improve idea generation and may speed up reaching to the final idea. That means designers can use brainstorming, mind map, or checklists before starting sketching or 3D modeling. This process can be iterative as designers move from mental to visual and then back to mental and then change in visualization. Mental and visual techniques also can be used in parallel such as brainstorming and sketching.
   Morphological charts can also be used to generate ideas through using charts to reach to a large number of concepts. It also can be used with sketching in case of concentration of product form. Designers can sketch many alternatives of product's parts and then these alternatives are arranged in the morphological chart. Different parts' alternatives are combined together to construct the product. Selection and evaluation take place to find out the final idea. Figure (3) shows the conceptual design framework and its relation with conceptual design phase.

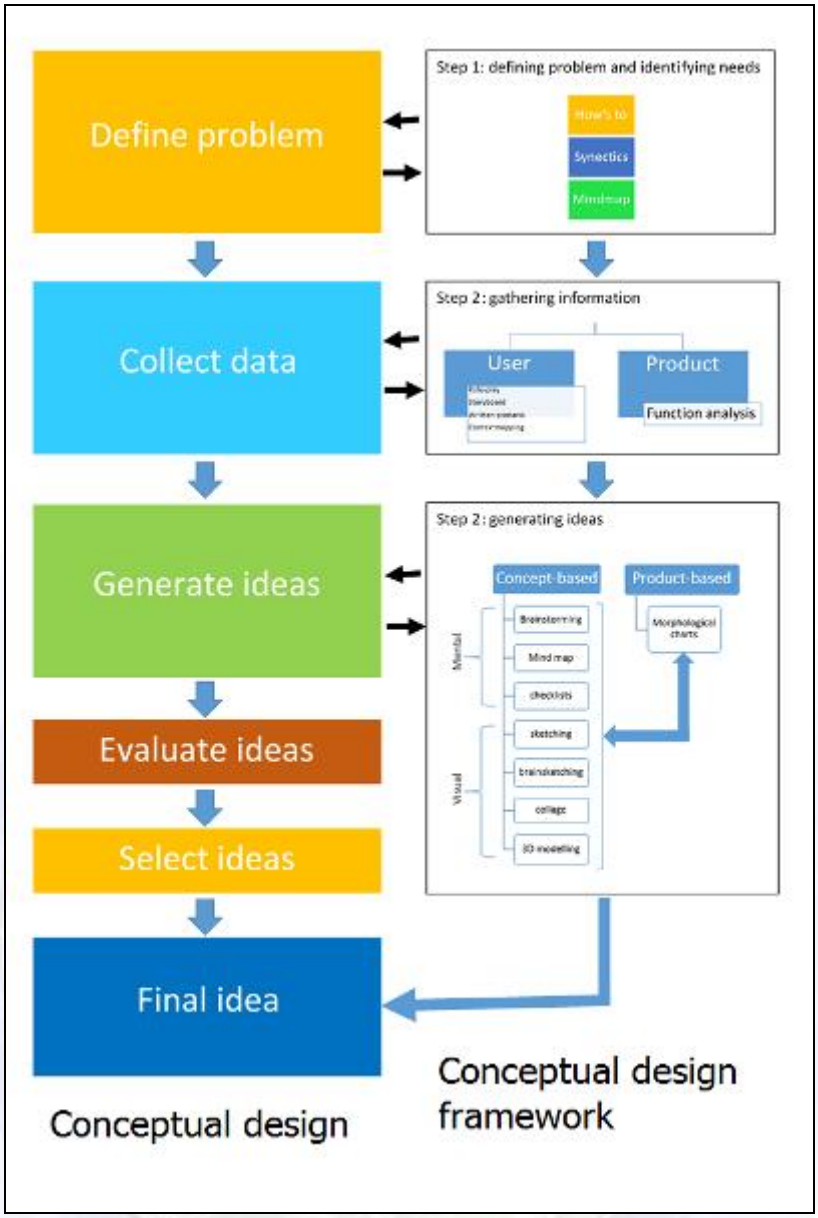

Figure (3) shows the conceptual design framework and its relation with conceptual design phase.

7. Conclusion and future work:

Idea generation process is considered the most important process in product design as the initial product concept is created in it. Many techniques were developed by designers and others came from other domains such as economy and psychology. In this paper, we reviewed 15 idea generation techniques and classified them into four categories: (1) problem-based techniques, (2) concept-based techniques, (3) user-based techniques, and (4) product-based techniques. After that, a conceptual design framework was generated to support designers through generating ideas. It works as a guide for designers to choose suitable techniques and combine between different techniques according to design situation.

Future works will include more studies about idea generation techniques and how designers can use them in efficient way. Also, we may study how these techniques can affect creativity and innovation through design process as they are key issues in design studies.

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