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Materials Research in Appropriate Technology: In the midst of Science, Engineering, and Technology

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Abstract. Materials research is often characterized as a pure scientific activity. However, such an approach cannot be applied when materials researchers must deal with Appropriate Technology (AT) development. Science and engineering, which focus on pure scientific background, must be integrated with the appropriateness of AT at engineering and technology levels. This study aims to discover such integration by investigating the proper positioning of materials research to AT development at the intersections between materials research and AT in Science, Engineering, and Technology research areas. Seven pillars of survivability, which describe the tiers of appropriateness, are also taken as the basis of exploration. They are coupled with the intersections to deliver a complete overview of research positioning of materials research in AT development. This study concludes that materials researchers become the inventors (Science), innovators (Engineering), and constructors (Technology) of materials used in AT. They have to produce materials for AT that must be able (Science), feasible (Engineering), and visible (Technology) to improve local activities through a technological solution. By looking at the discussion, this study contributes to several issues at once: AT, materials research, and research design, including all aspects considered as the fundamental principles of survivability, by taking these issues in the positioning of materials research in AT development.

Keywords: Appropriate Technology, materials research, research positioning, survivability

1. Introduction: Issues and Opportunities

Since firstly characterized as the effort to establish a technological solution in a limited circumstance, the thoughts of Appropriate Technology (AT) were focused on resources localization. Some researchers [1] have noted that everything taken into an AT must be started from local conditions. They have synthesized that AT was more likely to stand as a technological solution for empowerment purposes rather than neither development nor sustainable development. The same intention was also brought into discrete research related to a specific issue, such as materials research. It relied heavily on the purpose of AT development. In spite of the debatable engineering value of AT [2, 3], materials research remains interesting to be investigated in order to discover its position in AT development. Materials localization [4, 5] has produced a unique approach of AT, which must be derived into materials research. Some surrounding issues that might not be directly related to materials research were also required to be incorporated to deliver a seamless integration of AT into local daily routines.

These explanations underline the critical issue of materials researchers in designing their research, especially in AT development. To do so, materials researchers must understand the position of their research if they intend to deliver a robust contribution from materials research into the body of knowledge of AT. They must be able to bring materials research as an integrated entity in such an effort by incorporating AT characteristics into their research activities. The incorporation means that they do not do their normal activities, yet they focus on the localization of their research result. Such postulate must be carefully taken to achieve good results in materials research without ignoring local context. Therefore, this study needs to answer the following questions:

RQ1 How possible kinds of research areas are posited to the idea of AT?
RQ2 What kind of research must be done by looking at such positioning?

2. Conceptual Map: Three Facets, Seven Aspects

There are three research areas which are possibly correlated with those characteristics. These are "Science", "Engineering", and "Technology". The first research area is "Science", in which basic understandings on natural and/or abnormal phenomena are investigated [6]. Researches in science are characterized as inventions and more likely to produce a novel approach. The second one is "Engineering". In such area, any research is taken as a way to find the meaning of inventions in Science to the real world [7]. It has strong intentions to apply the results of Science by incorporating more general understandings to discover opportunities in supporting specific tasks. The last research area is "Technology", in which conceptual functions that have already existed in an engineering innovation are actualized as an integrated artifact to do a specific task [8]. It is the last research area in which an idea becomes an applicable solution to human life. Those three research areas also sometimes concurrently happen when an abstract idea goes through a complete transformation to be a meaningful socio-technical artifact [9].

Beside those facets of research areas, there are seven pillars which completely characterized the intention of AT [10]. The first pillar is Technical (T). Since the basic characteristic of AT is a technological solution, AT should first attempt to fulfill technical specifications addressed through AT development. The second one is Economic (E), with which economic value of AT must be matched with local capabilities to construct AT independently. These two issues are the basic understanding of appropriateness in AT [3, 11]. The third pillar is Environmental (V). By looking at recent efforts in environmental-related issues, AT needs to incorporate such kind of issue as one of its intentions [12, 13]. After that, Social (S) becomes the fourth pillar. It is the crucial aspect by which a technology is seamlessly integrated into social life of local people [10, 14]. Beside the general ideas behind such aspects in materials research [15], AT itself has further characteristics especially related to the fourth aspect. There are three intangible aspects that must be taken into consideration to produce real appropriateness [9, 10]: Cultural, Judicial, and Political. Cultural (C) is included as the fifth pillar to avoid cultural shock due to technological improvement. Judicial (J) is considered to ensure social justice between AT users through AT application. Political (P) becomes the last pillar to do such improvement and to distribute such application without triggering political conflicts between local stakeholders, and might be to national and/or international ones.

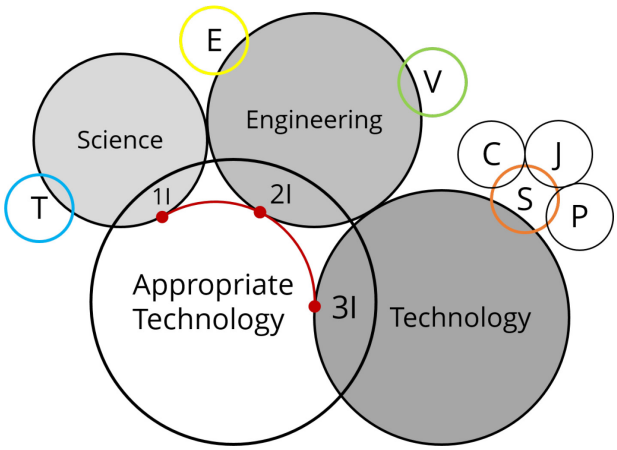

Figure 1. Bubble Map of Research Intersections

Those facets and aspects should be coupled in some combinations to investigate the positioning of materials research between the global idea of AT and the pillars of appropriateness. To answer research questions, conceptual map is required as the guidance in investigating prepositions of the discussed ideas. The correlations between characteristics of AT to possible research areas are exhibited in Fig. 1. Such bubble map is used to discover the possible appropriate position of materials research in AT development to support the purpose and intention of AT. The appropriateness would be explored based on research area and coupled aspects in respective area. They are indicated by intersections between research facets and AT through incorporated aspect(s) in each research area.

3. First Intersection (1F): Scientific Appropriateness

Possible bubble intersection of materials research first happened between Science and AT. As Science, materials research is purposed to discover new invention related to any attributes of materials. Such attributes are usually related to the characteristics of a specific materials, by applying intervention on natural phenomenon and/or by triggering new phenomenon through possible chance to combine two or more materials which was never be conducted before. In the intersection, materials research must discover any possible new characterization of materials which can be invented by using local artifacts. Such localization stands as the effort to bring Science in materials research into an applicable level without ignoring indigenous knowledge of local people [16]. Scientist can do research by discovering such opportunities together with local people, and at the same time, transferring scientific understanding of materials research to them, even in smallest forms of knowledge transfer. Based on those understandings, scientific appropriateness can be achieved by incorporating Technical aspect of AT [10]. Such incorporation means that materials researchers need to understand technical capabilities in local area and combine such capabilities with their scientific knowledge. The result will be a scientific appropriateness of materials to local conditions that may be ensured to be sustainably applied. By pursuing such goals, materials research can deliver a meaningful contribution in supporting local survivability by providing scientific appropriateness of materials and at the same time developing scientific knowledge of local people.

4. Second Intersection (2F): Engineering Appropriateness

The second intersection between bubble of research area and bubble of AT exists between AT and Engineering. As an engineering effort, materials research has a continuation process of research by applying engineering treatment to the results of Science. Such effort is indicated by investigating field feasibility studies to investigate the relationships between the results of Science to the constraints of field demands. The demands are exhibited through limitation occurring on target area, which may prevent the results of Science to be extensively applied. Such conditions are also in line with engineering facts on engineering approximation, on which an application of a scientific results will never be purely applied as the original inventions [17]. This intersection delivers a critical point of scientific results by emphasizing more constraints to them. Materials research as engineering must be able to support the application of Science's results but at the same time, be able to avoid undesired scientific intervention on local matters and manners. Such uncontrolled intervention will more likely happen as the trigger of scientific shock to indigenous knowledge, which will become the destructor of local capabilities in surviving their society through technological solutions.

Those understandings give a notion to incorporate other aspects of AT. The proposed incorporations are for Economic and Environmental aspects [10]. The incorporation of Economic aspect exists near Science area, which means that Economic aspect is the first thing to apply engineering appropriateness of Science's results [11]. Due to one of AT's intention stating that AT is a solution for people with limited economic prosperity, economic engineering is intended to ensure that the results of materials research can be applied in AT at an affordable level, which means that as many as possible requisites resulting in expenditures since construction until disposal can be invested by people themselves. Then, the incorporation of Environmental aspect is taken as the way to promote preservations of environment surrounding local people which may be related with the application of AT. Due to the unique merit of environmental issues in engineering research, materials researchers must be aware with the global issues of environmental impact of technological solutions [18], and apply similar intention to the results of Science into AT. Environmental engineering must be taken to ensure that Science results will not stimulate any conflicts with the intention of AT as cleaner solution, both in production as well as application [13]. Cleaner production means that materials researchers must apply production technique of AT as clean as possible by using clean artifact and raw materials that are available locally. On the other hand, cleaner application means that materials researchers must refuse environmental impacts as many as possible since the construction of AT until the disposal of all parts.

5. Third Intersection (3F): Technological Appropriateness

The last bubble intersection between AT and research area can be established between AT and Technology. In order to produce a technology, materials research becomes an applied science by which the results of Engineering – which are the transformation of Science's results – are further transformed into visible technological solutions. The position of materials research as applied science means that materials researchers must be able to investigate the application of scientific discoveries that have already been engineered for incorporating other aspects, not just technical one. Besides, the visibility through applied science means that engineering solutions are formed into an applicable artifact that can be directly used by its users. In this intersection, materials researchers become technologists to achieve technological appropriateness of AT. Due to ultimate technological appropriateness that includes social aspect in AT design [9, 10, 19], materials researchers must be able to produce applicable materials which can be used in AT to construct a technological solution that incorporates more intangible factors which influence the successful application of AT.

In those understandings, Social aspect [10] becomes the most understandable influence. Such aspect becomes the gate to achieve the ultimate tier of technological appropriateness. Due to the characteristic of AT as a socio-technical artifact [9], social technology means that materials research must produce a technology which can be seamlessly integrated with social life of local people. Such effort to do integration is intended to avoid social shock due to technological improvement, and to encourage local people to treat an AT as one of their own indigenous technology. Thus, materials researchers must discover any materials that can be used to locally construct AT. Social values must be taken into account to understand any kinds of material which have already been used, are preferably to be used, and do not want to be used by local people. The results of engineering research, which have constrained scientific discovery with local limitation on economic prosperity and global idea of environmental conservation, must be further constrained by social values. Such ideas will narrow the scope of materials research but at the same time, it will produce applicable materials that cover wider local issues [4]. In short, Social aspect is the critical issue in materials research in order to reach ultimate level of technological appropriateness.

Next, there are three other intangible aspects that must be taken into materials research in AT development. These three aspects are Cultural, Judicial, and Political, by which Social aspect is strongly influenced. These additional aspects cannot be intangibly ignored, yet as intangible aspects, they can only be tangibly understood through measurement on Social aspect [10, 19] as their bridge to tangible ones. The first additional intangible aspect is Cultural [10]. It is intended to preserve cultural conditions through any material usages in AT that have less interference with applicable cultural principles in local area. Incorporation of Cultural aspect in materials research will increase possibilities of cultural integration of engineered materials to local daily routines, meaning that local people will feel that any materials in an AT are their own materials with which they will do future development of an AT along with cultural development that affects any technological solutions. Thus, materials researchers need to do more works outside their nature [14] to ensure cultural appropriateness of their materials. After that, materials researchers must also be aware of judicial value. Such value means that any inventions, innovations, and constructions of materials need to be proportionally distributed among local people along with the goals of AT, in terms of applicable traditional rules and regulations. Materials researchers must avoid jealous attentions of local people to their own neighbors [16], so their materials will be in line with AT's intention. Then, the last aspect is Political [10], by which materials researchers must avoid conflicts with and, at the same time, prevent conflicts between stakeholders due to their unawareness on local extents about power distributions [3]. Local structures and organizational interactions between local influencers must also be taken into considerations in doing materials research to achieve political appropriateness of AT.

6. Conclusions: In the midst of Science, Engineering, & Technology

All research areas are critical to producing materials for AT. Materials researchers must be aware of their unique position when they are dealing with AT development. They must act from the right

position to do their work and support AT development to achieve its goal as a technological solution with high technological appropriateness. Therefore, in each research area, materials researchers become the inventors (Science), innovators (Engineering), and constructors (Technology) of materials used in AT. Each position has its own responsibilities, chances, and limitations. In each position, any materials researchers must always be aware of how they can conduct their research without triggering destructive influences on AT application. Because of that, the results of materials research in each research area can be characterized as an AT that must be able (Science), feasible (Engineering), and visible (Technology) to improve local activities through a technological solution. In the midst of Science, Engineering, and Technology, materials research can optimally contribute to AT's goals by providing materials that incorporate all AT characteristics into account.

References

[1] Sianipar, C.P.M., Yudoko, G., Adhiutama, A., Dowaki, K. (2013). Community empowerment through Appropriate Technology: Sustaining the sustainable development. *Procedia Environmental Sciences*, *17*, 1007-1016.

[2] Akubue, A. (2000). Appropriate technology for socioeconomic development in Third-World countries. *Journal of Technology Studies*, *26*(1).

[3] Lucena, J., Schneider, J., Leydens, J.A. (2010). *Engineering and sustainable community development*. California, US: Morgan & Claypool.

[4] Watson, M. (2009). Materials awareness: The ability to expose the hidden impact of materials on sustainability. In A. Stibbe (Ed.), *The handbook of sustainability literacy: Skills for a changing world*. Dartington, UK: Green Books.

[5] Sianipar, C.P.M., Widaretna, K. (2012). NGO as Triple-Helix axis: Some lessons from Nias community empowerment on cocoa production. *Procedia – Social and Behavioral Sciences*, *52*, 197-206.

[6] Fara, P. (2009). *Science: A four thousand year history*. Oxford, US: Oxford University Press.

[7] Blockley, D. (2012). *Engineering: A very short introduction*. Oxford, US: Oxford University Press.

[8] Wright, R.T. (2008). *Technology*, 5th ed. Tinley Park, Israel: Goodheart-Willcox.

[9] Vermaas, P., Kroes, P., van de Poel, I., Franssen, M., Houkes, W. (2011). *A philosophy of technology: From technical artefacts to sociotechnical systems*. California, US: Morgan & Claypool.

[10] Sianipar, C.P.M., Dowaki, K., Yudoko, G., Adhiutama, A. (2013). Seven pillars of survivability: Appropriate technology with a human face. *European Journal of Sustainable Development*, *2*(4), 1-18.

[11] Whitman, D.L., Terry, R.E. (2012). *Fundamentals of engineering economics and decision analysis*. California, US: Morgan & Claypool.

[12] Catalano, G.D. (2007). *Engineering, poverty, and the Earth*. California, US: Morgan & Claypool.

[13] Sianipar, C.P.M., Dowaki, K., Yudoko, G. (2014). Environmental impacts of Appropriate Technology: The system boundaries. *Advanced Science, Engineering and Medicine*, *6*(1), 141-142.

[14] Jamison, A., Christensen, S.H., Botin, L. (2011). *A hybrid imagination: Science and technology in cultural perspective*. California, US: Morgan & Claypool.

[15] Sianipar, C.P.M., Taufiq, H., Estiningtyas, H.R., Dowaki, K., Adhiutama, A., Yudoko, G. (2013). Materials selection in Appropriate Technology: Four focuses in design thinking. *Advanced Materials Research*, *789*, 379-382.

[16] Baillie, C. (2006). *Engineers within a local and global society*. California, US: Morgan & Claypool.

[17] Prantil, V.C., Papadopoulos, C., Gessler, P.D. (2013). *Lying by approximation: The truth about finite element analysis*. California, US: Morgan & Claypool.

[18] Jayasinghe, R., Mushtaq, U., Smythe, T.A., Baillie, C. (2013). *The garbage crisis: A global challenge for engineers*. California, US: Morgan & Claypool.

[19] Sianipar, C.P.M., Yudoko, G., Dowaki, K., Adhiutama, A. (2013). Design methodology for Appropriate Technology: Engineering as if people mattered. *Sustainability*, *5*(8), 3382-3425.