2.3 Information Analysis for Teaching Tool Design

The information from the survey was analyzed to find the ideas in teaching tool design such as the key components, the suitable model and size for application and the details to be identified on the tools. The 3D models were drawn in the SketchUp program before sending the digital file to control the 3D printer. Many tool components were created as prototypes with different styles and sizes for evaluation. The suitable functions such as the braille size, the joined line height, the pin-hole depth and the normal letter size for teacher reading were chosen from the teachers of mathematics and visually impaired students in a blind school. After evaluation the appropriate tool components for reading and learning by touching, the models were then corrected as the evaluators' opinion. The optimum size, shape and thickness of the components were further designed to develop the new models of "Geometry Board" which could enhance the teaching and learning of dimensional geometry.

2.4 Development of Geometry Board

The optimum size and style of components from the study was used to design the new model of geometry board which was developed from the traditional one. The actual model of geometry board included of many components such as a pin-studded z-axis in the slot for learning the dimensional shape of geometry were created by plastic injection with a 3D printer. The stainless steel pins with a height of 17 mm and diameter 3 mm were also prepared to use for stretching the rubber band with a diameter of about 3 cm. The prototype of developed geometry board to be applied as a new teaching tools for geometry learning will be further evaluated.

3. Results and Discussion

3.1 Needs of Blind Students and Teachers in Teaching Tool Development

The survey results showed that mathematics is the most important and difficult for blind students which have high demand for tool development, especially geometry. This issue matches the research of Andriyani et al. [5] that is visualization becomes one of the important ability used to help students in understanding spatial concepts, shapes, sizes and distances. However, blind students lose visual aid to learn the concept of geometry and losing of visual experience causes some difficulties in obtaining the concept of geometry directly. Their favorite learning tool is the real thing, embossed images and braille book, respectively. The important features are embossed images for touch able with braille description and 3D models. The blind children need modern technology to improve their ability as normal people, corresponding to Buteau et al. [6] that is technology can eliminate the tediousness of calculations, allowing students to focus more on conceptual understanding.

The teachers of mathematics also agreed that the teaching tools for geometry should help children drawing the geometric shape by themselves. The tools should enhance them in practice reading, writing and understanding for the real object which should be modern, suitable and portable. Approximately 95% of blind students do not understand the mathematics because there are no embossed images of geometry, graph, shapes etc. The braille codes contain too much styles to remember, read and understand. The students have to repeatedly read by self-learning and need special teachers to help. This problem is according to Vianna [7] that students with visual impairment have difficulty of geometry images understanding. The difficulty of learning geometry is not only experienced by students, but also by teachers who teach this subject. Although using tools in physical models, many teachers have difficulty to instruct geometry to blind students [8]. However, teachers suggested that the size of tool should not be larger than their hands to survey the area for learning by touching. Teachers also prefer the bright and colorful tools to motivate their normal students' attention.

3.2 Appropriate Proportion of the Components in Teaching Tools

The simulation of the Geometry board was used to evaluate the use of the blind students. The comparison between the grooved lines and the embossed lines in different levels are shown in Figure 1. The blind students chose the D line, which is the convex line of the 1.5 mm height from plane because the line is the easiest to read. The A line is a grooved line that is 1.5 mm depth which was difficult to find. The B and C line is raised from the