Engineering and economic analysis of the production of sieve shaker for teaching particle size to students with visual impairment

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ABSTRACT

The purpose of this study was to evaluate the feasibility study from the engineering and economic perspectives in the production of sieve shaker for teaching particle size to students with visual impairment. The sieve shaker is important as a tool for improving students' understanding of the definition of particles and their sizes. Different from other sieve shakers for industrial purposes, the present sieve shaker is inexpensive, simple, user-friendly, and portable. Since it is made for educational goals only and can be used for developing countries, the total cost is inexpensive. Engineering analysis was performed based on a mass balance analysis, whereas the economic evaluation was carried out using several economic parameters under the ideal and non-ideal conditions in 20 years of the project. The engineering evaluation confirmed the potentiality of the project even it is in small-scale industries because all processing steps could be carried out using commercially available equipment. Economic evaluation results showed positive values for all economic parameters with a few exceptions. This research was complemented by theories to support the definition and the importance of sieve shaker for supporting the education of students with special needs.

Keywords: economic analysis; economic parameters; education; sieve shaker; students with visual impairment; technical evaluation.

INTRODUCTION

Strategies for evaluating particle sizes have been well-documented, applied in industries and laboratories (both in schools and universities). Many apparatuses have been used, and one of the famous particle sizers is a sieve test (Hierl et al., 2019). The sieve test analysis is effective in filtering the sizes based on its pore (see Figure 1 (a)).

Although the sieve analysis is effective to distinguish particle size, problems in the use of this apparatus are found such as time-consuming analysis. To make it more efficient, the sieve test was supported with a shaker machine, which has been well-applied in the field of engineering. However, this equipment is expensive with a cost ranging from 65 to more than 107 USD. Indeed, this is a problem for schools and universities in developing countries like Indonesia because they cannot afford expensive equipment (Berry et al., 2001). Therefore, research becomes important in producing simple, portable, and inexpensive equipment (Harris, 2008). Although many studies showed the effectiveness of the prototype sieve test analysis, they explained only for limited uses (Qi et al., 2017). Furthermore, there is no information on the economic evaluation of the feasibility for commercial scale.

Based on our previous studies (Nandiyanto et al., 2016 & Nandiyanto et al., 2017) on the feasibility studies for the production of several materials, the purpose of this study was to evaluate the feasibility of the production of sieve shakers for educational purposes.

The main ideas for the need in the production of this equipment are due to the limitations for teaching the definition of particle sizes to students, specifically when we teach to students with visual impairment. Students with visual impairments are students with special needs who have problems with their sense of sight, making them having difficulties understanding something abstract and complex (Maryanti et al., 2021). They learn through the auditory and physical senses (Maryanti et al., 2020a). For making the learning process effective, learning media must be tailored (Maryanti et al., 2020b).

One of the important subjects for students with visual impairment is understanding the particle size of the material. Students with visual impairments need innovation from existing sieve test tools. The innovative use of an automatic sieve test using a machine, equipped with braille to make it easier to understand and distinguish particle sizes. Here, the present sieve shaker was easy to be used, versatile, and inexpensive, equipped with a combination of batteries and a 3 V dynamo (Guarnieri, 2018).

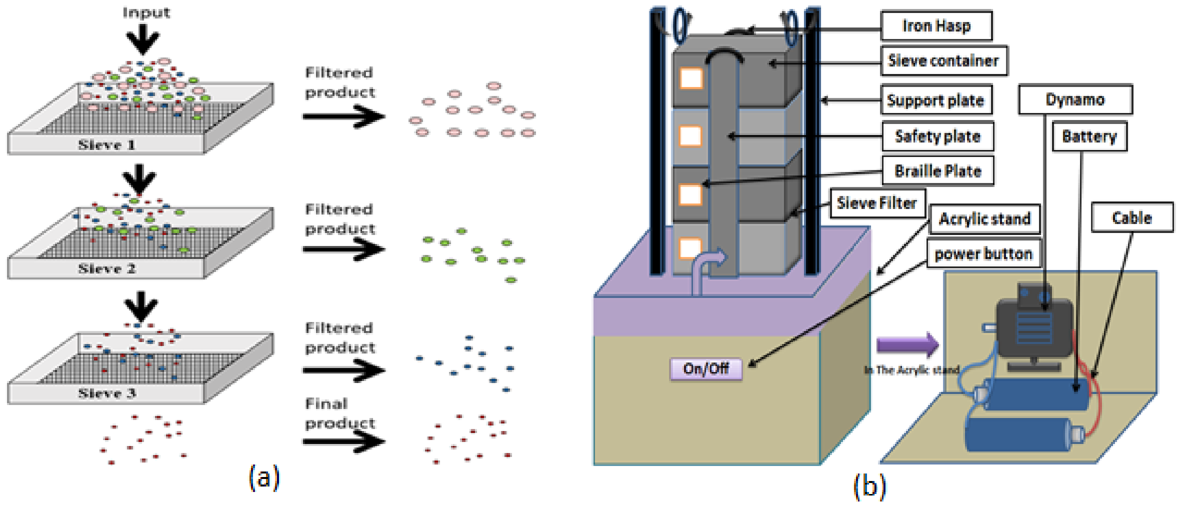

Figure 1. (a) Illustration of sieve shaker and (b) the principle of sieve test analysis

In the feasibility study, we compared the analysis from the ideal conditions to the non-ideal conditions (labor conditions, utilities, sales, and raw materials, as well as external conditions and environmental uncertainties (competition, taxes, and subsidiaries)). Engineering analysis was done based on the mass balance, whereas economic analysis was to get various parameters, including gross margin (GPM), internal rate of return (IRR), return period (PBP), cumulative net present value (CNPV), breakeven point (BEP), and profitability index (PI). All calculations were carried out under conditions for 20 years of production. In addition, we completed the basic information introduction research that is sieve shaker to make readers understand and provide further developments.

MATERIAL AND METHOD

Figure 1 (b) explains that the sieve shaker consists of two parts. In the first part, the sieve shaker consisted of 4 sieve containers equipped with 4 sieve filters, 4 braille plates to label the sieve size, 2 safety plates, and 2 iron hasps. The second part is a sieve-shaped sieve holder made of acrylic called an acrylic stand, cable, dynamo, battery, and power button.

The study was carried out by the engineering perspective and economic evaluation (Nandiyanto et al., 2017). Engineering analysis was calculated using a simple mass balance analysis, whereas economic evaluations were carried out using several economic parameters, including GPM, IRR, PBP, CNPV, BEP, and PI sales for investment. In the economic analysis, all calculations are carried out and compared to current economic engineering theories, in which this is well-explained in literature (Garrettt, 2012). To support analysis, prices, components, and equipment specifications, as well as raw materials, were taken based on the available online shopping web. All calculations are carried out under ideal and non-ideal conditions for 20 years of the project. We also neglected either inflation or deflation during the project.

In the engineering analysis, the mass balance calculations were assumed:

a. Equipment was adopted and developed from the existing equipment

b. The production cycle is around 2 h per equipment.

c. Working hours per day were from 8.00 to 16.00; or, working hours were 8 h/d.

d. One year contained 300 days of production, while the rest is day-off and preparation.

e. The project operation length was 20 years.

f. All costs were stable during project operation and calculated based on ideal conditions. There will be no economic fluctuations (either inflation or deflation) for labor and utility costs, as well as raw materials and selling prices.

g. Equipment prices were determined based on commercially available prices (Table 1). The Lang factor was used to analyze total factory costs (TPC) (Table 2) and total investment costs (TIC) (Table 3) (Garrettt, 2012).

h. Labor wages were 21.43 USD/d (= 535.71 USD/month = 6,428.57 USD/y), and production employed 5 workers.

i. The cost of electricity was assumed to be 2.46 USD per kWh (Nandiyanto, 2018). The utility was only for most electricity (Nandiyanto et al., 2018), assumed to be 100 W for soldering (with a usage time of 8 h 20 min per day), 35 W for refining iron (with a usage time of 5 h/d), 30 W for cutters iron (with a usage time of 1.2 h/d), and 835 W for other purposes (with utility h of work 8 h/d).

j. The annual discount rate was 15%, which was adopted based on the interest rate charged on the commercial banks. This study used the value of discount rate that is higher than the interest in the commercial banks.

k. Annual income tax was 10% based on general tax in Indonesia.

l. The project did not take a loan from the bank.

m. The selling price of the product was 57.14 USD per piece of equipment.

n. All products were fully sold. There was no product loss because of improper product quality or damage. No destroyed raw components and no waste were obtained.

o. All analyses were conducted in USD with a conversion rate of 14,000 IDR per USD.

RESULTS AND DISCUSSION

Figure 1 (b) illustrates the sieve shaker, consisting of four sieves (stainless steel, having a size of 4 x 4 cm and thickness of 0.3 cm) equipped with a micron nylon screen sieve (having a size of 4 x 4 cm), iron haps, two pieces of hand-held plate strips (to lock the four sieves), a beam-shaped holder (made of acrylic with a dynamo, cable, and two batteries equipped with an on/off button), and holder on top of the equipment equipped with two sieve support plates. Detailed components are shown in Table 1. The main part of the sieving apparatus is a stainless steel container below, equipped with a micron-sized nylon filter. The main difficult components are to equip each sieve with a size using embossed letters and to make them stand although the equipment is completed with electrical components to make the sieve working automatically.

Table 1 explains the price of the equipment used to create a sieve shaker. One sieve shaker required a capital of 18.78 USD, but there was additional production equipment (142.86 USD). Table 2 explains the total costs to be incurred by the factory to produce sieve tools. Thus, the data obtained that the total plant cost was 3,192.86 USD and plant cost - Land is 2,835.71 USD.

Table 1. Parts needed for designing a set of sieve shaker

No	Component	Quantity and dimension	Price USD
1	Dynamo 3 V	1	0.53571429
2	Battery	2	0.67857143
3	Cable	(40 cm)	0.00421429
4	Power button	1	0.35714286
5	Braille plate	4	4.57142857
6	Safety plate	2 (10 cm x 2)	0.21750000
7	Support plate	2 (10 cm x 2)	0.21750000
8	Iron Hasp	2	1.91807143
9	Bolt	4	0.07142857
10	Acrylic stand	1 (23 x 45.75 cm)	7.22500000
11	Sieve Container	4 (4 x 4 cm - thickness 0.3)	1.41071429
12	Sieve Filter	4 (4 x 4 cm)	1.42857143
13	Glue gun	1	0.14285714
14	Production tools	3	142.857143
	Total		161.635857
	The total price of the device (price total - Production Tools)		18.77871429

Table 2. Calculation of total plant cost

Component	Factor	Cost (USD)
Purchased Equipment	1.00	714.29
Piping	0.50	357.14
Electrical	0.10	71.43
Instrumentation	0.20	142.86
Utilities	0.50	357.14
Foundations	0.10	71.43
Insulations	0.06	42.86
Painting, fireproofing, safety	0.05	35.71
Yard Improvement	0.08	57.14
Environmental	0.20	142.86
Building	0.08	57.14
Land	0.50	357.14
Subtotal 1		2,407.14
Construction, engineering	0.60	428.57
Contractors fee	0.30	214.29
Contingency	0.20	142.86
Subtotal 2		785.71
Total Plant Cost		3,192.86
Total Plant Cost(-Land)		2,835.71

Table 3 explains the calculation of the total investment cost. We obtained data of 3171.43 USD for Total Plant Investment without land.

Based on the above considerations, the calculation can be considered as follows:

a. The total number of sieve shakers made by 5 workers is 20 equipment per day. By multiplying with 300 production days per year, the total sieve shaker is 6,000 devices.

b. The total utility used per day is around 835 W × 8 h, 30 W x 1.4 h, 35 W × 5 h, and 100 W × 8.2 h. The total power used is 23,000 Wh/d. Adding a total of 300 working days per year yields a total power of 6,900,000 Wh (= 6,900 kWh/y). Then, the cost of utilities can reach 739.29 USD/y.

c. TIC is relatively inexpensive because all processing steps are carried out using commercially available equipment in the market.

Table 3. Calculation of total investment cost total plant investment–land

Component	Factor	Cost (USD)
Other Capital Requirements		
Off-site Facilities	0.20	142.86
Plant start-up	0.07	50.00
Working capital	0.20	142.86
Total Plant Investment –land		3,171.43

Economic analysis in the ideal condition

GPM showed good results, which is more than 27.81 USD / 20 pcs per day. By calculating one year's production, GPM can reach 8,571 USD/y. BEP is 220 pcs.

Figure 2 illustrates the economic evaluation of sieve production based on the CNPV curve in the ideal condition (production capacities of 100% annually). The ideal conditions are assumed to have stable conditions for variable and fixed costs, labor costs, utility costs, and also the prices of raw materials and products. Production capacity illustrates the conditions of sales and products. 100% of the production capacity responds that all products are well distributed and sold. In the ideal condition, the profit increases continuously for 20 years, promising for the project to be applied with the PBP value of less than 3 years.

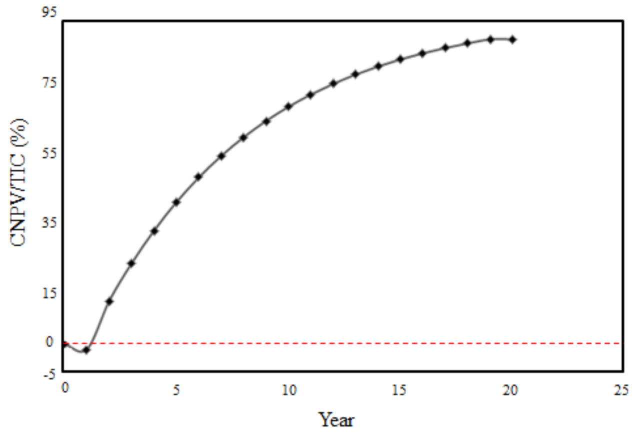

Figure 2. CNPV/TIC analysis of sieve shaker production under ideal condition

Economic analysis in the non-ideal condition

Analysis of the effect of production capacity shown by the CNPV/TIC curve is shown in Figure 3 (a). The CNPV/TIC curve shows that decreasing production capacity causes profits to decline. Although the production capacity has decreased, the benefits obtained are still relatively large. However, a decrease in production capacity of less than 10% will cause the project to suffer losses.

Analysis of tax variations from the CNPV curve is shown in Figure 3 (b). We also added the assumption that in 0 year until the first year, the tax is not charged to the company because the company is still in the stage of project development. To determine the effect of tax on corporate income, speculation is carried out by changing taxes ranging from 10 to 85%. The CNPV/TIC curve shows that the higher taxes imposed on companies can lead to getting lower profits. The effect of tax on CPNV/TIC is shown after the first year. Even though the tax imposed is getting higher, the company still benefits from the production of sieve shaker.

Analysis of variations in the variable cost from the CNPV value is shown in Figure 3 (c). Changes in variable costs are internal factors affecting the success of a project, such as the condition of raw materials, labor, and utilities. The CNPV/TIC curve shows that the change in variable cost does not influence profits significantly.

Figure 3 (d) is a graph of the effect of sales on the value of GPM. From this figure, the sensitivity of the estimated value (from -50 to 120%) was made to see the effect of sales on GPM. The value of sales has a positive correlation with the GPM value. In short, a high sale value can increase the profit (GPM) of the project. In this project, the minimum profit can be achieved when the sales have a sensitivity of 25% of the estimated value of the sale. However, when the sensitivity of sales value is less than 25%, (from estimated sales value), the project may be a failure. When we increased sales, the project can get more GPM.

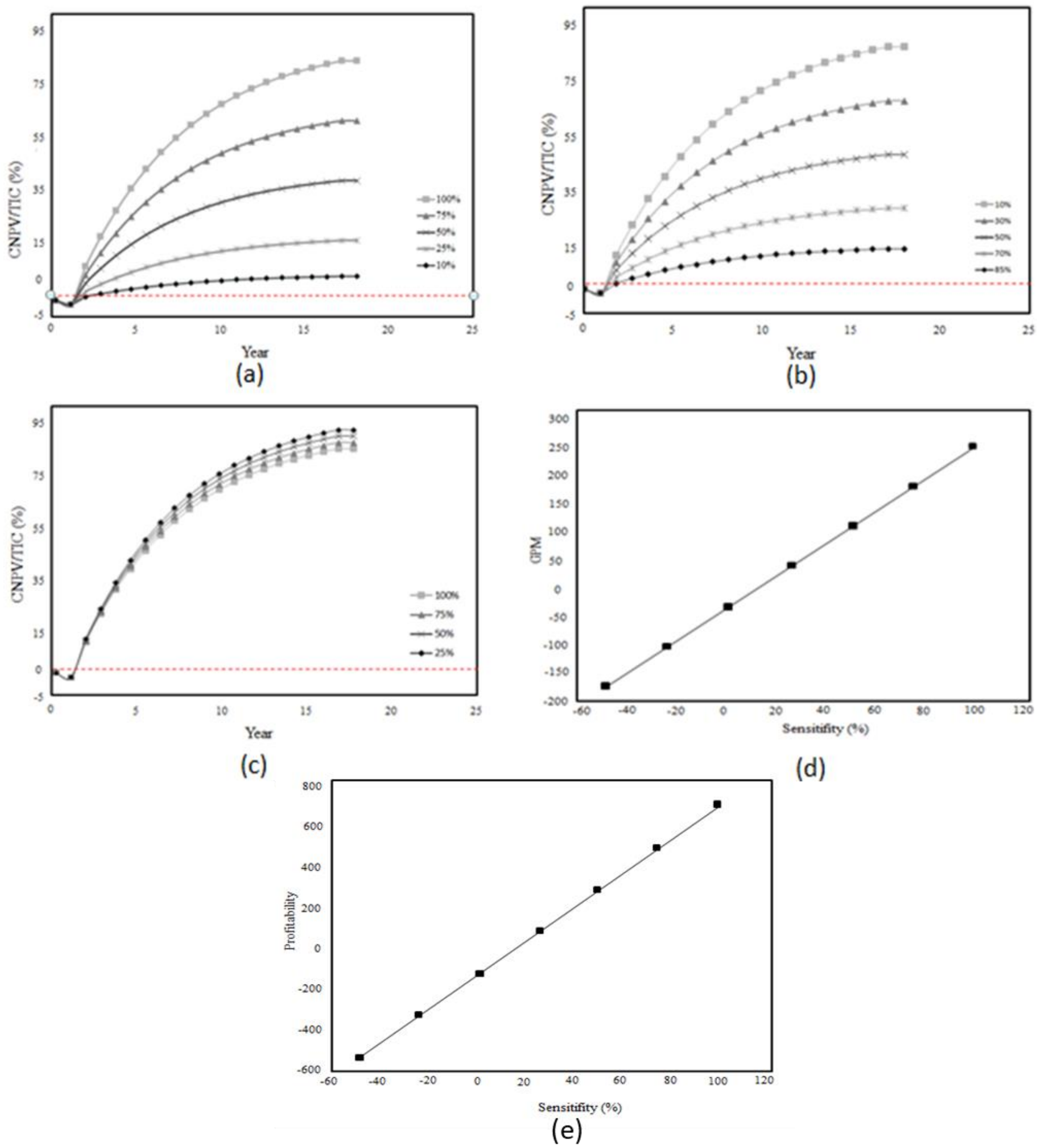

Figure 3. Effect of several parameters: (a) capacity production on CNPV/TIC, (b) taxes on CNPV/TIC, (c) variable cost on CNPV/TIC, (d) Sales to GPM, and (e) sales to profitability

The effect of sales (from the sensitivity of the estimated value (-50-120%)) on profitability is shown in Figure 3 (e). Sales influence project profits. The maximum profit the project can be achieved when the sales value has a sensitivity of 100% of the estimated value of the sales, and the minimum profit limit that the project can achieve is 25% of the estimated value of the sale. If the sales are less than 25%, the project may be a failure.

Analysis condition to make the successful production.

Engineering analysis confirmed that this project is promising. Based on the mass balance of raw materials and products, the production process can be done in a small-scale industry (Nandiyanto et al., 2018). The main reason for strengthening this argument is the conditions for the availability of parts and supporting components for assembling sieve shakers in the market. Engineering analysis also confirmed simple plant design since there is no need for complex utility systems, informing that project can be developed without specific limitation of the place (such as near the river, etc.). However, the better place for this project is near the transportation access area for distributing the raw materials and products.

To produce 6000 products, TIC is less than 38,304 USD. This is used mostly for systems, including assembling space, storage, and computerization. This lower cost can be obtained because all materials are commercially available and all production steps including the assembly process can be carried out in the small scale area.

The value of GPM shows more than 51.95 USD per pack. Selling 6000 products per year can generate GPM 8,571,428 USD per year. Although GPM shows huge per year, GPM analysis cannot be used directly to determine whether a project is feasible or not. Additional project factors must be added to confirm realistic profitability conditions.

Figure 2 shows evaluation using additional factors to the project (including utility, calculation of total investment costs, labor, etc.) (Machmud et al, 2019). The cost analysis on all economic parameters shows positive values, indicating a good opportunity to produce this product

(Nandiyanto & Ragadhita, 2019). Detailed information is as follows:

a. The BEP analysis shows that the minimum processing cycle is 73 processes, 1640 products per year (more than 135 products per month). Compared to the engineering analysis, one process cycle (to assemble products) takes 2 h. Then, because a one-year project contains 300 days (assuming holidays are non-day production), the maximum amount of production per year is 6,000 processing cycles. Thus, the BEP analysis shows that the current project will be profitable because the minimum BEP value has passed.
b. The profit to sales and TIC shows excellent results. 100% of production capacity can generate profit-to-sales and profit-to-TIC of more than 80 and 721%, respectively.
c. The CNPV curves show a positive value even though the initial years are negative. However, after passing more than 2 years of the project (for 100% of production capacity), CNPV showed a positive gradient, indicating the project was profitable. The final CNPV and TIC ratio in 100% of production capacity is more than 90%.
d. The results of GPM, BEP, sales profit, and TIC, as well as CNPV confirmed the positive results, indicating that this project seems to attract industrial investors. However, to increase interest, there are several considerations.
    1) Sales. The project must be sure that the product can be absorbed by the market. Otherwise, it will be difficult to run the project.
    2) Production capacity. This consideration can be made only if there is a large market for adsorbing products. The increases in the level of production have a great impact on the obtainment of higher profits. However, this analysis must be done carefully because the increases in the production capacity have a direct correlation to the increases in other elements, such as raw material, labor cost, as well as a utility cost. Thus, further feasibility studies must be conducted.
    3) Corporate social responsibility (CSR) of a company or government. However, CSR is related to social and political conditions (Nandiyanto, 2018).
    4) Join the project with a supplier or manufacturer company for raw materials. This

method can reduce the cost of raw materials, especially for shipping and handling costs. Indeed, this can have a great positive impact on profits.

Analysis of the effectiveness of the sieve test machine in the teaching process for students with visual impairments.

Students with visual impairments are students with barriers in the learning process, making them be treated with special education and services (Maryanti et al., 2020b). Students with visual impairments optimize auditory and tactile functions in the learning process. For making the learning process effective, learning methods and media must be tailored to the needs of students (Maryanti et al., 2021). One of them is in the learning process about particle size. Students with visual impairments have problems understanding and differentiating particles. They can study particle size through the sense of touch. One of the tools used in the learning process is to separate particles based on sizes, known as the sieve test. However, students with visual impairments have difficulties using this tool. Therefore, it takes innovation and modification of the sieve test tool to suit the needs of students. Making a sieve test device automatically and equipped with braille letters on each sieve container has the benefit of making it easier for students in the learning process to distinguish particle sizes. The sieve test machine is made automatically using a machine to make it easier for students to use it and to save time and energy because when a student uses a manual sieve test, he has difficulties arranging the sieve and shaking it; Thus, it will mess up the particles inside. Students with visual impairments have difficulties using complex tools (Maryanti et al., 2020c). The braille letters on each sieve container make it easy for students to read the particle size in the container. The sieve test is a learning medium that makes it easier for students with visual impairments to understand particle size, especially sizes of 34, 60, 100, 150, 200, and 250 μm. In addition, learning media at a low cost make it easier for educators and students to be able to obtain and own these media to be used in the learning process.

CONCLUSION

The production of a low-cost sieve shaker for students with visual impairment has been evaluated from engineering and economic feasibility studies. Analysis of the teaching process, this tool has benefits for students with visual impairments in understanding material about particle size. The innovation of tools using automatic machines makes it easier for students to separate particle sizes so that it is time-effective and efficient. Meanwhile, the innovation of adding braille letters to the filter sieve makes it easier for students with visual impairments to determine the size of the particles that are in it. Media that is concrete, simple, and according to student needs makes it easier for students to understand the material being taught. This project is prospective from the engineering and economic point of view. The analysis of the cost of economic parameters also presents positive values, giving information on the profitability of the project. To be more profitable, there are at least four considerations: certainty of the need for this apparatus in the market, understanding production capacity, implementing CSR, and joining production with suppliers or producers of raw materials.

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