The Elaboration of the Academic Technology Roadmap (ATRM)
-Three Cases in Academic Material Science Laboratories -

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ABSTRACT

The Academic Technology Road Map (ATRM[1]) was originally proposed to support academic Science and Engineering (S&E) laboratories. In this paper, ATRM is elaborated through three cases in academic materials science laboratories. According to those cases, a knowledge collaboration board (KCB) is newly designed based on the "Kadai-Barashi approach"and the original ATRM.

Keywords: Academic S&E labs, Research Planning, ATRM, KCB, Coordinator

1. INTRODUCTION : MANAGEMENT MEETS ACADEMIC S&E LABS.

Academic Science and Engineering (S&E) laboratories in Japan have faced radical environmental changes in recent years. For example, industry-academia collaboration and venture businesses have become increasingly popular. Academic S&E labs now have wider opportunities to present their results and meet a variety of people from diverse industries.

But there are also a negative consequences of this environmental change. While it enhances application research, it also could threaten the freedom of academic research, especially in basic research fields which usually take a longer time to arrive at final product.

So that people in academia can make full use of the research environment, including the relation with industries, they are being asked to be more competent managers and to take more initiative in their research: to find a research topic, set up, plan and conduct the research on their own initiative, organize and manage other research members if required, and of course complete the research. In other words, the ability to "manage" research activities is now strongly expected from researchers in academic S&E labs.

Not only academic researchers, but also researchers and engineers in industry are being asked to have managerial competence. One solution could be to provide Management of Technology (MOT) Education for adults with work experience. Actually many of Japan's MOT schools and programs were established in the last three years with political and financial support from the Ministry of Economy, Trade and Industry (METI)[1].

It is not difficult to imagine that students from S&E labs should be asked to "manage" their research since they will have to do it in the future, whether in academia or in industries.

2. THE FIRST CHALLENGE: TO BRING MANAGEMENT INTO ACADEMIC S&E LABORATORIES - ATRM

2.1 Can management fit into academic S&E laboratories?

Management is a concept from the business world and is normally applied to a company. But its methodologies and approaches are often useful for handling matters in other areas as well. These include diverging and converging ideas, planning the action, analyzing the improvement, and so on. In principle, management can be applied to all situations with human beings, including S&E laboratories.

2.2 The concept of Academic Technology Roadmap (ATRM)

ATRM was proposed to help researchers (including students) in academic S&E labs with their research planning [2, 3]. The concept is based on the fusion of two major methodologies: Technology Roadmap (TRM) and Soft Systems Methodology (SSM). The former is one of the widely-used planning methodologies of MOT [4], and the latter is a well-known soft systems approach for tackling unstructured problems [5]. These two methodologies complement each other in combination, when SSM is used as a guideline for TRM. Usually TRM is described with information about markets, products, technologies and resources according to a time scale, and is useful in

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[1] "ATRM" is an abbreviation which means both "Academic Technology Road Map" and "Academic Technology Roadmapping". The latter refers to the process of describing the map.

the creation of a "shared vision" among stakeholders [6].

As academic researchers do not necessarily need to create a product or even a market, ATRM was customized to meet their research activities, describing a research plan and the required / acquired knowledge skills to do the research. It is also not necessary to identify a detailed time scale for progress. So far there is only a simple "Past-Present-Future" time scale on the basic model of ATRM, as shown in Fig. 1.

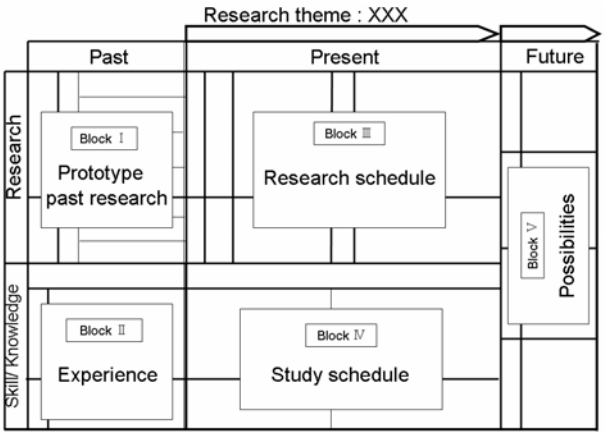

Fig. 1. The basic ATRM model (Okutsu, 2000)

SSM supports a process wherein stakeholders can voice their own opinions by having debates or discussions several times until they arrive at a common solution for their problem situation. The important roles of SSM in the ATRM can be summarized as follows;

- Guiding the mapping process
- Improving motivation to join the process
- Offering communication opportunities

The original SSM process contains seven stages with two different ways of thinking: the real and system worlds. These seven stages are repeated until stakeholders find a solution, but it is not necessary to follow each of them strictly in order. For example, redundant steps can be skipped and a stage that needs more discussion can be repeated again. The latest version of SSM has been simplified, but the original model was applied to ATRM so that stakeholders without a deep understanding of TRM and SSM could follow the process. The conditions or tasks of the seven stages are as follows.

Stage0: Present situation
Stage1: Description of the present situation by researcher (s)
Stage2: Free description of existing knowledge, skills and the future plans
Stage3: Description of ATRM / Advice or recommendation from stakeholders
Stage4: Feasibility check / Advice and recommendations from stakeholders
Stage5: Revised ATRM
Stage6: Research supported by ATRM

Fig. 2 shows the SSM used as the guideline for ATRM.

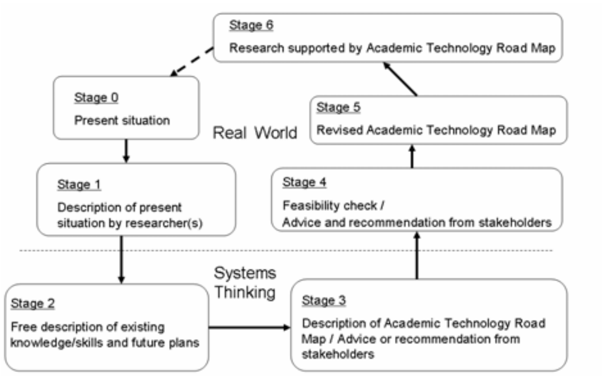

Fig. 2. SSM procedure for ATRM (Okutsu, 2000)

Since ATRM is for research planning, it should be repeatedly revised as the research progresses. This process relates to the SSM stages as shown in Fig. 3. This process shows how to use ATRM with the research activity. While SSM is for the description of the ATRM, this process is for the introduction and the revision of ATRM, in the other words, the dynamic process of ATRM. The dynamic process contains the following 5 steps:

Step1: Explanation of ATRM
Step2: Compilation of data, setting a rough time schedule and contents of ATRM
Step3: Discussion and interview on ATRM
Step4: Feedback from Step3
Step5: Action (research activities based on the ATRM)

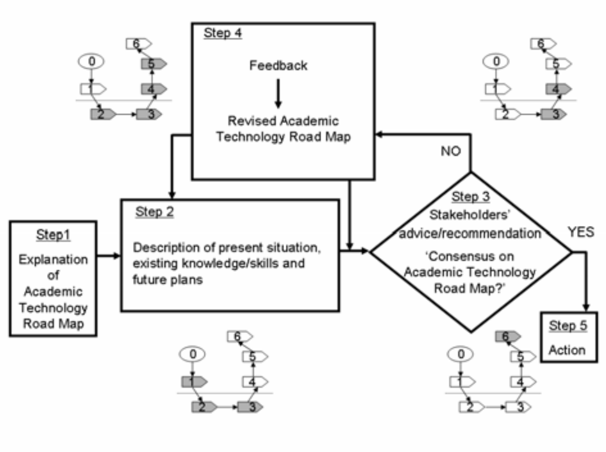

Fig.3. The relation of the SSM to the dynamic process (Okutsu, 2000)

2.3 Action research with ATRM at the AI-lab.

ATRM was applied in an existing academic S&E lab and its applicability was verified through action research [2, 3]. The action research was conducted in the Artificial Intelligence Laboratory (AI-lab) at the University of Zurich from April to June 2002. One of the doctoral students was chosen as the owner of ATRM and described the situation of his research. Contents of the ATRM were designed together with the practitioner of the action research (Okutsu) according to the owner's requests as shown in Fig.4.

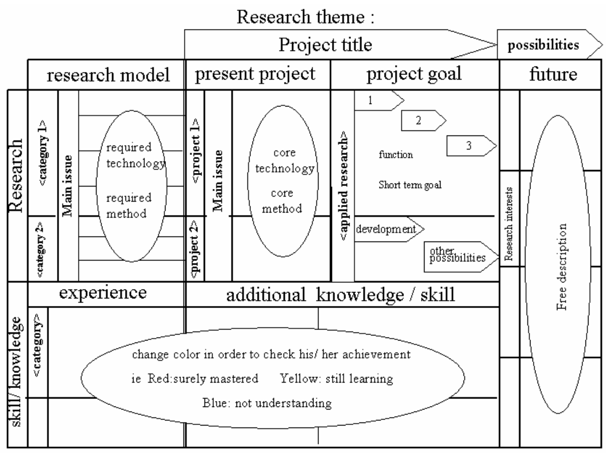

Fig.4 Customized ATRM for AI lab. (Okutsu,2000)

Since the owner had a project, the time scale was separated into four parts: Research model (Past), Current project (Present), Project goal (Near future), and Long-term future. Past experience and required skills & knowledge were described on the ATRM skill/knowledge column, as the owner was in the process of doctoral study and wanted to record what he had learned and what kinds of skills and knowledge should be acquired in the coming months.

There were two main stakeholders in the ATRM: one was the professional researcher (a guest professor), and the other was his senior student in the same research field. With the contribution of these two stakeholders and the other laboratory members who were interested in the research project and joined the discussion, the first draft of ATRM was described.

Through the acquired ATRM, the owner could confirm the current situation of his research project and plan the actions needed to reach his research goal. But it was more important to revise the ATRM then to have the first version.

To make full use of the plan, we revised the ATRM on the web while storing the old ATRM. Related documentation was also stored, such as the research proposal, research notes, and papers and articles, with links to the revised ATRM.

As a result, the following rules[2] were acquired for adopting ATRM to an academic S&E laboratory.

Rule1 (Implementation): The implementer of the ATRM should explain the ATRM concept and the process well enough to the researcher(s) and the all stakeholders before its adoption.

Rule2 (Stakeholders): The owner of the ATRM should ask all stakeholders to join the roadmapping process.

Rule3 (Customization): ATRM should be "customized" by the owner and the stakeholders, according to their purposes and needs

Rule4 (Shared vision): The description of the ATRM should be well structured, and accepted by the owner and all the stakeholders as a "shared vision"

Rule5 (Revision): Continuous revision of the ATRM is vital and indispensable

3. ELABORATION OF ATRM -THREE CASES IN ACADEMIC MATEIAL SCIENCE LABORATORIES -

The action research described in Section 2 verified the practicability of the ATRM. Here we could conclude

[2] In the original thesis [2, 3], these were not summarized as rules. One of the authors (Okutsu) revised that thesis for this paper.

that ATRM worked in an academic S&E lab, but there were some remaining points to be investigated further. These are as follows:

(1) Implementor / Supporting tools
In the action research project the ATRM was implemented by a person who well understood the concept, and it was revised on the web by storing the old data and related documentation. This type of support for starting and reviing ATRM should be explained in detail.

(2) Design and Process
We claimed that ATRM should be customized. Guidelines for that customization should be suggested. Also, the limitations of the basic model should be clarified.

Since TRM is a static plan, there is always worry that it may diminish imagination or research serendipity. There may be a way to modify or improve this inherent weakness of TRM, for example, by combining the method/approach for the divergence and converegence of idea.

(3) Stakeholders
In the previous research, the stakeholders were the people who could give advice to the owner. The conditions of stakeholders could be further investigated in more detail: for example, the way to give advice, the timing and the incentive to join the process, different roles of several stakeholders, and so on.

The following three cases were designed to tackle these points and elaborate ATRM.

3.1. Case 1: Elaboration of ATRM from the application in the basic model for AI-lab. to a different research field

The action research in Section 2 took place in an AI-lab, which is an interdisciplinary field with a comparatively short research cycle from basic research to application. Is the format for this type of academic S&E lab applicable to other fields? What type of support system would be required if the format is applicable? Case 1 partly answers these two questions.

As a support tool for describing and revising ATRM, a computer program, the Lab Roadmapping Support System, was developed [7]. The system helps owners fill the blanks in ATRM, but it is not possible to customize the format which was thebasic model for the action research held in AI-lab. (Fig.1). To test the usability, a masters student described his ATRM with this system. He was a student from the School of Materials Science at the Japan Advanced Institute of Science and Technology (JAIST), and had no management experience [8].

The student found the proposed format is useful to describe his ATRM and it saved time for the first draft, but he wanted to customize the format still further to meet his own research needs and make full use of the feedback from stakeholders.

As an alternative to the AI-lab formatted system, it would have been better to modify each column as amodule in which it is possible to arrange positions within the format. This is a strong claim for the importance of "customization" of ATRM.

In this case there was no implementor of the ATRM. As a result, the user of the ATRM had difficulty understanding the basic concept of ATRM and following the process of describing it. This, in combination with the customization problem, made it impossible to reflect the advice from stakeholders.

As a result, the importance of these elements of ATRM were verified.

- *Step1 (Explanation of ATRM) can not be ignored*
- *Rule3 (Customization) is critical for ATRM*

This can be a part of the answer to elaboration point (1) from the beginning of Section 3.

3.2. Case 2: Proposal of a knowledge collaboration board (KCB) with "Kadai-Barashi"

3.2.1 Introduction of "Kadai-Barashi" to the academic S&E labs

ATRM was originally designed to support researchers in academia, to help them maintain the freedom of their research even while working closely with industry and under the pressure of producing practical results. But there is room to grow in the context of "idea generation", which is the most important for creativity in research activities as mentioned above in point (2).

"Kadai-Barashi" is a management approach for the divergence and converegence of ideas, often used by professional consultants. It was born in the early 1980's in Japan through an industry-academia collaboration. "Kadai" maens "Task", and "Barashi" is the noun of the verb "Barasu" which means "Clarify" in English.

A Kadai-Barashi stakeholder describes all the tasks he/she needs to do on small pieces of paper, and then arranges, or systematizes, them on one large sheet of paper. In the research context, Kadai-Barashi can start with establishing the purpose of the research. Then the purpose is embodied in concrete actions through analysis. After these steps, a scenario is described and finally the stakeholder acquires a research plan.

Since the process of this approach requires a highly skilled professional, an experienced consultant joined the research project for Case 2.

To verify the usability of Kadai-Barashi in academia, a professor and a masters student from the School of Materials Science challenged to plan the student's research with this approach[9].

As a result of this trial, the advantages and requirements of the approach were identified as follows:

Advantages
- The visualization of the research from the holistic view enhanced the discussion about the future
- The description of the research was a bird's-eye view and helped the student see the situation objectively

Requirements
- Adjusting schedule among stakeholders[3]
- Instant revision of the plan according to progress
- Evaluation by a third party

Since these remarks correspond to *Rules 2-5* of ATRM, it seems that they may be generally applicable for supporting acdemic S&E labs..

3.2.2 Designing the Knowledge Collaboration Board (KCB)

Kadai-Barashi was practical for identifying the current research situation, but this approach is not necessarily appropriate for taking the time scale into account. How could this static result become a dynamic plan with a time scale? Here the ideal combination of Kadai-Barashi and the way of thinking in ATRM arose in the form of a Knowledge Collaboration Board (KCB), which was designed as a supporting tool for academic S&E labs. [9].

A KCB has two parts: one for a static and the other for a dynamic research condition. Concretely, the results from Kadai-Barashi are described on board 1 (KCB1) as shown in Fig. 4. Based on the information on KCB1, a research schedule with a time scale is described on KCB2 as shown in Fig. 5.

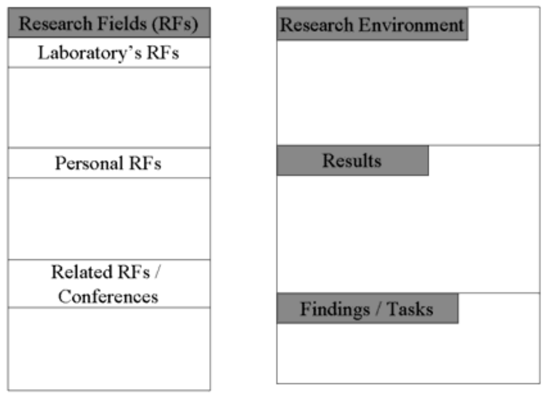

Fig. 4. KCB1 for "Kadai-Barashi" results

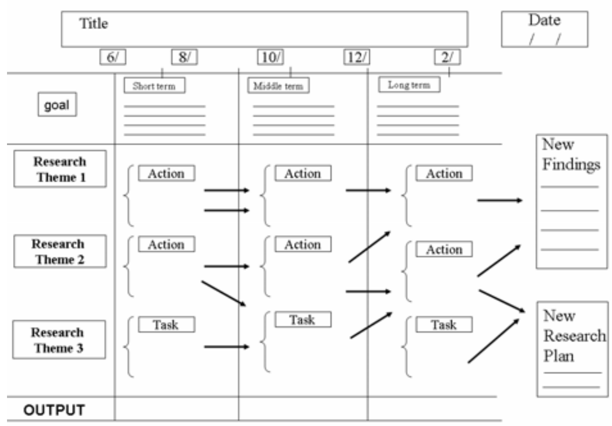

Fig. 5. KCB2 for a research planning with a time scale

Since the School of Materials Science has an official format for research proposals and people there were the expected users of the KCB, the time scale was adopted to their yearly schedule: "short-middle-long" term.

To link with the KCB1, KCB2 is filled with "actions" and "tasks". Through the descriptions of KCB1 and 2, students may see the new findings or research plans. There are also areas for these description on KCB2.

While ATRM was designed for general use in an acdemic S&E lab, KCB was based on the requirements of the School of Materials Science at JAIST. This means that the KCB is already a customized format.

According to the discussion above, *Rule 3* and *Rule 4*

[3] Schedule adjustment was critical since the participants had to meet to do "Kadai-Barashi" together

also seem to be applicable to KCB, though the KCB was designed independently from ATRM itself. Following is a summary of remarks from Case 2:

- *Rules 2-5 of ATRM seem to be generally applicable for supporting academic S&E labs.*
- *Rules 3 and 4 seem to be applicable to KCB*

This can be not only a part of answer to elaboration points (2), but also to (1) and (3).

3.3. Case 3: The role of coordinator in the use of KCB

3.3.1 Conditions of the Action Research

Case 2 revealed further practical opportunities for supporting the academic S&E labs., but had not yet been verified in reality when the KCB concept was proposed.

To investigate the practicability of KCB, we asked a doctoral student from the School of Materials Science at JAIST to use it for planning his research.

So that we could determine the strengths and weaknesses of the KCB framework, it was very important to ask an appropriate person to conduct the trial. If the trial did not work, a student who was not yet sure about the contents of his research would find it difficult to judge whether is the failure was because of the framework of KCB or himself. Then the strengths and weaknesses of KCB would not be evaluated.

The student chosen for this action research had been engaged in his research for three years and was about to complete his dissertation. While he already had enough results, he was planning to expand his research even further before graduation.

Research in materials science is usually limited according to the laboratory's facilities for experimentation. Also the custom in his lab made it easier to handle the research plan, since the plan was based on discussions with his supervisors whenever he obtained a result; he also had an opportunity to give a progress report once a month to the other lab members. All these customs worked to create a "shared-vision" in the laboratory. For these reasons, he had never planned a schedule as detailed as in KCB.

3.3.2. Action Research: Trial description of KCB

As KCB1 is based on Kadai-Barashi, there was a question as to whether it was possible to use the approach without the guidance of a highly skilled professional. If it is to be a practical tool for supporting academic S&E labs., KCB should be independent from the professionals.

To verify the practicability of KCB, the action research was conducted only by the student and authors. One of the author supported him with the description by asking the simple questions when he had difficulties, and the other recorded all what happened during the action research.

The student did not have difficulties in writing the short term actions and goals, but took a longer time for the middle and long term items. This was simply because since he usually planned the next steps of his research according to his daily progress and results, it was difficult to predict future actions based on not-yet-completed goals. When KCB was designed, difficulties in writing actions and goals according to the time scale were not expected. This may be a unique problem in the laboratory sciences or it may happen in academic research in general. Also it may depend on the user. This should be clarified by further research.

This remark applies not only to KCB, but also to ATRM, since a time scale is part of the main framework of both. This relates to *Rule 3.*

3.3.3 The role of the coordinator

Starting in the middle of the action research, one of the authors often asked the student a simple and brief question such as: Why do you need this experience? What do you need in order to go to the next step? and so on. These questions were not made to guide the direction of the action research, but to encourage the student to think deeply from a different point of view about his research and obtain appropriate expressions for the description. This was a coordinating function since the chaotic problem situation was clarified step by step through the questions and answers.

In this action research, the "coordinator" did not have a background in science and engineering, but had experience in industry and as a project leader. This worked both positively and negatively: When the student needed a professional opinion on his research, the coordinator could not answer. When the student needed to refresh his usual ways of thinking and had difficulties with the description, the simple questions helped him to find a breakthrough by himself. The latter role was like coaching.

The functions of "coordinator" or "coach" are based on human skills, in other words, tacit knowledge. This type of knowledge is deeply buried in individuals and difficult to articulate [10]. Thus, it is important to ask the right people to coordinate a KCB process and give comments. These people could be called stakeholders, as in ATRM.

All these remarks from the action research can be summarized as follows:

- *As part of Rule3, length of time scale should be considered*
- *Related to Rule2 ,the role of coordinator was identified as a new function of stakeholders*

This can be a part of answer to the elaboration point (2) and (3).

4. CONTINUOUS USE OF THE MANAGEMENT METHODOLOGY / APPROACH

As a planning tool, it is important to have a structure and process that is easy to revise the plan according to the research progress. Two months after the action research of Case2, a revision was held together with the student and the two authors.

At that time, the student was confronted with a difficult phase in his research. The coordinator tried to guide him by means of simple but instructive questions. This time, however, the coordination was less effective than expected. The student needed very specific technical advice which was, unfortunately, not available at that moment. As a result, the revision was not successfully completed.

In retrospect, we recognize the limitations of the coordinator and the other problems concerning the stakeholders. The coordinator is helpful if the owner of KCB has opinions which have not yet been well summarized, but the coordination does not work as well when the owner does not have any ideas for solutions. In that case, professionals are strongly required as stakeholders. In brief, without an appropriate combination of stakeholders relating to a problem situation, the supporting tool can not be fully helpful. This can be critical not only to KCB but also to ATRM.

If KCB is to be truly verified as a supporting tool for academic S&E labs, feedback from users is critical. Also opinions from the potential users such as other students, not only from the School of Materials Science but also from the other disciplines and researchers are necessary for further improvement. We had a feedback session with the student of Case 3 and others from the School of Knowledge Science at JAIST to exchange opinions about KCB. We can separate the feedback into two parts: about Stakeholders and Customization.

Stakeholders

- Coordinators and professionals play different roles as stakeholders. According to the student of Case 3, he wanted to get opinions from professionals about the detailed plan, as happened in the revision. “From the coordinator, I expected not only guidance about the descriptions, but help in realizing the applicability of my research results in the context of the relationship between society and technology.” (The student of Case 3)

Customization

- “The contents of the KCB were too detailed for me (as mentioned in 3.3.2), and this made me feel nervous.” (The student of Case 3)
- “The framework would not always work. Some researchers may prefer a free description.” (The student with the other major)
- “The design of the KCB makes it difficult to find where to start and to understand what the theme is.” (The student with the other major)

Again customization arose as a critical point. As clearly shown in *Rule3* of ATRM, and as mentioned in all remarks for the previous cases, customization is required for supporting planning in academic S&E labs.

Through the three cases and the feedback session, details of stakeholders were investigated, which in the original ATRM are mentioned as varieties of people related to the owner’s research. The new function of coordinator was identified for stakeholders and the positive impact of a professional was confirmed through Case 3.

5. SUMMARY and CONCLUSIONS

Supporting academic S&E labs sounds like an ideal area for management research, but it has not been actively investigated. ATRM, an attempt to support research planning in academic S&E labs, was applied to an existing lab as an action research project. Through the action research, five major rules and three challenges for its revision were identified.

Adding the Kadai-Barashi approach of the divergence and convergence of ideas to the concept, a knowledge collaboration board (KCB) was proposed together with a professional consultant and people from the JAIST School of Materials Science.

Through three cases on ATRM and KCB, the detailed conditions and requirements of stakeholders and customization were identified.

6. FUTURE RESEARCH

ATRM was applied to two widely different areas of research, i.e., AI and materials science. It would be interesting to apply the method to other cases with a large variety of disciplines, especially with the aim of developing the customization process.

As KCB is based on the use of professional skills to handle the process and has no systematic guidance for non-experts, one option would be to combine the major concepts of ATRM and KCB into one supporting methodology. Complimenting each other, these two may work better together than when they are individually applied

As a whole, stakeholders and customization were identified as critical elements to be deeply investigated. Referring to the remarks and feedback acquired through cases and the feedback session, further improvement can be expected to offer truly practical support to academic S&E labs.

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