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Parametric Design In Phase Of Schematic Design Case Study: Student Creativity On Form Studies

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***Abstract*—Nowadays, the parametric design is one of the design approaches or method that architect and designer believe can be a tool for analyzing the possibility of geometric deformation and easily anticipating it by changing parameters. The parameters were changed through the parametric design software, which allows the user or designer to specify relationships between the various parameters in the design process.**

Still, architecture students were required to be able to use a design software. Students used a design software primarily to help them to develop the design concept or to apply their design analysis. Arguably, the student's ability of a design software impact on their creativity of form studies or design exploration. Furthermore, limited of design features in the design software was an obstacle for the student when they found it took a long time to explore the 3-dimensional model or not easily developed. That reason was believed to affect the quality of design that proposed by architecture students in schematic design and development phase in Architecture Design Studio.

The research was done with the correlational descriptive approach. This research introduced a parametric design software to architecture students at the Technology University of Yogyakarta. The software in this research was Rhinoceros and Grasshopper. The respondents in this study were selected, they are 100 people consist of the second and third year of architecture student. Data collected using a Likert questionnaire that contains responses and suggestion after following a series of parametric design software training. In summary, the results of this study show that students were satisfied with their form studies or exploration that created using a parametric design software. Their skill on the design software slightly affects the creativity based on the number of form studies.

Keywords—Parametric Design, Design Schematic, Form Studies, Rhinoceros and Grasshopper Software, Likert Questionnaire

I. INTRODUCTION

Today, almost all architects use software, both for 3-dimensional modeling, documentation and simple calculations. The role of computer software and architectural professions is very close. Architects are now required to know almost all software related to structure, building standards, and design development. Software development is increasingly rapid and complicated, architects are required to develop and evolve in developing their working methods.

Architecture students are also required to be able to use the software. Students learn software that is primarily to help develop a design by applying the understanding of design theory they get in class. The limited ability of students to software has an impact on the lack of exploration to create designs or problem-solving solutions. Limitations in software also become an obstacle when 3-dimensional models are not easily changed or developed. This is alleged because of the lack of products submitted by students in the design development phase in the Architecture Design Studio. In fact, the notion of design in terms of terminology is a product of the process of finding solutions to solve space problems that come from the development of knowledge of design theory with the ability to use the software. So the more alternative design products are produced, the greater the likelihood that problems can be solved.

The computational or general design called digital design is a broad term that refers to a variety of digital activities, ranging from the appearance of designs to the calculation of structures. The most common use of the definition of digital design or computational design is the creation of visual images using the software. Some of the advantages gained from using the digital design method, according to the researchers, is the increased ability to explore forms so as to bring up more diverse design alternatives and increase creativity in architectural detail.

Parametric design is a paradigm in design, which is a technique or method of solving problems. Parametric design becomes a fundamental thinking in design. Wassim Jabi in his book "Parametric Design for Architecture" says that parametric design is a design process based on algorithmic thinking which brings out the details of a parameter, where the parameters together strengthen and clarify the relationship between design goals and how the design will respond to problems. The parametric design tool is software that allows users or designers to specify relationships between various parameters in the design process.

Rhinoceros and Grasshopper relate to parametric design software. Rhinoceros, Rhino or Rhino 3D are 3D computer graphics software and CAD (Computer Aided Design) application software developed by Robert McNeel & Associates; an American company founded in 1980. Rhinoceros Geometry based on the NURBS (Non-Uniform Rational Base Splines) mathematical model that focuses on creating precise free curve and surface representations on opposite graphics computers from polygon-mesh based applications. Grasshopper is a graphical algorithm based editor that offers extensive mathematical operations for code writing and is directly connected to Rhino 3D modeling software. Writing the code in Grasshopper is to use logical operating components that function as generators.

Components that represent parameters as exploration keys are number sliders. This component contains the domain of variables that are used as parameters with numbers that are an integer, floating, odd, and event types that have upper, lower, and range numbers that can be changed by simply shifting the button after being defined. The advantage is that users or designers can then replace some of these parameters so that the model will react consistently based on changes.

The evaluation of students' creativity in the study of form and architectural detail through this parametric design was carried out in synergy with the architectural design studio design activities in the design development phase. This phase is an exploration stage of ideas which is usually related to the search for architectural forms and details. The purpose of this study was to examine parametric design methods in enhancing student creativity to process architectural shapes and details.

II. Architectural Design Studios

Architectural Design Studio is a course where architectural students conduct learning activities to solve design problems. Through this activity, students will be guided to understand the design and know how to solve problems in design. This activity is a lecture activity which includes the formulation of the problem, proposing a design and finally choosing an alternative design as a solution which is then displayed into a digital form or physical model.

Development of study forms and architectural details is one of the focuses in the Architectural Design Studio. Geofrey Broadbent describes six functions that can be implemented by architecture in solving problems in design. The six functions are:

1. Environmental Filter (modifier of the physical climate). Buildings can control the climate. The building acts as a filter or filter between the outside environment and the activities we will do. Buildings can help us to make conditions so that activities can be carried out pleasantly and in comfort. We can determine which spaces should be close to each other and which ones can be kept away.
2. The container of Activities. The building as a place of activities that places it in a specific and specific place.
3. Capital Investment (changer of land value). In this sense, the building can give more value to the site. Both can be good sources of investment.
4. Symbolic Function (cultural implication). In this sense, buildings can provide symbolic values, especially in activities that are religious or have cultural implications.
5. Behavior Modifier. In the behavior modifier function, buildings can change behavior and habits, according to the atmosphere of the room.
6. Aesthetic Function (pursuit of delight).In this sense, the building will be great if the building looks good or beautiful, in accordance with the current fashionable imagination, according to certain principles of visual orders and others.

The architect as a built environment designer is certainly a profession that must consider architectural design from complex aspects as previously mentioned. The use of digital technology in general in Indonesia is currently still popular limited to the visualization of 3D virtual or digital models. The limitations of the software have raised the potential for the use of digital technology in the field of architecture still not fully applied. According to Szalapaj (2005), several roles of using digital technology in the field of architecture are as follows:

1. As a tool to represent architectural design
2. As a simulation tool
3. As an evaluation tool
4. As a bridge between the design process and the construction stage
5. As a translator of digital information into the development process

III. Parametric design

The term 'parametric' comes from mathematics (Parametric equation) and refers to the use of certain parameters or variables that can be edited to manipulate or change the final result of an equation or system.

Parametric design is a paradigm in design, where the relationship between elements of the element is used to manipulate and inform design, into complex geometries and structures. Parametric design is a design process based on algorithmic thinking that raises the pattern of a parameter, where the parameters together strengthen and clarify the relationship between design goals and how the design will respond to the problem[1].

Parametric design is not a new concept and always forms part of architecture and design. Consideration of the power of change such as climate, regulation, culture, and usage is always part of the design process. The form in parametric design is not defined first but is classified in a particular template and controlled based on the determinant parameters. Therefore a new design can be generated from a basic template ‘only’ by entering parameter numbers that correspond to the project data[2].

Embryological House by Greg Lynn in 1999 is an example that can represent this process. Embryological House is a series of house designs created by including determinants such as a number of occupants, climate, site conditions, construction methods, materials, space requirements, functions needed, special aesthetic effects, and user lifestyles[3].

Each house created with parametric designs then becomes unique and different from each other, even though it still has a similar character (signature). You could say these houses are similar but not the same. Embryological House is interesting not from the form that looks individually organic and unusual, but that this project is 'serial'. This project emphasizes that through a parametric approach, the final product variation can be created through basic calculations and determining parameters[4].

According to Khabazi in his book, in addition to drawing or creating digital 3d objects, designers are required to understand the basic aspects of geometry (generally geometry mathematics) which will be translated into numerical parameters or mathematical equations. These mathematical numbers and equations are steps or a set of algorithms to create objects in virtual space. One object that

is formed from this algorithm will then be the basic input or even the basic form that is imposed by the algorithm to produce the next form. This process is known as an "algorithmic" process. So that each component or generated form of this process will be connected to each other and the parameters that become the generator.[5]

IV. Research Methods

The primary data collection method uses survey techniques. The primary data in this study is a questionnaire that collect students response on form studies creativity. According to Hurlock, creativity is imagination or directed fantasy. They need knowledge received before they can use it in a new and original way. The results achieved are directed at the references and knowledge they had before, both and the knowledge provided and the readings or impressions they have seen.

Form study creativity was carried out with experiments, exploring variants through computational parametric design modeling at grasshopper. The characteristic of experimental research is the existence of control variables[6]. The control variable is the parameter data set by the researcher so that it affects the dependent variable.

A. Research Variable

The dependent variable in this study is the evaluation of students' creativity through the study of form and architectural detail, while the control variables in this study are the parametric design workflow software Rhino and Grasshopper.

TABLE I. Research Variable

No.	Dependent Variable	Parameter	Indicator
1.	Creativity	Form	Volume
		Proportion	Symmetric – asymmetric
		Color	Characteristic
		Composition	Balance – unbalance
2.	Highrise Building	Number of Floors	Unit
		Floor to floor	Meter
		Floor thickness	Meter
		Building form	Volume

B. Questionnaire Design

Based on the problem formulation, this study discusses "creativity". Creativity is subjective data. So the instrument that needs to be made to measure is in the form of a questionnaire in the form of a Likert scale. Likert scale is a scale that can be used to measure attitudes, opinions, and perceptions of a person or group of people about a phenomenon or phenomenon. Likert scale in the form of tiered size with very positive gradations to very negative. The Likert scale can consist of 5, 7, and 9 levels[7].

TABLE II. 5 Level Likert Scale

Perception	Respond	Behavior
a. Very Much	1. Strogly Agree	a) Almost Always
b. Somewhat	2. Agree	b) Sometimes
c. Neutral	3. Neutral	c) Every Once in a while
d. Not Really	4. Disagree	d) Rarely
e. Not at All	5. Strongly Disagree	e) Never

Questionnaire Page 1

Fill in the personal data below and put a sign (√) on the appropriate answer

Full name :

Gender : a. Male; b. Female;

Semester :

No.	Question	Answer				
		VS	S	N	Ds	VD
1	Are you satisfied with the exploration that you made using rhino and grasshopper software?					
		VM	Sw	N	NR	NaA
2	How is the development of your design creativity before and after learning the rhino and grasshopper software?					
No.	**Statement**	SA	A	N	Di	SDi
3	Rhino and Grasshopper software is useful for me to improve my design creativity					
4	My ability in exploring architectural forms and details is increased through software Rhino and Grasshopper					
5	My design ability increased through parametric design methods					
6	Parametric design supports my understanding to solve design problems					
7	Parametric design learning using Rhinoceros and Grasshopper software is included in the UTY Architecture curriculum					

Note :		
VS : Very Satisfied	VM : Very Much	SA : Strongly Agree
S : Satisfied	Sw : Somewhat	A : Agree
N : Neutral	N : Neutral	N : Neutral
Ds : Disatisfied	NR : Not Really	Di : Disagree
VD : Very Disatisfied	NAA : Not at All	Sdi : Strongly Disagree

Fig 1. Quetionnaire Design Page 1

Questionnaire Page 2

No.	Statement	Answer
8	Mention the software that you usually use to explore architectural forms and details	
9	How long do you usually need to explore forms using the software (software no.8)	
10	How many compositions do you usually get when exploring forms using software (software no. 8)	
11	In the time available at workshop, How many exploration of forms did you get using Rhinoceros and Grasshopper?	
12	Give your comments about Rhino and Grasshopper as parametric design software for exploration of design and architectural details	
13	Give your comment on the research conducted	

Thankyou

Fig 2. Questionnaire Design Page 2

Respondents in this study were 100 people and were students of architecture at the Technology University of Yogyakarta. Respondents are architecture students in semester 4 and 6, they have never studied rhino and grasshopper software before. The research location is in the computer lab at the Department of Architecture, Yogyakarta University of Technology.

V. Analysis and Discussion

The research was done in several stages. The first stage was the process of preparing and agreeing on research designs, data collection methods, and analysis of research data. This stage includes literature study, research tool procurement

planning, the creation of Rhino and Grasshopper software use workflows for parametric design, questionnaire making and preparation of research implementation plans.

The next stage is the implementation of software simulation with students. The process of introducing Rhino and Grasshopper software with the demonstration given in the workshop. At the end of the introduction and demonstration of the software, the task was to process architectural shapes and details and then fill out the questionnaire when collecting tasks

The last stage is the process of analyzing research data. Data from the filling out of the questionnaire was transformed into a diagram form then explained by a qualitative approach.

A. Design Parameters

The design case in this study following the architectural design studios is a 10 to 15 storey tall building. Focusing on the initial phase of design, namely form studies. Parameters used as the basis for the development of parametric designs in the form of inter-floor distance, number of floors, floor thickness, and building volume. The distance between floors, the number of floors, and the thickness of the floor have a dimension in the form of meters, where the Number slider is used to change the value. Graph mapper is used to evaluating bezier curves that form the volume of objects to change the proportion and composition of shapes. The study of the form of parametric designs is carried out from curves, the curve consists of 3 basic forms namely square, round, and equilateral triangle.

The workflow created using Rhino and Grasshopper software for parametric design and definition of parametric design is done by researchers. The basic form is in the form of a square, round, and triangle formed in the Rhino software[8].

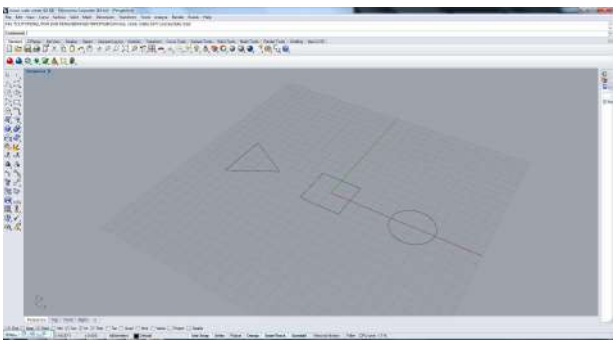

Fig. 3. Basic Form as Parametric Design in Rhinoceros

Definition prepared using the grasshopper by making an operational step. Operational steps in the form of procedures are presented in the panel box at the grasshopper.

Shape using curves as initial operations. Curve operations are objects in the form of one or more straight or curved lines. Curves can be lines connected or closed.

The main operations that used in grasshopper are move, rotate, scale, loft, and extrude. The move is used to adjust the parameters of the floor between floors, and the number of floors. Rotate operation is used to adjust the rotate degree parameter. The scale operation is used to adjust the volume composition form parameters using the graph mapper operation. Loft operation is used to bring the skin of the building from the selected shape. Extrude operation is used to adjust the floor thickness parameters.

The following Table III. is a list of parameter operation steps in the grasshopper in this study.

TABLE III. GRASSHOPPER OPERATION LIST

No	Grasshopper Operation
1	Curve Geometry
2	Series Number
3	Series Degree
4	Move Motion Z
5	Rotate Radian
6	Scale Factor Graph Mapper
7	Loft curve
8	Boundary Surfaces
9	Extrude motion Z

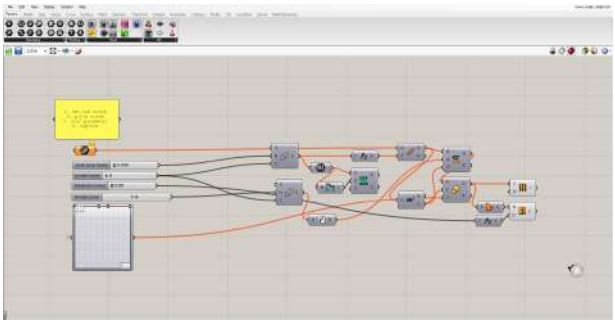

Fig. 4. Definition in Grasshopper

A more detailed step from the list of operations is to choose one of the 3 basic forms available at Rhino by performing a set one curve operation at grasshopper. The basic shape of the selected square is shown in the picture below.

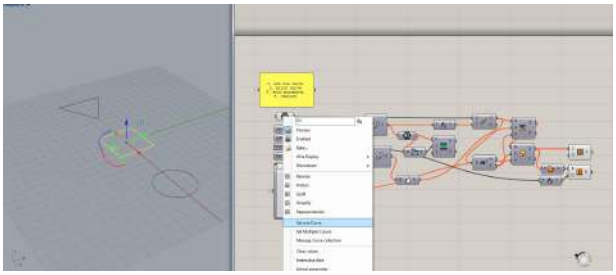

Fig. 5. Detailed Step of Set One Curve in Grasshopper

The next step after choosing the desired basic form, which then adjusts the parameters of the distance between floors, number of floors, and floor thickness. Dimensions between floors and floor thickness are meters, and the number of floors is in units. The parameter in Fig. 6. Floor to floor is 4 meters and 10 floors with a thickness of 0.5 meter.

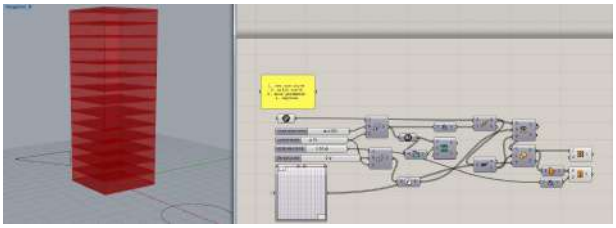

Fig. 6. Parameter Setting

The example forms in Fig. 7. done by setting the rotational degree and shape parameters using a graph mapper. The value is 10 with a one-sided curved mapper.

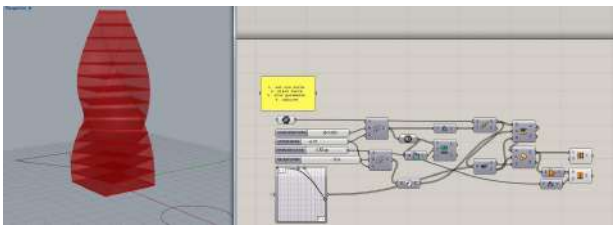

Fig. 7. Alternative of Parameter Setting in Rotational Degree and One Sided Curved Shape Mapper

Fig. 8. is formed alternative with a two-sided curved mapper. The process ends by storing the processed image. This form search process continues for 1 hour. Every alternative result of the form is saved by the respondent into an image.

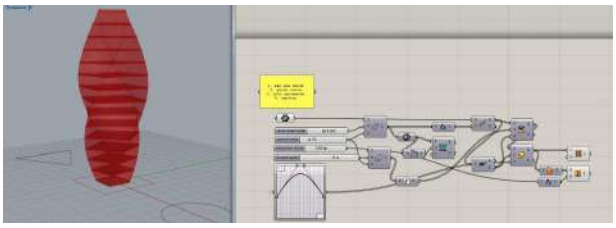

Fig. 8. Alternative of Parameter Setting in Rotational Degree and Two Sided Curved Shape Mapper

B. Workshop dan Questionnaire Data Collection

The learning and exploration of innovative architectural forms, also the search for unconventional forms using Rhino and Grasshopper is carried out in Fig. 9. It was the computer lab at Technology University of Yogyakarta. The number of respondents in this study was 100 people. Divided into 2 groups, namely 4th-semester architecture students, and 6th-semester architecture students.

Fig. 9. Workshop of Parametric Design

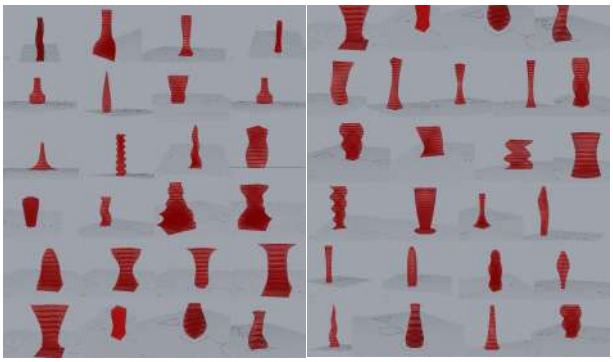

Fig. 10. Several Form Studies by Student

C. Questionnaire Analysis

Based on the questionnaire design, number 1 through 7 is a statement, which number 1 and 2 are perception type statement, then the questions number 3 to 7 are the attitude type statement. While statements number 8 through 13 are essay questions.

Answer choices of number 1 to 7 was a 5-level Likert scale. The answer for number 1 is optional from Very Satisfied (Sangat Puas) to Very Dissatisfied (Sangat Tidak Puas). The option answer for number 2 is from Very Good (Sangat Baik) to Bad (Buruk Sekali). While the answer choice of questions number 3 to 7 is from Strongly Agree (Sangat Setuju) to Strongly Disagree (Sangat Tidah Setuju).

Questionnaires were submitted to respondents after completing parametric design workshops. The questionnaire was filled in by each respondent by referring to the results of their workshop. The results of the questionnaire that had been answered by respondents were analyzed by converting the answer options. The most positive (very good, very agreeable, and very satisfied) answer choices are converted to -2. While the results of the answer choices are very negative (very bad, very dissatisfied, strongly disagree) converted to 2.

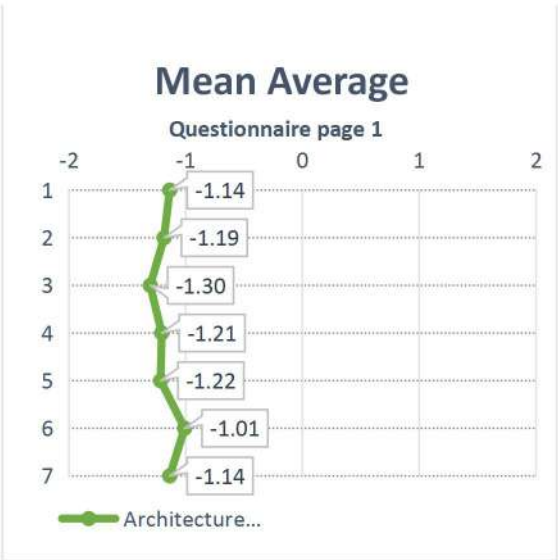

Fig. 11. The Mean Value of Questionnaire Number 1 to 7

The diagram Fig. 11. shows that the average value of numbers 1 to 7 ranges from -0.92 to -1.53. This shows the choice trend of all architectural students leads to positive answers, namely between good, satisfied, agree, to very good, very satisfied, and very agreeable. Comparison of the average value of semester 4 and 6 students in questions number 1 to 7 is not significant. Thus, the average value of semester 4 and 6 architecture students can be combined.

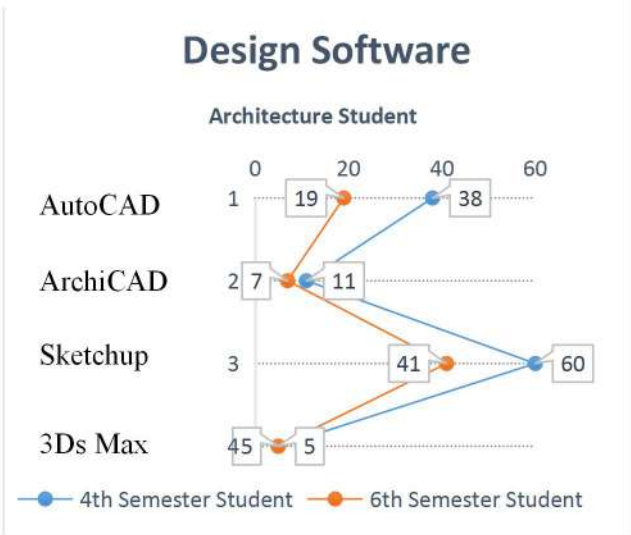

Fig. 12. The Alternatives of Design Software for Form Studies Used by Architecture Student

The diagram Fig. 12. shows there are 4 design software commonly used by students of architecture, namely AutoCAD, ArchiCAD, SketchUp, and 3D max. Indicated in the Fig. 12. Sketchup software is the most widely used software for students as exploration software. Fig. 13 shows that the average number of alternatives produced by students in semester 4 and 6 is relatively the same, which is 2.65 for students in semester 6 and 2.43 for students in semester 4. However, with average needs a little different time, which is 42 hours for students in semester 6 and 27.23 hours for 4th-semester students. If converted for 1 alternative, 4th-semester students need 11.2 hours and 15.86 hours for 6th-semester students. This can be observed from the software used, among others Sketchup as the software that is most widely used as exploration software. The constraints of conventional design methods are more time consumed to bring up alternatives[9][10].

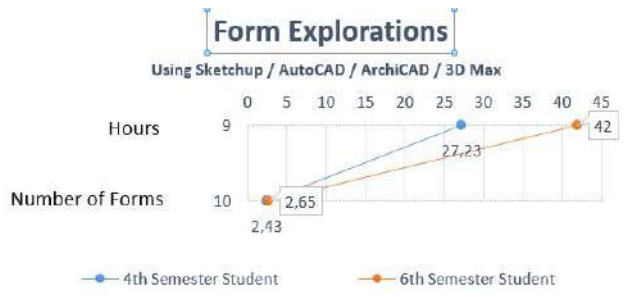

Fig. 13. Comparison Number of Forms and Time Consumed of Architecture Student That Using Common Design Software

Parametric design as a method of thinking that focuses on processes, not results or forms[2][11]. The algorithmic process is where the parameters used together to strengthen and clarify the relationship between design goals, and how the design will respond to the problem[1][5]. Creativity is imagination or directed fantasy[12]. They need a background knowledge that received before they can use it in a new and original way. The results achieved are directed to the references and knowledge they have had before and the knowledge provided by the reading or impressions they have seen. Referring to Hurlock's explanation about creativity, the creativity of students in this study was shown by the analysis of the results of the form exploration using grasshopper software. The Background knowledge of form exploration software previously already composed by students, then in this study students get the additional knowledge for form exploration. Fig 14. shows that the average number of alternatives obtained in 1 hour are 6 up to 7 forms.

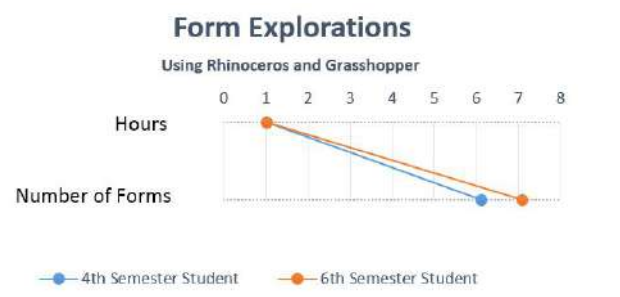

Fig. 14. Comparison Number of Forms and Time Consumed of Student That Using Rhinoceros and Grasshopper

Creativity in architecture is very important in the professional world. If a student does not learn to understand cognitive variables such as knowledge and skills of tools or

software for drawing techniques, he cannot succeed successfully in design, due to lack of structural knowledge and presentation skills, even if he has innate creative abilities[13]. Architecture education must provide cognitive development to students, and the ability to use it in creative processes. The diagram above shows an increase in the number of alternatives obtained by students compared to the abilities that previously owned. Rhino and Grasshopper software can increase students' creativity in form studies.

TABLE IV. RANK OF STUDENT'S COMMENT

No.	Comment	Percent
1	very good for form exploration	32,5%
2	produce dynamic shapes	12,3%
3	very interesting	9,9%
4	more effective if you understand to operates	8,4%

Table IV. shows the rank of student's comment. It shows that architecture students' comments on the exploration of the composition using rhinoceros and grasshopper were positive, with the number 1 largest percentage of 32,5%, namely students felt that the rhino and grasshopper software was very good for form exploration. Followed by number 2 with 12% percentage, namely the parametric design produces a dynamic form. The next number 3 percentage of 9,9% of students said that exploration activities using rhino and grasshopper composition are very interesting. This can be seen from the many alternatives that can be raised, on average as many as 6 alternatives in a fairly short time. Only 8,4% of comments rhinoceros and grasshopper will be more effective if you already understand how to operate it. Programming logic is needed and basic understanding of coding and scripting is required to learn the flow of parametric design in Rhino and grasshopper but not a necessity[14][15][16].

VI. CONCLUSION

This study succeeded in introducing parametric design methods in enhancing the creativity of architecture students through parametric design software learning for form studies. The algorithm definition in grasshopper that has been prepared by researchers and form studies conducted by students brings understanding to the role of parametric design as an interesting way to bring up alternative forms of form in the design development phase. The design parameters that have been prepared at the grasshopper are felt to be effective in the design process and facilitate the exploration of forms so that changing objects can be done simply by changing the parameter values without starting the design from the beginning.

The results of the questionnaire analysis showed a positive response from students which added to the importance of applying parametric design methods to be applied to the lecture curriculum, one of them by opening elective courses. One of them is about the logic of programming and algorithms needed to understand the flow of parametric design in Rhinoceros and Grasshopper so that it takes more time and learning. It was noted that parametric design using Rhinoceros and Grasshopper software can enhance student creativity. The increase in student creativity in study forms can be seen from the number of alternatives. Architecture education must provide cognitive development to students, and the ability to use it in creative processes.

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